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ABSTRACT

"Data Management and Decision Making" is a set of instructional materials designed to teach practicing and potential educational administrators about the uses of operations research in educational administration. It consists of five units--"Operations Research in Education," "PERT/CPM: A Planning and Analysis Tool," "Linear Programming," "Queueing Theory," and "Computer Simulation." The first unit is an introduction. Each of the subsequent four units introduces a specific operations research technique and provides instruction on the basic terminology and skills involved in the technique. These materials were subjected to extensive testing and revision as part of the developmental project. The evaluation included a needs assessment, field testing, and cost-benefit analysis. Information on the evaluation is included along with the needs assessment instrument. (Author/IRT)

Technical Report No. 14

Research and Evaluation Division

Data Management & Decision Making

2

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PREFACE

The following document is the final technical report on the materials developed under contract number NE-C-00-3-0075 with the National Institute of Education by the Computer Technology Program of the Northwest Regional Educational Laboratory. The purpose of the report is to document the development and evaluation of the product contracted for: Data Management & Decision Making.

This report is designed to be of use to a variety of different audiences. The summary given at the beginning of the report provides information on the effectiveness of the Data Management & Decision Making materials for those interested in adopting them for instructional use. The body of the report gives a detailed evaluation of Data Management & Decision Making and provides evidence of successful completion of the contract. This report is not intended to reach all possible audiences interested in these materials; this will be attempted by other means.

A number of persons on the Computer Technology Staff were involved in the development and evaluation of Data Management & Decision Making. Stuart Speedie and Susan Sanders were the primary developers of the materials. They were also responsible for conducting the formative and summative evaluations of the materials. Duane Richardson served as project director and was responsible for the overall management of the project. Antoinette Ellis served as the editor for these materials and Nancy Fargo performed all secretarial duties associated with the project.

Particular gratitude must be extended to several persons outside the Laboratory who were helpful in completing the project. The help of Drs. Ralph VanDusseldorp and Francis Miles in implementing the field tests is greatly appreciated. The reviews of Drs. John Lind, James MacNamara, Donald Treffinger and Ralph VanDusseldorp were extremely helpful in revising the materials.

Any questions regarding Data Management & Decision Making should be addressed to Dr. Duane Richardson, Computer Technology Program, Northwest Regional Educational Laboratory.

THE MATERIALS IN SUMMARY

Description of the Materials

Data Management & Decision Making is a set of instructional materials designed to teach practicing and potential educational administrators about the uses of operations research in educational administration. It consists of five units:

1. "Operations Research in Education"
2. "PERT/CPM: A Planning and Analysis Tool"
3. "Linear Programming"
4. "Queueing Theory"
5. "Computer Simulation"

The first of these units is designed as an introduction to the other four, and is intended to be an "organizer" for the other units. Each of the units introduces a specific operations research technique and provides instruction on the basic terminology and skills involved in the technique. Each unit gives the user practice in the procedures of the technique and in using the computerized versions of the technique. In each case, instruction is provided in using the computer terminal, inputting the data, and interpreting the output of the computer program.. Throughout each unit, examples from the field of education are used to illustrate points and procedures, and the final portion of each unit discusses how the technique can be used in solving problems in educational administration. The units are constructed so that the user is made aware of the instructional objectives of the unit before starting work on it and exercises are interspersed throughout the tests to give the user practice in using the concepts covered.

As the titles of the units listed above indicate, the materials are concerned with four specific operations research techniques beginning with PERT, which is a technique for planning the allocation of resources in large projects. The second is linear programming, which is a mathematical technique for optimizing such quantities as cost under conditions of constraints. Queueing theory, the third technique, is a mathematical method for analyzing situations in which a queue or line of customers must wait for some service. The final technique, computer simulation, is a much more general problem solving method. It is the process of using the computer to investigate situations in which it is too dangerous, expensive, or would take too long to experiment with the actual situation. The two examples that are used as illustrations in the text are bus routing and enrollment prediction.

Evaluation of the Materials

These materials were subjected to extensive testing and revision as a part of the developmental project. The first step in the development was to determine whether the goal of the materials was worthwhile and fulfilled a need. This was first attempted by reviewing the literature in educational administration. It was found that a number of experts in educational administration held that the operations research techniques covered in these materials could solve important problems in educational administration and that training in these procedures was needed. This provided justification for the initial development of the materials.

Further evidence of need was sought by implementing a needs assessment among the target populations--students, administrators, and professors of educational administration. This was accomplished by surveying samples from each of the three groups. A questionnaire was designed to elicit subjects' opinions about the importance of problems solved by the four operations research techniques and their perceived need for training in these techniques. Subjects were cooperating classes of students in educational administration, a random sample of chief school district officers, and a random sample of the American Educational Research Associations members in the Administration Division. The sample totaled 550 subjects. The outcome of this needs assessment was that in all three groups, approximately 50% of the respondents indicated a high need for the techniques and more than 70% indicated that there was a need for the materials, though it may not be pressing. It was concluded that there was evidence of need in the general population of administrators and professors of educational administration, but that the conclusion could not be quite so strong among students since the sampling procedures did not permit it. This survey provided further justification for the development of the materials.

After the initial development of the materials, they were subjected to two rounds of formal evaluation. In the first, the pilot testing, the materials were tried out in college classes. The sample consisted of 82 students who were both regular students and practicing administrators. Each subject was randomly assigned one of the technique units and was given a pretest over the unit's cognitive and affective objects. The unit was then studied for approximately six to eight hours. Each student then took a posttest over the material's objectives. At the conclusion of the testing, a random sample of students were interviewed about the materials. The results indicated three outcomes:

1. In each case the unit caused significant learning with respect to the objectives of instruction.
2. In each case, the unit was associated with positive changes in attitudes towards operations research in education.
3. In each case, the students reported that they found the materials to be motivating and relevant.

After completion of the pilot test it was determined that Data Management & Decision Making (DM/DM) was sufficiently developed for a summative evaluation by the developers (a possible source of bias). The summative evaluation of the materials was concerned with several issues. First, could it be confirmed that the materials caused significant learning, for both the cognitive and affective objectives? Second, how does this learning compare with that caused by likely competitors of the DM/DM materials? Third, what were the side effects of using the DM/DM materials and how do they compare to those of the competitors? And fourth, what were the costs and benefits of using the DM/DM materials and how do these compare with those of their competitors?

The first part of the summative evaluation was a field test of the materials against their competitors. The sample for this field test consisted of 102 college students drawn fro[redacted] asses in educational administration at two differe[redacted] With certain exceptions, each student was randomly assigned two units to study--a DM/DM unit and one of the competitor units which did not correspond to the DM/DM unit. In two cases only one unit was assigned. Each student took pretests over the two units assigned to him and then posttests after finishing the materials. Generally two class sessions were allowed for the experiment, but some classes used three sessions. At the termination of the last session, students also filled out a questionnaire giving their reactions to the materials.

There were two major results of this field test. First, the significant learning caused by each of the DM/DM units in the pilot test was confirmed for the cognitive objectives. In no case was an average of less than 60% of the instructional objectives achieved for a unit, and this was always a significant gain over performance on the pretest. With respect to attitude change, no information was obtained from the field test. However, using information previously obtained, it was determined that the materials did not cause any overall significant positive change in attitude toward operations research. Yet, it is important to note that the attitude instrument indicated that these attitudes were quite positive before the students started the units.

With respect to the competitors, the results were mixed, though in no case did the DM/DM materials do worse than the competitors. In several cases the DM/DM materials were associated with significantly better performance than their competitors--PERT/CPM, Linear Programming, and Computer Simulation. But these results depended on whether or not the unit and its competitor were compared on the full set of cognitive test items or only those test items which the two units had in common. There was no consistent pattern. Thus, the conclusion was that the DM/DM materials do cause learning and they sometimes do better, and never worse, than their likely competitors in the educational marketplace.

The second area of concern in the field test was side effects of the materials, where side effects were considered to be unexpected outcomes of the materials. This data was obtained by interviewing the principal instructors and analyzing the responses of the students to a questionnaire. Due to the nature of the data collection, only information on short-term side effects was obtained. The results of this investigation indicated that the primary side effects of the DM/DM materials had to do with the computer. Students reported and instructors observed that students learned to use the computer as a problem solving tool, they gained confidence in using it, they wanted to participate in additional use of the computer, but they became somewhat frustrated when first using the terminal. Positive side effects of the materials themselves were that a majority of all users would recommend the materials to others and that students wanted to learn more about operations research in education. However, a sense of frustration with the materials was expressed by almost all students. The side effects reported for the competitors were essentially similar to those reported for the DM/DM materials except they were smaller in number and there were not any associated with the computer. It was concluded that the DM/DM materials have more side effects than their competitors and that these side effects ar[illegible] ositive and had to do with the computer.

The final phase of the summative evaluation dealt with the costs and benefits of using the DM/DM materials and how these compared with those of its competitors. Costs such as cost of the materials, computer usage, instructors, and lost personnel time were identified as the major cost sources; however, the total costs of using either set of materials is highly variable based on how the materials are used. Thus, the costs of using the DM/DM materials ranged from $41 in the least expensive condition of self study to $3,500 for a most expensive condition of a four day workshop for 15 administrators. Costs for using the competitors in the same conditions were comparable, ranging from $45 to $3,400.

The benefits of the materials were considered to be the objectives that they met and the side effects they demonstrated. Thus, the primary benefits of the DM/DM materials are the knowledge and skills imparted by the materials as described above. The benefits of the competitors are essentially the same, excluding those objectives dealing with using the computer as a problem solving tool. As stated previously, the side effects of the DM/DM materials were also associated with the computer, while the side effects of their competitors were negligible. The DM/DM materials appeared to have more benefits of use than did their competitors. Thus the conclusion of the cost and benefits study was that for about the same costs as its competitors the DM/DM materials provide more benefits for the user in terms of knowledge about, confidence in using, and awareness of the usefulness of the computer as a problem solving tool in educational administration, in addition to successfully imparting knowledge of operations research techniques.

The summative conclusion of this technical report is that Data Management & Decision Making is a validated product with respect to its use as instructional materials in college courses in educational administration. This was concluded for the following reasons. First, there is empirical evidence of need for these materials. Second, using the DM/DM materials causes significant increases in learning, with students achieving more than 60% of the instructional objectives on any one unit after six to eight hours of study under conditions not designed to promote maximum learning. Third, the use of the DM/DM materials was associated with a number of positive side effects with regards to computers. Fourth, in comparison with its possible competitors, the DM/DM materials caused significantly more learning for three of the four techniques units, and in no case did they perform any worse; they had more positive side effects than did their competitors; and they were more cost-effective. It was thus concluded that Data Management and Decision Making is a validated product which meets an established need and is therefore a worthwhile product. In addition, because of its comparison with competitors it was concluded that it also has relatively more worth in the educational marketplace than its competitors.

THE DEVELOPMENT OF DATA MANAGEMENT & DECISION MAKING

The Developer

Data Management & Decision Making was developed and tested by the Computer Technology Program of the Northwest Regional Educational Laboratory. This set of instructional materials was developed in accordance with the mission of the Computer Technology Program which is stated in part in their Basic Programs of 1972 as:

> Objective: The objective is to create a system of models, materials and procedures that will facilitate appropriate use of computer technology to effect educational renewal. Strategy: The program is product oriented, directed primarily toward the development of: (1) materials for the education of educational personnel and (2) curricular materials and administrative applications for their use. They are designed to provide: (1) school administrators the opportunity to become competent in designing, evaluating and implementing administrative uses of computer technology, (2) teachers the opportunity to become competent in designing, evaluating and implementing instructional uses of computer technology and (3) students the opportunity to become more knowledgeable about computers and gain career capabilities in computer related occupations. Expected Outcomes: Once the total, integrated system of products is available, a significant increase is foreseen in the availability of preservice and inservice training for educators. An extensive library of computer oriented curricular materials will be available in a wide range of secondary subjects. The number and quality of courses relating to the social implications of computer technology will increase. Ultimately, this will facilitate education which is relevant, practical, humane and appropriate for the individual needs of students.[1]

The personnel training component of this mission provides for the development of instructional products for administrators. It states in part that

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1 Computer Technology Program, Basic Program Plans, April 1972, p. iii.

Objective: The objective is to provide educators the opportunity for training both in using available computer applications and in actively participating in decisions which shape technology for education and the implementation of that technology. Strategy: Three types of personnel training systems are planned. (1) Four courses for administrators include an introduction to computers, administrative applications, data management and decision making, and implementing computer systems. (2) Three courses for teachers include an introduction to computers, subject matter applications, and selection of instructional materials. (3) A course for developers of computer instructional materials provides relevant skills for teachers, writers, subject area specialists and persons involved in computer related activities. Expected Outcomes: Preservice and inservice training utilizing Laboratory systems will increase the knowledge of school personnel about computers, their skill in using applications of computer technology for instruction and administrative tasks, and abilities to develop computer based materials.[1]

One particular product of the personnel training component was Data Management & Decision Making (DM/DM). The overall goals of these materials were specified as the instillment of an awareness of and some familiarity with specific operations research techniques in educational administrators and creation of a positive attitude toward using operations research in educational administration. The techniques were identified as Program Evaluation and Review Technique (PERT), linear programming, queueing theory and computer simulation.

The target groups were determined to be persons who were significantly involved in educational administration. They were divided into primary and secondary target populations. The primary target populations were identified as students in educational administration and practicing educational administrators returning to school for continuing education. It was expected that these target groups would accomplish the general goal of the materials by using Data Management & Decision Making as part of a college or university course in educational administration.

1 Computer Technology Program, Basic Program Plans, April 1972, p. iv.

Two secondary target groups were also identified. These groups were considered secondary targets in the sense that it was not intended that they should accomplish the goals of the materials by directly using them. Rather, they were to be persons who were interested in using the DM/DM materials as an instructional tool. It was assumed that the two groups with this interest would be professors of educational administration and persons responsible for conducting administrator inservice workshops. It appears that these groups overlap considerably, and thus for the purposes of this technical report these two groups are considered one.

Preliminary Evidence of Need

After the general goals of the product were developed, it was necessary to determine if there was an apparent need for the product as defined by its general goals. The method by which this was accomplished was a review of the relevant literature in education. It was assumed that this literature was written by experts in education in general and specifically by experts in educational administration. The following reasoning was used to determine evidence of need from the literature. If experts claim that operations research techniques can produce needed solutions, then there is the possibility that there exists a need in educational administration for knowledge of these techniques. Also, if there is the possibility that a need exists for knowledge of these operations research techniques, then there is the possibility that training materials in these techniques are needed. If this is the case, then there is some justification for the development of these techniques.

The following review of the literature is divided into five sections. The first deals with the need for operations research in general, and the other four deal with the need for specific techniques.

Operations Research In General

A number of authors have indicated that there is a need in educational administration for operations research techniques. Hirsh et al. (1967) in Inventing Education for the Future stated that education needs to change to keep pace with the rest of society and that operations research in planning and forecasting are one of several innovations which can effect these changes. Sisson (1967) indicated that operations research techniques are potentially useful for study of large urban school district problems such as administrative decision making and board policy functions. Cook (1968) also stated that operations research would be useful for solving problems in educational project management and administrative decision making. McNamara (1972) strongly implied that operations research can be successfully utilized in educational organizations to effect needed changes and program improvements. Bruno and Fox (1973) asserted that quantitative methods can greatly assist the school administrator in certain decision making processes; that there is an increasing demand for administrators trained this way; and that training materials in such quantitative techniques as those in operations research were needed. VanDusseldorp, Richardson and Foley (1971) demonstrated that operations research techniques can be used to solve a number of types of problems in educational administration. Alkin and Bruno (1970) claimed that systems approaches are useful for solving both mico-problems such as school business functions and la[illegible]problems. Operations research would be useful. The predominant opinion expressed by these authors appears to be that operations research techniques can be very useful in education and that knowledge of these techniques is important for educational administrators.

Planning, Evaluation and Review Technique

A number of authors provided evidence that there is a need for PERT. Cook (1966, 1967), perhaps one of the foremost proponents of PERT in education, asserts that an important problem in educational planning is the allocation of time and manpower for specific projects, and PERT is a technique which facilitates this type of planning. Cochran (1969) indicated that planning is an important part of decision making and that PERT has great utility in planning. Knezevich (1969) stated that new approaches to decision making and problem solving in educational administration are needed; that systems analysis affords promising approaches, and that administrators would benefit from implementing such a rational approach as PERT. Maier (1970) asserted that PERT is a basic procedure for project management in education. Kaufman (1970) agreed. Alkin and Bruno (1970) maintained that PERT and the Critical Path Method have much to offer the implementor in managing and controlling educational systems. Finally, VanDusseldorp et al. (1971) stated that "The use of PERT to allocate and manage time involved in the various activities comprising a project have proven very useful in education." Thus it is possible to conclude that experts conside PERT to be an important tool for educational administrators.

Linear Programming

The need for linear programming was also expressed in terms of its usefulness to the educational administrator. Correa (1966) demonstrated that linear programming can be used to help solve the problem of whether we should have more or better schools. MacNamara (1971, 1973) examined recent developments in linear programming and demonstrated h it could be applied to problem solving at the state and local level. Alkin and Bruno (1970) asserted that there existed a large class of assignment and distribution problems in education, such as allocating classrooms and facilities, which linear programming is especially suited to solve. Finally, VanDusseldorp et al. (1971) claimed that linear programming is useful for solving educational problems in which resources are allocated or are assigned so that the outcome is optimal, and thus it can be a powerful tool for educational problem solving and decision making. From this it may be concluded that these experts viewed linear programming as applicable to educational problems.

Queueing Theory

Two authors have indicated that there is a need for queueing theory. Alkin and Bruno (1970) state that "By applying the queueing theory techniques to the business-like activities of education, those activities could be greatly systematized." And VanDusseldorp et al. (1971) indicated that waiting lines are common in education whenever facilities are shared by a number of persons and that queueing theory is applicable in making utilization of facilities more efficient. Thus there is some evidence of the usefulness of queueing theory.

Computer Simulation

As was the case with queueing theory, the need for computer simulation in educational administration was implied by two authors. Wilson (1969) asserted that there was a need to establish goals, guidelines and constraints in educational planning and furthermore that there was a need to study large and complex educational systems. He concluded by stating that computer simulation can provide a powerful tool for meeting these needs. Alkin and Bruno (1970) maintained that there is a need to examine and understand educational systems interactions and that this is feasible by means of a model where the model reflects the complexity of the system. They conclude that computer simulation can provide such models. Consequently, there is some evidence in the literature that computer simulation could be a useful tool in educational administration.

Conclusion

From the literature cited above, it is possible to conclude that there exists evidence in the literature of education that operations research and its techniques, such as PERT, linear programming, queueing theory and computer simulation, can be used to solve important educational problems. Furthermore, a number of sources (Alkin and Bruno, 1970; Bruno and Fox, 1973; VanDusseldorp et al., 1971; Hirsh, et al., 1967; Knezevich, 1969; McNamara, 1972; Sisson, 1967) indicate that these tools are not widely used. Therefore, it is possible to conclude that training materials which are concerned with these operation research techniques are needed and thus that there is justification for developing the Data Management & Decision Making materials in line with the stated goals.

Detailed Description of Materials

In this section the instructional materials that were developed out of the generalized goals for DM/DM will be described. The purpose of this section is to inform the reader of the nature of the DM/DM materials with respect to instructional objectives, specific content and structure. In the following sections each of the units will be described.

Operations Research in Education

This unit is intended as the introduction to operations research and was constructed to serve as an "advanced organizer" (Ausubel and Robinson, 1969) in that it should organize the thinking style of the users so as to be more readily adaptable to the rest of the materials. Since this is the case, specific instructional objectives were specified for the unit, but it was considered of little importance whether or not the individual user actually achieved them.

The unit discusses the decision process in general terms and analyzes this process into three major components--the decision context, decision strategies, and the payoff. These components are discussed in some detail. This unit also introduces the four specific decision strategies or operations research techniques which are treated in the other four units. These are PERT/CPM, linear programming, queueing theory, and computer simulation. The purposes and applications of each of these techniques are briefly described and are intended to serve as organizers for the four other units. The booklet concludes with a summary of the main points and a listing of the instructional objectives. These instructional objectives may be found in Appendix A. The present form of this unit is a paperbound booklet of

20-pages printed on both sides, with intervening illustrations and exercises. These exercises are interspersed through the unit for purposes of providing the student with practice in the concepts under discussion. After completing this unit, the student is free to proceed to any or all of the remaining four units.

PERT/CPM

This unit provides an introduction to PERT for the educational administrator. The technique is a method for planning the allocation of resources in the execution of projects. The version of PERT covered in this unit is concerned with several tasks in the planning process:

1. Identifying the specific activities in a project
2. Determining their interrelations
3. Mapping these relations in network form
4. Assigning estimated time durations for each of the activities
5. Determining various timing characterisitics of the project, including the key sequences of events for completing the project on schedule, called the Critical-Path Method (CPM).

This content serves as the basis for the instructional goals of the unit.

The unit first discusses the applications of PERT/CPM in general with particular references to applications in educational administration. The unit then goes on to introduce the user to the steps in executing a PERT/CPM analysis including identifying the activities, constructing a PERT/CPM network, computing project times, and finding the critical path.

After the user has learned to execute a PERT/CPM analysis by hand, he is introduced to a computer program which carries out these analyses. This program is GCPATH, which is presently implemented on a Hewlett-Packard 2000F time-sharing computer, and is written in the BASIC language with the intent of being transportable to a variety of BASIC systems. The user is lead through a step-by-step process of using the computer program and is provided with a variety of exercises to practice his or her skill. Next the user is taken through a section which discusses other uses of PERT/CPM and the advantages and disadvantages of using PERT/CPM in an educational setting. The unit concludes with a summary of the topic and a list of the instructional objectives for the unit. (These objectives may be found in Appendix A.) The unit presently takes the form of a 68-page booklet with illustrations and interspersed exercises. The answers to the exercises are included at the end of the booklet. This unit may be used alone, being dependent on only the introductory unit, or in conjunction with any of the other three technique units.

Linear Programming

This unit deals with applications of the mathematical techniques of linear programming in educational administration. Linear programming is a mathematical process for determining a set of conditions under which a specific quantity may be optimized. The technique assumes that all conditions in the problem situation can be expressed as mathematical equations or constraints, that the basic components of th system under consideration are quantifiable, and that the quantity which is to be optimized is expressable as a function of the basic quantities. The technique will take these mathematical expressions and find the values of the basic components such that the quantity of concern (e.g., cost) is optimized (either maximized or minimized). This forms the content from which the instructional objectives for this unit are derived.

In introducing the educational administrator to the operations research technique of linear programming, the unit first leads the user through a detailed but conceptually simple example of a problem solved by linear programming. Since the mathematical procedures for solving linear programming problems are quite sophisticated and complex, and since the purpose of the unit is to introduce the administrator to the technique rather than make him an expert on the subject, no attempt is made to teach the user any of the applicable mathematical manipulations. Rather, the user is provided with a computer program to use in solving linear programming problems. This program is called LINPRG and is presently operational on a Hewlett-Packard 2000 F computer and is written in the BASIC language with the intent of being transportable to a variety of BASIC systems. In teaching the user to employ the program, he is lead through a step-by-step process of entering the necessary information on a computer terminal. Then the unit goes back to a more general discussion of the procedures for formulating linear programming problems. The text then describes in detail several applications of linear programming in education such as planning low-cost school lunches and determining a salary schedule. In the process of going through this section, the user is confronted with a number of opportunities to use the computer program to solve a variety of problems. In the final part, the advantages and disadvantages of using linear programming in educational settings are discussed. The unit concludes with a summary of the main points of the unit and a listing of the instructional objectives. These objectives may be found in Appendix A. The unit presently takes the form of a 124-page booklet with illustrations and interspersed exercises. The answers to the exercises are included at the end of the booklet. This unit may be used with the introductory unit alone or in conjunction with any of the other three specific techniques.

Queueing Theory

This unit is concerned with the application of the mathematical techniques of queueing theory to educational administration. This technique provides several mathematical models of situations in which queues form. In education it is applicable to situations in which some customers are waiting to use a service where the customer and the services may be a great number of different things. Queueing theory will yield a number of quantities which describe this situation such as what the average time a customer must wait for service, how much of the time the service is idle and what is the probability that there will be a given number of customers waiting in line. All these characteristics of the queueing system can then be used to make decisions about changing the components of the queueing system. This mathematical technique forms the basis from which the instructional objectives for this unit were derived.

The unit begins with an explanation of the terminology of queueing theory and the conditions necessary for it be be employed accurately. The unit then presents four sets of conditions under which queueing theory may be applied and gives examples of problems which illustrate these conditions. In the process of presenting these problems, the user is introduced to a computer program which will solve queueing theory problems. This program is called QUEUE and is implemented on a Hewlett-Packard 2000 F computer. This program is written in BASIC so that it can be transported to a variety of BASIC systems. In teaching the user to use the QUEUE program, the unit provides a step-by-step process of entering the necessary information on a computer terminal. This program is used throughout the test to solve queueing theory problems. The final part of the unit presents the advantages and disadvantages of using queueing theory in educational settings, summarizes the main points of the unit, and gives the instructional objectives for the unit This unit is presently 89 pages with illustrations and exercises interspersed throughout the test. The answers to the exercises are included at the end of the booklet. This unit may be used with the introductory unit alone, or in conjunction with any or all of the other three units.

Computer Simulation

The unit on computer simulation is concerned with familiarizing the educational administrator with simulation as a problem-solving technique. In this case, using a simulation involves identifying a model of the system of interest. This model is then computerized and the behavior of the system is investigated by experimenting with the computerized model.

The unit begins with a theoretical treatment of simulation. It details the components of a simulation, the classes and types of simulation, and the purposes of simulation. This general treatment is followed by two specific educational applications of computer simulations. The first involves a computer program called BUSRUT which simulates the routing of school buses. The second is a computer program named ENRPRO which simulates the changes in a school district's student population over a period of years. Both of these programs are implemented on a Hewlett-Packard 2000 F computer and are written in the BASIC language for maximum versatility. In the case of each simulation, the student is lead through a detailed, step-by-step procedure for using the simulation and interpreting the output, and then is confronted with a series of problems which can be solved by using the simulation. The final portion of this unit is an overview of computer simulation. It discusses the advantages and disadvantages of using simulation in educational settings, summarizes the main points of the unit and lists the instructional objectives for the unit. This unit presently takes the form of a 101-page booklet with illustrations, computer printouts, and interspersed exercises. The answers to the exercises are included at the end of the booklet. Like the other technique units, this unit may be used with only the introductory unit or in conjunction with any or all of the other three units.

Intended Uses for the Materials

Data Management & Decision Making is designed to be used in any of three instructional situations:

1. College level courses in educational administration

2. Inservice or normal training workshops

3. Independent study in operations research.

Each of these three uses of the DM/DM materials requires different conditions.

When the DM/DM materials are used in a college course in educational administration, they are intended to serve as a supplement to the usual course content. Consequently, it is possible to use anything from a single unit to all of the units, depending upon how much time the instructor wishes to devote to operations research. Due to the structure of the units, it is not necessary for the instructor to lecture on the techniques he or she wishes to cover, but the learning process will be facilitated by having the instructor available to answer questions and conduct group discussions concerning the topics under consideration. Optimal use of these materials requires having access to a time-sharing computer and several computer terminals. Some evidence indicates that it is also facilitative for students to work on the materials in small groups, as it is conducive to problem solving. In addition, the testing of the materials indicated that a minimum of two class sessions should be devoted to each unit, since approximately six to eight hours are necessary to go through each of the units. With arrangements such as those stated above, it should be possible to obtain results as good as those obtained in the field test, and with the additional participation of the instructor, it is anticipated that the results of instruction should be even more positive.

When the DM/DM materials are used in inservice training or a workshop, a large variety of instructional configurations are possible. The three most probable configurations will be discussed here. The first is a one-day inservice training session for practicing administrators. Here it will probably be most appropriate to concentrate on only one technique, since about six to eight hours will be required. Again, computer access must be arranged for and terminals must be available. It is also assumed in this situation that the presence and participation of the instructor is particularly important. The most successful use of the materials in this situation would probably be a combination of lecture, discussion, group work and self-study. These same cautions and conditions will also be true of short duration workshops of a day or two. The second alternative is the long-duration workshop in which the entire set of DM/DM materials is used. This will be a period of concentrated study in which each of the four techniques would occupy one day of study. Again leadership will be important to the success of the workshop, even though the materials are designed to be largely self-instructional.

The third method of use of the DM/DM materials is in the self-study mode. The materials were designed so that individuals interested in using operations research in education could learn the use of some techniques by working through the booklets; however, in this mode additional assumptions are made about the user. In using some of the units, the mathematics is moderately complex, and so an individual, to be entirely independent, must have a good background in mathematics. Also, in order to effectively use the computer as a learning tool he or she must be somewhat familiar with the operation of a computer terminal and have some knowledge of what to do to correct mistakes. In addition, in this mode it is especially important to work through the exercises, because the user has no other source of feedback.

In summary, this section has described in detail the content and structure of Data Management & Decision Making. In addition, it has also described the three modes of instruction for which the materials are intended. This completes the description of the materials.

Developmental History

The Data Management & Decision Making materials passed through several stages of development and evaluation before the product which is described in this report was produced. The developmental process had three formal stages. Associated with these developmental stages were two formative evaluations of the products. The first development stage was the Exploratory Product which was subjected to Exploratory Testing. Based on this evaluation, the Prototype Product was developed and this, in turn, was subjected to Pilot Testing. Out of this Pilot Testing, the Interim Product was developed, and this was the subject of the final investigation presented in this report.

In the development of the Exploratory Product, a number of steps were carried out. First, the instructional goals were developed for each of the units based on the overall goal of the materials. Each unit was then outlined, and suitable computer programs to accompany each unit were searched out. As the last step in this initial development, the first version of each unit was drafted.

At this point the Exploratory Testing of the materials took place. This involved two activities--expert review and individual trials. In the expert review, five authorities were selected to review the first draft of the materials. These individuals were:

1. Dr. John Lind, Professor of Educational Administration, Portland State University
2. Dr. Charles Klein, Professor of Educational Administration, Purdue University
3. Dr. James MacNamara, Professor of Educational Administration specializing in Operations Research, University of Texas
4. Dr. Donald Treffinger, Professor of Educational Psychology and specialist in curriculum design, University of Kansas
5. Dr. Ralph VanDusseldorp, Professor of Educational Administration, and specialist in Operations Research, University of Iowa.

Each of these persons was sent a copy of the product along with a specific list of questions concerning the materials and was asked to carry out a detailed review of the materials. Each performed the review and the developers received back the answers to their questions and the review copies with profuse marginal comments.

The other activity involved in the Exploratory Testing was individual trials. For the purposes of these trials, about 20 persons were randomly selected from a list of students in educational administration at Portland

State University and asked to be paid volunteers. Each of these volunteers was randomly assigned to one of the technique units making a total of five volunteers per unit. A time was then set when the volunteer and the evaluator could meet. At this meeting, each volunteer was asked to work through the material in the presence of the evaluator and to comment on anything that caused difficulty or was worthy of comment. These sessions were also tape recorded. After all volunteers had gone through the materials, the materials were revised by the developers based on the outcomes of the trials and the validity of these changes was confirmed by going through the same process with two other individuals for each unit.

The information derived from this Exploratory Testing became the basis for the revision of the Exploratory Products to Prototype Products. The suggestions and comments of the experts were collected with the responses from the individual trials. These were then used to again revise the materials. These reviseo materials were then printed to produce the Prototype Version.

This Prototype Version of the DM/DM materials was evaluated in an initial test. The initial testing of the Prototype Version is reported in detail in the document entitled Report on the Evaluation of the Prototype Version of Data Management/Decision Making (Speedie, 1974). This formative evaluation of the materials will be summarized here.

In this initial testing, the cooperation of classes of summer students was obtained at Portland State University and Northern Arizona University. Two class sessions were used at Northern Arizona University and four class sessions were used at Portland State University. At the beginning of the first class all students received "Operations Research in Education" and were randomly assigned to one of the four technique units. Before studying the units each student took a pretest over both cognitive and affective objectives of the units. They then worked through the units, reading the materials, performing the exercises, and using the computer. Then at the end of the last class session, the students took a posttest over the same objectives. Finally a randomly selected sample stratified by technique unit was interviewed by telephone concerning their reactions and opinions about the materials they studied.

The results of this evaluation indicated a number of things. It was discovered that students needed a minimum of six to eight hours to work through the materials. Apparently by studying the materials the students were able to achieve significantly more objectives on the posttest for each of the units. The units appeared to change some attitudes toward operations research in education and in the positive direction. Finally, the interviews indicated that the students were generally satisfied with the materials and thought them appropriate for educational administration students.

Since the results of the pilot test were so positive and no changes in the materials were indicated as necessary, it was the decision of the project staff that the materials should be advanced to Interim status and subjected to field testing. At the same time a summative evaluation of the materials was called for by the contract so that these two activities were combined. The summative evaluation of the DM/DM materials is in the next section.

SUMMATIVE EVALUATION OF DATA MANAGEMENT & DECISION MAKING

The purpose of the summative evaluation of the Data Management & Decision Making materials is to determine the worth of the final outcome of the developmental process executed in this project. The materials studied are therefore those which emerged from the Interim stage of product development. The purpose of this report is to communicate the results of this evaluation to the audiences interested in the product and those responsible for decision making with respect to this product.

All persons reading this report should take note of the possible sources of bias which may exist in those individuals who executed the summative evaluation and who prepared the report. The circumstances were such in the Computer Technology Program that the person primarily responsible for product evaluation within the program was initially assigned the responsibility for developing the DM/DM materials. After the initial development, this same person conducted the formative evaluations of the product though he was no longer directly responsible for the development of the materials. Finally, this person also executed the summative evaluation of the product. Thus, the possibility of co-option does exist; however, the responsible evaluator attempted to the best of his ability to maintain maximum objectivity throughout the evaluation. Since this might not prove sufficient, this summative evaluation was also reviewed by knowledgeable persons within the Laboratory who were in no other way connected with the project. Therefore, while the possibility of bias in this report exists, every reasonable attempt within the limitations imposed by the funding agency, has been made to minimize this bias.

Areas of Concern In the Summative Evaluation

The summative evaluation of the Data Management & Decision Making materials was concerned with judging the worth of the product with respect to five criteria. The first of these focused on the empirical justification for the development of these materials. The question of concern was whether or not there was a demonstrable need for this product. The second concern focused on the ability of the product to cause learning--particularly with respect to the attainment of the objectives specified for the materials. That is, it considered the question of whether or not using the product resulted in the achievement of the specified learning objectives. The third criterion focused on a comparison of the developed product with materials which were its likely competitors. It was concerned with determining if DM/DM performed better than its likely competitors with respect to a number of criteria. The fourth focus of attention in this evaluation was the side effects of the product. It focused on determining if the product and its likely competitors had important side effects. The fifth and final concern centered on the cost-effectiveness of the product. It was concerned with determining the costs and benefits of the product and comparing them with those of its likely competitors. The following list of questions summarized the major areas of concern in the summative evaluation of Data Management & Decision Making.

1. Is there empirical evidence of a need for Data Management & Decision Making?
2. Does using the Data Management & Decision Making materials cause attainment of the specified goals of instruction?

3. Do the Data Management & Decision Making materials perform better than other materials which can compete with them in the educational market?

4. What are the costs of using Data Management & Decision Making, how do these costs compare to the benefits of these materials, and how do they both compare to the costs and benefits of its likely competitors?

5. What are the important side effects of the Data Management & Decision Making materials and how do they compare to those of its likely competitors?

Assessment of Need

In order to determine if there was empirical evidence of need for the Data Management & Decision Making materials a needs assessment was conducted. That is, there was an attempt to determine if there was a need for the results of attaining the goals of this project.

To accomplish this task a survey of the target groups for this product was undertaken. From the empirical results of this survey, inferences were made about the need for the DM/DM materials. In the following sections, the sample, procedures, results and conclusions will be described and discussed.

Sample

The populations of interest for this needs assessment were those groups which were specified as the target groups for DM/DM. These groups involved both primary users of the materials and those in decision making roles with respect to using the materials. The groups were:

1. Students enrolled in educational administration courses at the college or university level
2. Practitioners of educational administration
3. Professors of educational administration

Sampling Plan

Each of the three groups was sampled from a defined sub-population of the total population of that group. The population of students was considered to be all students enrolled in educational administration in the United States. The population of practitioners was defined by the entries in Patterson's American Education (1973), a listing of all school districts in the United States along with their chief administrators. The population of professors of educational administration was defined as all members of Division A (Administration) of the American Educational Research Association, as listed in the 1973-1974 Directory of Members.

Individuals were sampled in each of these aggregations so that the final sample was stratified according to group membership. The sample of students consisted of 50 students enrolled in educational administration courses at Portland State University. This group contained some practicing administrators returning for further education as well as full-time students in educational administration. The practitioner sample was selected by randomly choosing approximately five school districts within each state to yield a stratified national sample. Within each of these districts the chief administrator was contacted. To choose the sample of professors, persons were selected from the AERA Directory. Each twelfth individual listed in the Directory with Division A membership was selected to be contacted. It should be evident that only the practitioner sample was a truly random sample. The professor sample approximated a random sample, and the students sample was an "opportunity" sample.

Survey Instrument

The survey instrument was based on the validity of an inference designed to infer need from two "lower order" responses. Since it was assumed that most of the survey subjects were not familiar with operations research terminology, it was decided that the problem of determining need was to be approached indirectly. Instead of asking directly if there was a need for training in a specific operations research technique for educational administrators, all subjects were asked two related questions, concerning problem types theoretically solvable by the operations research techniques of concern in this project. That is, each subject was presented with a brief description of a problem type and asked how frequently they encountered that problem type in their work and what level of need they perceived for training materials in techniques that could solve that problem type. The inference was then constructed that "if a subject indicated that he encountered a problem type in his work and that if he felt that there was a need for appropriate training materials, then it was inferred that there was not only a desire for appropriate training materials, but a genuine need for them." That is, such responses indicated that appropriate training materials were wanted and that accomplishment of the goals of these materials would be of some utility in solving problems encountered by educational administrators. To illustrate how this was accomplished, a sample item is shown below. See Appendix B for the full form of the instrument.

PROBLEMS ENCOUNTERED			MANAGERIAL FUNCTION	TRAINING MATERIALS		
Please check only one box.				Please check only one box.		
Often	Some-time	Hardly Ever		Needed Very Much	Needed But Not Essential	Not Needed
☒	☐	☐	13. Predicting changes in school enrollment	☐	☐	☐

Fig. 1. Sample item from the needs assessment instrument.

Procedures

The procedures involved in executing the survey involved drawing the samples, mailing out the instrument, and tabulating the responses. Clerical personnel selected the survey subjects according to the sampling procedures as specified in the sampling plan. The names drawn from the professors and practitioners samples were typed on reproducible labels and stamped self-addressed envelopes were prepared. An introductory letter (see Appendix B) was prepared by the evaluator and attached to each copy of the instrument. In addition, all professor and practitioners instruments, along with the introductory letter and the return envelope, were mailed to each subject. After a period of 30 days, all instruments which had been returned were checked off against a master list of instrument numbers. These returns were to two types--completed forms and mail not deliverable. For those subjects it was not possible to contact (i.e., mail not deliverable) replacements were drawn from the populations as in the original sampling. These new subjects, and all other subjects who had not responded to the first mailing were sent a second mailing, identical to the first. This completed the attempts to contact subjects.

After an elapsed time of approximately six months, the survey instrument was tabulated and the results analyzed. First, the forms were divided into three groups corresponding to the three groups of interest. The responses were tabulated in matrix form as in Fig. 2.

		Problems Encountered		
		Often(1)	Sometimes (2)	Hardly Ever (3)
Training Materials	Needed very much (4)	Level 1 Response		
	Needed but not essential (5)		Level 2 Response	
	Not needed (6)			

Fig. 2. Possible combinations of responses as portrayed by a matrix.

Since there were two responses for each item and thre[illegible]ssible levels for each response the data were tabulated in a 3 x 3 matr[illegible]ntaining all possible combinations of responses, where each entry represented the total number of responses of that type for that group. Since all the operations research techniques of interest to this project were represented by more than one problem type, the matrices for each technique were aggregated in order to derive a total response matrix for each technique. The combinations of items which were used to calculate the total responses for each technique are given in Table 1.

Table 1.

Correspondence of Questionnaire Items with Content of DM/DM

Content Area	Pertinent Items
1. Operations Research in Education	1, 8, 14
2. PERT/CPM	2, 3, 6, 10, 15
3. Linear Programming	4, 11, 15, 16
4. Queueing Theory	5, 7, 12
5. Computer Simulation	9, 13, 17

Then in order to translate the results into readily comparable terms, the entries in each total matrix were transformed into percentages of the total responses for that matrix. At the next level of summation, percentages were calculated for the matrices of:

1. Each technique across all groups
2. Each group across all techniques
3. Overall responses across all groups and all techniques.

Finally, in order to facilitate interpretation, two additional figures were calculated for each technique in each group, and the three listed above. The first of these was called Level 1 response and was the percentage of responses in each matrix which rated a technique as pertaining to problems which were often encountered and in which training was very much needed. The second was the Level 2 response and was the total percentage of responses which indicated that problems related to techniques were at least sometimes encountered and training was needed if not essential. Thus the Level 2 response included Level 1 response. See Figure 2 for a pictorial representation of these two figures. The final analysis performed on this data was to test the differences on Level 1 and Level 2 responses among the groups by means of a t-test on the proportions.

Results

The first result calculated was the response rate for the survey--the percentage of subjects who responded to the survey. The student response rate was 100% due to the nature of the administration procedures. The response rate for the sample of practitioners of educational administration

65% and the response rate for the professors of educational administration was 63%.

The basic results of the survey, the total response matrices, and percentage matrices are presented respectively in Tables 3 and 4, on the next two pages. Since these tables are large and complex and their information density is so thin, these tables are included here for perusal but they will not be directly discussed.

The most important results of this study, the Level 1 and Level 2 responses, are given in Table 2. The first figures that this table presents

Table 2

<u>Data Management & Decision Making</u> Needs Survey--
Percentage Indicating Level 1 and Level 2 Responses*

Technique	Students (1)		Administrators (2)		Prof. of Ed. Admin.		All	
	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2
Analysis of Decision-Making	45	85	44	85	50	87	45	84
PERT/CPM	50^{3**}	91	48^{3}	85^{3}	$39^{1,2}$	90^{2}	46	88
Linear Programming	48^{2}	88^{2}	$60^{3,1}$	$95^{3,2}$	51^{2}	91^{2}	53	91
Queueing Theory	26	71^{2}	33^{3}	$89^{3,1}$	22^{2}	76^{2}	27	79
Computer Simulation	20	63^{2}	28	74^{1}	27	67	25	68
Total	38^{2}	$80^{2,3}$	$43^{1,3}$	$87^{3,1}$	39^{2}	$84^{1,2}$	41	85

* Level 1 response: Indicating that a type of problem is often encountered and training is needed very much.
Level 2 response: Indicating that <u>at least</u> a problem type is encountered sometimes and that training is needed, if not essential. (Level 1 is included.)

** Indicates that the Student Level 1 response to PERT/CPM is significantly different at the .01 level from the Level 1 response of Professors of Educational Administration (3).

are the Level 1 and Level 2 responses by technique within survey group. Student, practitioner and professor Level 1 responses indicated that all groups considered the introduction to operations research, PERT, and linear programming to be the three areas in which training materials were most needed. For all three groups much smaller Level 1 responses were given for queueing theory and computer simulation. For the first three techniques the Level 1 responses across all three groups ranged from 39% to 60% indicating that approximately one-half of the respondents in each of the groups felt that these were techniques which solved frequently-encountered problems and were techniques for which training materials were much needed. Level 2 responses for each of the groups followed essentially the same pattern as those for the Level 1 responses with one exception. Administrators gave a high Level 2 response to queueing theory. It is important to note that practically all Level 2 responses exceeded 70%, except for students' and professors' responses to computer simulation which were slightly less.

Significance tests among the Level 1 and Level 2 responses within techniques across groups revealed a number of significant differences; however, most of these differences were reasonably small in that they did not exceed 11%. The one exception was between the Level 2 responses for students and administrators to queueing theory. The response for the administrators exceeded the response for the students by 18% and proved to be the second highest response for the practitioners.

Table 3

Total Response Matrices for Each Technique for Each Target Group.[1]

Technique		Students 1	Students 2	Students 3	Administrators 1	Administrators 2	Administrators 3	Professors of Ed. Admin. 1	Professors of Ed. Admin. 2	Professors of Ed. Admin. 3
Introduction to Operations Research	4	66	28	2	210	80	8	253	49	11
	5	1	29	11	11	107	17	17	122	15
	6	0	1	10	1	11	37	2	9	23
		N = 148			N = 482			N = 501		
PERT/CPM	4	124	41	9	392	79	5	305	132	3
	5	13	49	8	34	183	15	57	213	23
	6	0	1	4	46	17	39	11	13	25
		N = 249			N = 810			N = 782		
Linear Programming	4	96	28	4	389	62	1	348	71	10
	5	8	44	9	33	129	7	60	148	12
	6	0	2	8	6	5	17	1	9	20
		N = 199			N = 649			N = 689		
Queueing Theory	4	38	13	4	160	61	3	111	60	8
	5	9	45	23	27	179	11	23	181	31
	6	0	1	15	4	13	25	1	20	60
		N = 148			N = 483			N = 495		
Computer Simulation	4	30	26	8	134	68	3	132	66	10
	5	7	31	21	16	140	23	21	114	30
	6	0	1	27	11	14	76	0	26	93
		N = 151			N = 485			N = 492		
Total	4	322	129	25	1181	355	20	1113	360	42
	5	37	192	72	126	714	71	167	747	108
	6	0	6	60	31	58	190	15	77	218
		N = 843			N = 2746			N = 2847		

OVERALL

	1	2	3
4	2616	844	87
5	330	1653	251
6	46	141	468

N = 6436

[1] See Fig. 2 for the responses corresponding to the numbered categories.

Table 4

Percentage Response Matrices for Each Technique for Each Target Group and Summary Percentages

	Students			Administrators			Prof of Ed Administration			All Groups		
	1	2		1	2	3	1	2	3	1	2	3
4	45	19	1	44	17	2	50	10	2	45	15	2
5	1	20	7	2	22	4	3	24	3	2	22	5
6	0	1	7	0	2	8	0	2	5	0	2	7
	1	2	3	1	2	3	1	2	3	1	2	3
4	50	16	4	48	10	1	39	17	0	46	14	2
5	5	20	3	4	23	2	7	27	3	5	23	3
6	0	0	2	6	2	5	1	2	3	2	1	3
	1	2	3	1	2	3	1	2	3	1	2	3
4	48	14	2	60	10	0	51	10	1	53	11	1
5	4	22	5	5	20	1	9	21	2	6	21	3
6	0	1	4	1	1	3	0	1	3	0	1	4
	1	2	3	1	2	3	1	2	3	1	2	3
4	26	9	3	33	13	1	22	12	2	27	11	2
5	6	30	16	6	37	2	5	37	6	6	35	4
6	0	1	10	1	3	5	0	4	12	0	3	9
	1	2	3	1	2	3	1	2	3	1	2	3
4	20	17	5	28	14	1	27	13	2	25	15	3
5	5	21	14	3	29	5	4	23	6	4	24	8
6	0	1	18	2	3	16	0	5	19	1	3	18
Total	1	2	3	1	2	3	1	2	3	OVERALL 1	2	3
4	38	15	3	43	13	1	39	13	1	41	13	1
5	4	23	9	5	26	3	6	26	4	5	26	4
6	0	1	7	1	2	7	1	3	8	1	2	7

Table 2 also presents the Level 1 and Level 2 responses of all three groups combined for each of the techniques. These appear in the last set of columns in the table. These figures reveal a similar pattern of responses for both levels. The highest rated was linear programming (53%, 91%) followed by PERT (46%, 88%), introduction to operations research (45%, 84%) queueing theory (27%, 79%) and computer simulation (25%, 68%). Level 1 responses ranged from 25% to 53%, while Level 2 responses ranged from 68% to 91%.

Finally, Table 2 presents the responses across all techniques combined for each of the three groups and their aggregation. These figures appear in the last row of the table. The practitioners gave the highest level Level 1 (43%) and Level 2 (87%) responses of all the groups, which were, in fact, significantly greater than the responses for either of the other two groups. The responses of the students and professors were essentially similar, with the exception of a significant 4% difference between Level 2 responses. The final summary figures are the Level 1 and Level 2 responses across all groups and all techniques. These were 41% and 85% respectively. These last figures would appear to indicate a reasonable level of need for the techniques.

Conclusions

Several conclusions are readily evident from the above stated results. First, since almost all Level 1 responses exceeded 25% it may be concluded that at least one-quarter of all surveyed groups saw the problems related to operations research techniques as encountered often and felt that need for training in these techniques was great. Second, since almost all of the Level 2 responses exceeded 66%, it may be concluded that at least two-thirds of all surveyed groups saw the problems solvable by the operations research techniques as sometimes encountered and that training in these areas was needed, if not essential. Third, the survey revealed that all groups surveyed had differential perceptions with respect to the different techniques, with linear programming given the highest response. Fourth, the practitioners of educational administration seemed to hold these techniques in greatest value. And fifth, for the total package of techniques across the combined groups, slightly less than half the respondents perceived it as being greatly needed, while more than four-fifths perceived the package to be needed if not essential. Thus it would appear that there exists strong evidence of need for Data Management & Decision Making.

Before drawing the final conclusion, however, it is appropriate at this time to discuss briefly some of the cautions concerning the conclusions. It should be evident that the student sample was drawn from a single university in a specific geographic region, and thus may not be representative of the entire population of students in educational administration. In addition, there may be some bias in the professors of educational administration sample. Since all respondents were members of a research organization, it is possible that there is a bias in this group toward using scientific techniques for problem solving, and thus a higher level of response may be given that is actually the case for the entire population. Since these sources of possible bias exist the strength of the conclusions must be tempered.

What may be concluded from this survey is that among important decision making groups, though they may not be entirely representative of the target groups specified for the product, there is strong evidence of need for training in the techniques of operations research as specified in Data Management & Decision Making. Among students in educational administration, there is some evidence of perceived need but it is not possible to generalize this to the entire population.

Field Test of Product

The field test of Data Management & Decision Making dealt with three aspects of the summative evaluation--achievement, competitors and side effects. As previously stated, however, these concerns are insufficiently precise for conducting an experimental inquiry into the effectiveness of the DM/DM materials. In the following paragraphs the evaluation questions will be refined so as to derive testable hypotheses for the field test.

The first aspect, achievement, has to do with whether or not the product is able to cause achievement with respect to the goals of instruction. If we define learning as a positive change in the level of goal attainment, then the question becomes one of learning. Consequently, one of the questions this field test inventigates is whether or not the DM/DM materials cause cognitive learning. For purposes of generating the experimental situation, this question was phrased as:

> "Do the DM/DM materials cause a significant positive change from pretest to posttest on a questionnaire designed to measure attitude toward operations research in education?"

The second aspect of the field test, competitors, has to do with comparing the DM/DM materials to possible competitors in order to ascertain if they "do better" than their competitors. We are therefore interested in determining whether or not the DM/DM materials compare favorably with their competitors with respect to a number of criteria. In this field test two particular criteria are of interest--cognitive learning and attitude change. For the purposes of the field test these concerns are phrased in the form of two questions:

> "Are the statistically adjusted posttest scores on a test designed to measure objective attainment for the DM/DM materials significantly better than those of its competitors?"

and

> "Are the statistically adjusted posttest scores on the instrument designed to measure attitude toward operations research in education for the DM/DM materials significantly better than those of its competitors?"

The third and final aspect with which this field test is concerned is the question of side effects. That is, the investigation is interested in determining if there are important outcomes of using the DM/DM materials which were not planned for in the original description of the intents of the materials. A subsidiary matter of concern in this area is a comparison between the important side effects of the DM/DM materials and its competitors.

It is important to note that the questions as phrased above imply that it is desired to evaluate the overall performance of the DM/DM materials. This is not the case. Since the materials were originally designed so that the instruction on each technique would be independent of any other of the units of instruction except for the introduction, it is appropriate to focus on how each unit performs. Consequently this evaluation is concerned with how each of the questions stated above is answered for each of the units of instruction. "Introduction to Operations Research" is not included since it is intended merely as an "advanced organizer" for the four technique units. Therefore this evaluation will attempt to answer each of the six evaluation questions stated in the previous paragraphs for each of the four technique units--"PERT/CPM: A Planning and Analysis Tool," "Linear Programming," "Queueing Theory" and "Computer Simulation."

Design of the Field Test

In the following sections the sample and sampling procedures will be described, the testing instruments will be depicted, the procedures explained and the analyses delineated.

Sample. The sample for this field test was drawn from the primary target populations of the DM/DM materials. It consisted of students in educational administration courses in universities at the graduate level. Due to the nature of postgraduate education in the field of education, the sample included both practitioners of educational administration and full-time students in educational administration. The sample was drawn by contacting professors of educational administration at several universities around the country and asking for their cooperation in this field test by making their classes in educational administration available. This search revealed four such persons who were willing to cooperate. Three of these were at the University of Iowa (UI) and one was at Northern Arizona University (NAU). These persons volunteered a total of six graduate classes for the field test. Two of these classes were at NAU and totaled 27 students. The other four classes were at UI and totaled 75 students.

Table 5 reports a number of characteristics of the sample which are considered relevant for this field test. At both schools the predominent

Table 5

Descriptive Characteristics of the Sample Used in the Field Test of Data Management and Decision Making

	SCHOOL	
	NAU	UI
Position		
Student	2	20
Teacher	7	28
Administrator	1	14
Other	6	3
No Response	11	10
Degree		
Bachelors	-	20
Masters	15	41
Doctorate	1	3
No Response	11	11
Administrative Experience		
0	15	34
1-5 years	1	13
6-10 years	-	6
11-15 years	-	7
16 +	-	3
No Response	11	12

number of respondents were either students or teachers. While there was only one practitioner at NAU, there were 14 at UI, a reasonable number considering that the courses were in the fall term. Most of the degrees held were either Bachelors or Masters with a very few Doctorates. The predominant years of experience in administration was zero for both schools. At UI approximately one-third of the subjects had some administrative experience ranging from 6 to 16 years. From this information it would appear that the subjects sampled met the specifications for the target groups for the materials in that they are generally either students or administrators returning for further education generally at the graduate level, though there is a predominance of potential over practicing administrators.

Instruments. Ten instruments were designed for this field test. They were intended to measure both the cognitive and affective outcomes of the products and their competitors. Eight of those were cognitive learning instruments constructed in four subject-matter pairs. Each pair was used to measure cognitive learning with respect to one of the four operations research techniques--PERT, linear programming, queueing theory and computer simulation. The purpose of constructing the instruments in pairs was to provide parallel forms for use in a pretest-posttest situation. Each form in the pair of instruments was constructed so that each item corresponded to an instructional objective for the unit concerned with a particular technique. Thus in each instrument-pair there were two items for each instructional objective--one on one form of the instrument and one on the other. All instrument-pairs were evaluated during the pilot test of the materials. They were found to be generally acceptable according to some heuristic criteria for objective-referenced tests. Before the field test, however, some item pairs were revised to correct for deficiencies discovered in the pilot testing. After the completion of the field testing, internal consistency reliability coefficients were calculated for each of the forms in each of the instrument pairs. Since the item scores were variable rather than dichotomous, the Kuder-Richardson Formulas were not appropriate. In this case, the measure of internal consistency was that for the reliability of a composite test--Coefficient Alpha (Lord and Novick, 1968). It should be noted that this is not the true internal consistency reliability of the test, but rather a lower bound on that reliability. These reliability coefficients are reported for both the pretest and posttest in each of the following instrument descriptions.

1. PERT: The pair of instruments designed to measure the content learned from the unit on PERT consisted of 18 item pairs keyed to the instructional objectives for this unit as listed in Appendix A. These pairs were split as described into a pretest and a posttest form with a total of 34 points on each. These forms took approximately 45 minutes to complete each. The lower bound of their internal consistency reliability as expressed by Coefficient Alpha was .24 for pretest and .65 for the posttest.

2. Linear programming: The pair of instruments designed to measure the content learned from the unit on linear programming consisted of 16 item pairs keyed to the instructional objectives for this unit as listed in Appendix A. These pairs were split as described into a pretest and a posttest form with a total of 30 points on each. Each form took approximately 35 minutes to complete. The lower bound of of their internal consistency reliability as expressed by Coefficient Alpha was .63 for the pretest and .66 for the posttest.

3. Queueing theory: The pair of instruments designed to measure the content learned from the unit on queueing theory consisted of 17 item pairs keyed to the instructional objectives for this unit as listed in Appendix A. These pairs were split as described into a pretest and a posttest form with a total of 30 points on each. These forms each took approximately 35 minutes to complete. The lower bound of their internal consistency reliability as expressed by Coefficient Alpha was .60 for the pretest and .71 for the posttest.

4. Computer simulation: The pair of instruments designed to measure the content learned from the unit on computer simulation consisted of 16 item pairs keyed to the instructional objectives for this unit as listed in Appendix A.

These pairs were split as described into a pretest and posttest form with a total of 34 points on each. Each form took approximately 40 minutes to complete. The lower bound of their internal consistency reliabilities as expressed by Coefficient Alpha was .62 for the pretest and .72 for the posttest.

Each of these instruments was scored in two ways. The first score reflected achievement on the entire set of cognitive objectives for each DM/DM unit, and was the total points scored on the test. This score was known as the Full Cognitive Test Score. In order to make a more rigorous comparison between the DM/DM materials and their competitors, an additional score was calculated. This score was determined by adding up the scores on items which reflected objectives in common for the two sets of materials. This score was called the Common Objectives Score. Both these scores were then used to compare the two sets of materials.

The two affective measurement instruments were designed to measure attitude toward using operations research in education and toward using the developed products as a learning tool, and feelings about the structure within which the materials were used. A copy of each of these instruments may be found in Appendix B. The first of these instruments, Questionnaire 2a, was used to measure attitudes both before and after the products were used. This questionnaire consisted of 18 statements with five point Likert scales of agreement. The first 10 of these items were designed to measure participants' attitudes toward using operations research in education. The measure of the attitude was the average response on the 10 items by each individual. The last eight items dealt with attitudes concerning the materials studied. In using this questionnaire as a pretest of attitudes the students were instructed to ignore the last eight items. When the questionnaire was used as a posttest, the students were asked to respond to all items. The internal consistency reliability of the first 10 items of the questionnaire was evaluated by means of Coefficient Alpha. For the pretest the lower bound of the internal consistency reliability (Coefficient Alpha was .81. This was judged as acceptable. No attempt was made to evaluate the reliability of the last eight items since each item was interpreted individually.

The other instrument designed to determine attitudes related to the use of these materials was Questionnaire 3 which may be found in Appendix B. This questionnaire collected the descriptive data given in the Sample section and asked several free response questions about the materials. These questions concerned the students feelings about the manner in which they studied the materials, difficulties in using the computer, the best and worst things about the units they studied, possible improvements, specific criticisms, their recommendation to others concerning these materials, and their overall reaction to the materials.

It is important to note in judging the quality of these instruments with respect to reliability that several factors may have contributed to the rather low values. Accurate estimates of reliability of this type are dependent on two factors. The items must be approximately homogeneous and the size of the sample must be fairly large in order to obtain a "good" estimate of the internal consistency reliability by means of Coefficient Alpha. The validity of both of these assumptions is in doubt for this field test. The objectives for the materials specified a number of different pieces of knowledge and several skills, all of which are not necessarily closely related. Thus, the items may lack homogeneity in that they attempt to measure different things. Second, the group sizes used to determine the reliability were rather small (all less than 30 Ss). The effect of the violation of these two assumptions is that the lower bound of the reliability is generally underestimated. As a result all lower bounds on the reliability of the instruments used may be underestimated.

In the next section the uses to which these instruments were put will be described.

Procedures

The first step of the procedures for this field test was the identification and selection of the competitors against which the products were to be compared. The first attempt at this involved a search for a single product which could compete directly with DM/DM in the educational marketplace. This attempt resulted in nothing directly comparable to the DM/DM materials in a single entity. The search then shifted to a second focus--locating competitor materials for each of the four operations research techniques units. In this second phase of the search, materials were sought which possessed evidence of empirical validation and which were parallel in content to the DM/DM units. The search was unable to discover any materials which met either of these criteria. There were no units of instruction concerned with the four techniques of operations research which were empirically validated. In addition, there were no materials which included both a discussion of the operations research techniques and emphasis on using them as computer-based problem solving tools. The search did reveal, however, a number of units of instruction that did speak to a subset of the instructional goals specified for the DM/DM materials.

PERT and/or CPM has been a popular instructional subject in many fields of management for about the last ten years. This popularity has resulted in a profusion of tests and instructional materials on the subject. However, without exception, they maintain an abstract or general business emphasis. Problem examples are generally concerned with demonstrating the application of PERT or CPM to general management tasks or typical business projects. Nowhere was there any evidence of concern with problems characteristic of educational administration. Thus, it was not possible to select a competitor that was concerned with problem solving in educational administration. The best that could be done was to select an acceptable general test concerned with PERT and/or CPM.

The competitor selected as being the best treatment of the subject within the stated restrictions was A Programmed Introduction to PERT (1967). This particular text was chosen for several reasons. First, being programmed instruction, it was intended to be largely self-instructional as was the DM/DM unit on PERT. The basic objectives concerning the technique were essentially the same as those expressed for "PERT/CPM". The text was fairly short and was estimated to take the same amount of instructional time as "PERT/CPM." And finally, this text was not heavily business oriented. For purposes of the field testing the text was modified slightly in that a section concerning probability calculations using PERT was deleted. This was done since research dealing with PERT has revealed that these calculations are quite often spurious and useless (Cook, 1968).

There are also a number of texts which deal with linear programming; however, most of these are written at a very sophisticated level and are often heavily mathematical. Most have been written either by econometricians or mathematicians with the intent of communicating the mathematics of the techniques rather than its uses. Only a very small number of texts deal with applying linear programming to practical problems, and even fewer with applications of linear programming in education.

The competitor selected as being the best treatment of the subject within the stated restrictions was Making Reliable Decisions with Linear Programming (1968), published by the American Management Association. This text was also chosen because it was a programmed text and therefore highly self-instructional. It covered the same basic topics as "Linear Programming" including the basic terminology, model formulation, meaning of solutions, and interpretation of the results of a linear programming analysis. In addition, it had a section on using the computer as a tool in linear programming, but there was no "hands-on" experience included. One modification was made in the materials. A section on the mathematical technique of the simplex method was deleted. This was done since it was determined that it was not relevant to the important goals of instruction in linear programming. With this deletion, it was estimated that the materials would take as long to work through as "Linear Programming."

The number of instructional materials available in queueing theory proved to be quite small. Most information existed in the form of journal articles rather than texts. Of the few that were available, most were mathematically oriented and highly complex. In addition, almost none attempted to demonstrate any practical applications of the technique and even fewer applied the technique to educational administration.

The instructional material selected as being the best treatment of the subject within the stated restrictions was the queueing theory chapter from Educational Decision-Making Through Operations Research, (VanDusseldorp et al., 1971). It was chosen as the competitor to "Queueing Theory" for two reasons. First, it is, to the best knowledge of the evaluator, the only non-technical treatment of queueing theory presently available. Second, it attempts to deal with queueing theory applied to educational administration. Since it was a chapter from a text, it was not designed to be largely self-instructional in the manner of the DM/DM materials. Also, since it was only about 13 pages long, it did not take the same time to complete as the "Queueing Theory" unit. It was selected, however, since it seemed to be the only existing competitor of any similarity.

The field to choose from in selecting a competitor for "Computer Simulation," also appeared at first to be fairly large. A closer examination of the available texts revealed, however, that the number of directly relevant texts was quite small. Most of the available texts dealt with constructing simulations of specific systems rather than using existing simulations.

In addition, most of these texts were either oriented toward deriving mathematical equations for portraying a system or constructing systems for business applications. No available text dealt with using simulations in educational administration or involved direct experience with the computer.

The competitor selected as being the best treatment of the subject within the stated restrictions was a set of chapters from A Primer on Simulation and Gaming, by Barton (1970). While this text did not deal with examples of computer simulations that educators could use in administration, it did discuss some of the terminology of computer simulations and described the different types of simulations that did exist and examples of each. The discussion was essentially non-technical and non-mathematical as was appropriate for the target audiences and it appeared to fit the same time frame as "Computer Simulation."

The four sets of materials described above were chosen as the materials with which the DM/DM units would be compared. No competitor was chosen for "Operations Research in Education" since the primary intent of this unit was to serve as an advanced organizer for the other units rather than as a primary instructional unit. None of these competitors were perfect fits with the DM/DM materials, especially since none included hands-on computer experience; however, they appeared to have enough objectives in common to warrent their use as standards against which to judge the Data Management & Decision Making units.

After the critical competitors were selected, the experimental treatments were specified. The particular combinations were determined in part by the number of subjects that were available. Calculations of power (cf. Cohen, 1969) revealed that a group size of approximately 30 subjects would be needed in order for a statistical comparison between two treatment groups to have sufficient power to detect moderate treatment effects. Since one major purpose of the field test is to compare the DM/DM materials against their competitors, it would first appear that eight groups would be needed with about 30 students each, or 240 students. Since it was also important to keep time to a minimum (all classes were volunteer classes taking time out of their regular classwork), the size of the treatment must be kept as small as possible. One possible compromise in this situation is for each student to study more than one unit of instruction. The compromise made for the purpose of this field test was that most students would study two booklets. For reasons of scheduling and lack of access to computers, this was not true for all groups.

In designing the experiment it was also necessary to control for two sources of bias. One source of bias was the possible effects due to different instructors. This was controlled in two ways. First, for purposes of assignment to treatment, all the NAU classes and almost all of the UI classes were combined into single groups. Then students within each of these groups were assigned randomly to a set of treatment conditions. The exception was one class at UI which was an extension class and had no access to computers. Therefore, it was necessary to assign them all to a competitor condition. The other method by which instructor-effect was controlled was by instructions to the professors. They were asked to keep their interaction with the students concerning these materials to an absolute minimum--answering only procedural questions. In this way, the effect of teaching style answering only procedural questions. In this way, the effect of teaching style was reduced if not minimized.

The other source of bias lay in the possible interactions of the materials studied where students studied more than one unit. To control this source two methods were used. First, it was decided that to control for interactions among the DM/DM materials and among the competitor materials, no student should study two of each. That is, within the DM/DM units and within competitor materials, interactions were to be precluded. This left only competitor DM/DM interactions, which it was not possible to control completely. Since it was not completely possible to control for this interaction, its effects were tested to determine if they actually existed. First DM/DM units were randomly paired with competitor units. Then most of the treatments were defined by using both possible sequences of these pairs. Due to the problem with the extension class, however, this was not possible for all materials. The "Computer Simulation" unit and the competitor for queueing theory were assigned alone to groups. The resulting eight treatments for this design are given in Table 6.

The procedure for administering these treatments consisted of the following steps. These steps were spread over two contiguous class sessions at NAU and three contiguous class sessions at UI. At the beginning of the first class each instructor briefly explained what the students were going to do, described the nature of the field test and assured the students that their performance on the tests they were about to take would remain anonymous and have no effect on their grade in the course. They then distributed a

Table 6

Treatment Groups for the Field Test of DM/DM

Group No.	University[1]	Treatment 1[2]	Treatment 2	N
1a	UI	PERT/CPM	CSC	9 (10)
1b	UI	CSC	PERT/CPM	8 (10)
2a	UI	LP	PC	7 (10)
2b	UI	PC	LP	8 (10)
3a	NAU	QT	LPC	8 (13)
3b	NAU	LPC	QT	8 (14)
4	UI	CS		14 (16)
5	UI	QTC		13 (17)

UI - University of Iowa, NAU - Northern Arizona University

PERT/CPM - PERT/CPM: A Planning and Analysis Tool
PC - PERT/CPM Competitor
LP - Linear Programming
LPC - Linear Programming Competitor
QT - Queueing Theory
QTC - Queueing Theory Competitor
CS - Computer Simulation
CSC - Computer Simulation Competitor

packet containing the attitude questionnaire, pretests over the unit(s) assigned to the student (these were in the same order as he was to study the booklets if he was assigned more than one), and the assigned units. Students were asked to first complete the questionnaire and then complete the pretests in the order that they were in the packet. The students were instructed to answer only those questions for which they knew the answer and to avoid guessing.

The students were then instructed to begin studying the first unit that they found in their packet. That is, they were instructed to read the materials, work the exercises as they came to them, and interact with the computer at the specified points if they were studying a DM/DM unit. They were also given explicit instructions to work through the units they had in the order that they appeared in the packet, and they were informed that the instructors were to help only with procedural questions such as how to use the computer terminal.

The posttesting sessions differed for the NAU and UI groups and also within the UI groups. At NAU, at the beginning of the second class session, each student received a packet of tests corresponding to the units he studied. The student was instructed to first complete the test over the first unit he studied and then to complete the second test. Again, students were asked only to complete those items for which they knew the answers. After completing the cognitive tests, students were asked to complete the full attitude questionnaire. Finally, they were asked to complete a Questionnaire 3 for each of the units that they studied. The two single treatment groups at UI (groups 4 and 5) went through a similar procedure except that there were no second forms of the cognitive instruments and Questionnaire 3. The six groups at UI (1a through 3b) who had two units followed essentially the same procedure except that there was a two-week lapse between the two testing sessions. As a final step in the procedure, all instructors were interviewed after the conclusion of the testing to obtain their impressions of the materials and how they worked.

Analyses

In order to check if the sequence of materials had any effect on either cognitive learning or attitudes, it was necessary to compare the pretest scores, the posttest scores, and posttest attitudes between the members of each pair of groups. Thus, these scores were compared between groups 1a and 1b, 2a and 2b and 3a and 3b. These group differences were statistically tested by means of a t-test.

To determine if cognitive gains were caused either by the DM/DM materials or the competitors, it was necessary to compare the pretest and posttest performance on the cognitive instrument pairs for each of the unit. In the event that the sequence effect was significant, this test would have to be carried out for each of the groups that received two units; however, if the sequence effect proved not to be significant, each of the pairs of groups that studied the same materials could be combined. The statistical procedure for testing these gains was a correlated t-test on the gains from pretest to posttest for each of the groups. Attitude change was to be tested by the same method for each group.

The final analysis had to do with comparing the performance of the DM/DM_5 units against their competitors with respect to cognitive learning and attitude change. This was accomplished by using an analysis of covariance with one factor and two levels of treatment corresponding to a DM/DM unit and its competitor, for each unit. The covariate used was the pretest score on the appropriate instrument.

Results of the Field Test

Means and standard deviations for each of the subgroups for each of the instruments used in the field testing for each testing session are given in Table 7, with the exception of the results from Questionnaire 3. Since these figures do not relate directly to the evaluation questions even though they form the basis of the data, they will not be discussed here.

In order to determine the structure of further analyses, it was first necessary to analyze the sequence effects for the materials. The means, standard deviations and t-tests between the groups with the different orders of materials are given in Table 8. This table compares the scores on tests concerning a particular unit when that unit is studied first or second. These means and t-tests are given for the pretest and posttest cognitive instruments, the subset of common objectives both pre- and post, and the attitude posttest. It is evident from the table that there was no difference in performance which depended on the order of unit studied for any of the measures used in the field test for any of the groups. Thus, it would appear to be true that the order of study of the units does not affect the subsequent performance on instruments designed to measure either cognitive learning or attitude change.

Table 7

Means and Standard Deviations for Each Treatment Group in DM/DM Field Test

	Group[1]							
	1a	1b	2a	2b	3a	3b	4	5
ATTITUDE								
Pretest								
$\overline{X}$	2.25	2.40	2.58	1.86	2.27	2.09	2.23	2.18
SD	.20	.74	.15	.47	.64	.50	.41	.59
Posttest								
$\overline{X}$	2.11	2.05	2.31	1.88	2.14	1.92	2.13	1.96
SD	.34	.53	.68	.54	.41	.51	.47	.28
Materials Posttest								
$\overline{X}$	2.65	2.38	2.98	2.54	2.24	1.89	2.49	2.60
SD	.54	.80	.61	.74	.55	.51	.48	.36
COGNITIVE								
Operations Research								
Pretest								
$\overline{X}$	5.10	4.70	6.22	3.56	6.73	5.85	3.69	5.50
SD	1.52	3.77	4.60	2.40	4.24	3.46	1.99	2.42
Posttest								
$\overline{X}$	18.10	21.13	16.80	17.50	7.10	13.22	14.87	18.00
SD	5.88	3.23	5.59	6.06	5.88	2.73	6.50	5.20
Treatment 1								
Pretest								
Full Cognitive	(PERT/ CPM)	(CSC)	(LP)	(PC)	(QT)	(LPC)	(CS)	(QTC)
$\overline{X}$	2.50	11.10	3.89	4.11	10.82	5.38	11.88	9.44
SD	1.96	6.90	4.28	2.09	6.66	2.93	4.99	6.95
Common Objectives								
$\overline{X}$	2.50	3.00	3.89	3.78	6.36	5.31	2.75	5.69
SD	1.96	.94	4.28	1.92	3.83	2.84	1.39	3.65
Posttest								
Full Cognitive								
$\overline{X}$	19.90	15.38	10.30	15.10	17.70	11.44	21.07	17.93
SD	7.91	6.46	5.81	7.72	9.67	3.28	5.94	6.83
Common Objectives								
$\overline{X}$	18.20	5.25	9.50	14.30	10.50	10.11	6.64	11.50
SD	7.47	1.49	4.97	7.35	5.99	2.76	2.53	3.32
Treatment 2								
Pretest								
Full Cognitive	(CSC)	(PERT/ CPM)	(PC)	(LP)	(LPC)	(QT)		
$\overline{X}$	13.30	4.20	2.00	4.67	6.64	7.00		
SD	6.02	2.97	1.51	1.58	5.66	3.11		
Common Objectives								
$\overline{X}$	2.40	4.00	2.00	4.67	6.09	5.85		
SD	1.65	3.06	1.51	1.58	5.03	2.19		
Posttest								
Full Cognitive								
$\overline{X}$	15.80	16.75	9.80	16.10	8.30	23.11		
SD	7.91	2.19	7.27	7.14	5.72	1.45		
Common Objectives								
$\overline{X}$	5.00	15.13	9.50	13.70	7.50	13.[illegible]8		
SD	1.56	2.10	6.98	5.14	4.66	1.56		

[1] See Table 6 for descriptions of these groups.

Table 8

Means and Significance Tests Between Sequences of Booklets for Three Groups with Multiple Booklets

	Group 1 PERT/CPM and CSC		Group 2 LP and PC		Group 3 QT and LPC	
	PERT/CPM	CSC	LP	PC	QT	LPC
Full Cognitive						
Pretest						
$\bar{X}_a$	2.50	13.30	3.89	2.00	10.82	6.64
$\bar{X}_b$	4.20	11.10	4.67	4.11	7.00	5.38
t	-1.51	.76	-.51	-2.36	1.85	.70
d.f.	18.00	18.00	16.00	15.00	22.00	22.00
Posttest						
$\bar{X}_a$	19.90	15.80	10.30	9.80	17.70	8.30
$\bar{X}_b$	16.75	15.38	16.10	15.10	23.11	11.44
t	1.09	.13	-1.99	-1.58	-1.66	-1.44
d.f.	16.00	18.00	18.00	18.00	17.00	17.00
Common Objectives						
Pretest						
$\bar{X}_a$	2.50	2.40	3.89	2.00	6.36	6.09
$\bar{X}_b$	4.00	3.00	4.67	3.78	5.85	5.31
t	-1.31	-1.00	-.51	-2.10	.41	.48
d.f.	18.00	18.00	16.00	15.00	22.00	22.00
Posttest						
X_a	18.20	5.00	9.50	9.50	10.50	7.50
X_b	15.13	5.25	13.70	14.30	13.78	10.11
t	1.12	-.34	-1.86	-1.50	-1.59	-1.42
d.f.	16.00	16.00	18.00	18.00	17.00	17.00
Attitude						
Posttest						
$\bar{X}_a$	2.11		2.31		2.14	
$\bar{X}_b$	2.05		1.88		1.92	
t	.28		1.57		1.04	
d.f.	15.00		18.00		17.00	

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Therefore, the combination of groups 1a and 1b, 2a and 2b and 3a and 3b is justified for purposes of further analysis.

With the question of sequence effect no longer of concern, we may proceed to the results concerning the evaluation questions. The first has to do with whether or not the DM/DM materials caused learning with respect to the cognitive objectives. Of subsidiary interest are the similar figures for the competitor materials. Table 9 contains these figures. This table presents the mean and standard deviation of the gain from pretest to posttest and the correlated t-test for each of the operations research techniques for both the DM/DM materials and their competitors on both the full cognitive instruments and the subsets of common objectives. It is immediately evident

Table 9

Mean Gains on Instruments Designed to Measure Achievement of Cognitive Objectives for the DM/DM and Competitors Materials

	DM/DM				Competitor			
	X_D	SD_D	t	d.f.	X_D	SD_D	t	d.f.
PERT/CPM								
Full Cognitive	15.17	7.08	9.09*	17	10.29	7.94	5.34*	16
Common Objectives	13.50	6.83	8.39*	17	9.88	7.67	5.31*	16
Linear Programming								
Full Cognitive	8.83	7.02	5.34*	17	4.25	4.58	3.71*	15
Common Objectives	7.17	5.25	5.79*	17	3.25	3.84	3.39*	15
Queueing Theory								
Full Cognitive	11.81	7.98	5.92*	15	7.62	4.79	5.73*	12
Common Objectives	6.69	4.08	6.56*	15	5.46	3.28	6.00*	12
Computer Simulation								
Full Cognitive	8.21	6.55	4.69*	13	2.63	6.41	1.88	17
Common Objectives	3.93	2.37	6.21*	13	2.39	2.00	5.06*	17

*p < .05

that all gains are positive and that all are significant at the .05 level, with one exception. Under the computer simulation competitor condition, the gain on the full cognitive instrument was not significant. Since all the gains are positive and almost all of them significant, it is evident that both the DM/DM materials and their competitors caused statistically significant increases in performance from pretest to posttest for the cognitive instruments. The mean gains for the DM/DM units ranged from 8 to 15 points from pretest to posttest. This is a gain of 24% to 45% of the points on the tests. By contrast, the competitor gains represented gains of from 8% to 30% of the points on the test.

The other part of the achievement question had to do with attitude change as a result of using these materials. Unfortunately, a lack of foresight in designing the testing situation lead to an inability to determine these results from the field test. It was originally hypothesized by the evaluator that the primary attitude change would be effected primarily by the first unit that a treatment group studied, and thus attitude changes could be estimated, if not identified exactly. Also, since the DM/DM units evidenced a greater concern for educational problems than their competitors, it was hypothesized that these units should cause a greater change in attitude toward operations research in education than their competitors. Evidence to support these hypotheses should come from the comparison between treatment sequences on the attitude posttest score. If these hypotheses are true, the groups studying the DM/DM units first should demonstrate more positive attitudes toward operations research in education than those groups that studied the competitors first. The evidence from Table 8 does not support these hypotheses. There were no significant differences between the groups using different sequences of the materials on the posttest attitude score. Consequently, it is not possible to attribute any attitude to a <u>single</u> unit within any of the six groups that studied more than one unit. The only two treatments for which this information is available are "Computer Simulation" in the DM/DM materials and the queueing theory competitor. The mean attitude change for the group using "Computer Simulation" was not significant (mean = -.12, S.D. = .47, t = -.96, d.f. = 12).

Despite the fact that it was impossible to derive information from the field test concerning attitude change caused by most of the materials, it is not impossible to obtain information concerning this evaluation question. The pilot test can provide some evidence concerning attitude change caused which occurred concurrently with the use of the DM/DM materials. Table 10 summarizes this information. Due to the scoring procedure for the attitude

Table 10

Mean Attitude Change Concerning Operations Research in Education from Pilot Testing of Prototype Version

DM/DM Unit	N	X_D	$S.D._D$	t
PERT/CPM	12	-.60	.86	-2.40*
Linear Programming	10	-.41	.73	-1.78
Queueing Theory	12	-.26	.93	-.96
Computer Simulation	22	-.67	.81	-3.94*

instrument a negative gain indicates a positive change in attitude. In the pilot only two of the four DM/DM units caused a significant change in attitude--"PERT/CPM" and "Computer Simulation." This evidence is a bit contradictory, however, since in the field test "Computer Simulation" was not associated with a significant change in attitude. It would appear that the available evidence does not provide a great deal of support for the hypothesis that the DM/DM materials change attitudes; however, some additional information may be gained by examining the mean attitude scores. (See Table 7.) The mean attitude scores of all groups on the pretest ranged from 2.09 to 2.58 indicating that before the students studied the materials they generally had a positive attitude toward using operations research techniques in educational administration (where 1 is strongly agree, 3 is neutral and 5 is strongly disagree). The posttest attitude scores ranged from 2.31 to 1.88 which would seem to indicate a slightly more positive attitude, though not significantly so in any case. These mean scores indicate, however, that students still held positive attitudes toward the use of operations research in educational administration. It may be important to note the fact, therefore, that students still were positive about operations research techniques after using the materials.

The final statistically tested question in this field study was concerned with comparing the DM/DM units with their competitors, both with respect to cognitive and affective outcomes. For the reasons stated previously, no information was derivable from the field test about the relative changes in attitude as a result of using either a DM/DM unit or its competitor; however, considerable information was derivable concerning cognitive learning. The first step in analyzing this data was to perform analyses of covariance comparing each DM/DM unit with its competitor with respect to performance on the cognitive instruments. Table 11 on the next page summarizes these analyses. This table presents analyses both of the scores on the full cognitive instrument and on the subset of common objectives for each of the operations research techniques. There were significant differences between the competitor and DM/DM groups for PERT, linear programming, and computer simulation; however, the pattern of significant differences was not consistent. For "PERT/CPM" and its competitor, the difference between the full cognitive scores was significant while the difference for common objectives was not. For "Linear Programming" and its competitor the opposite was true. Finally, for "Computer Simulation" and its competitor, both differences were significant.

The meaning of these significant differences can be more clearly understood by considering the adjusted posttest scores for each of the experimental conditions. Table 12 contains these means along with a summary of the analyses of covariance. The first thing that is evident from this table is that in no case does the adjusted mean posttest score for the competitor exceed the comparable mean for the DM/DM unit. Thus, all of the significant differences favor the DM/DM units.

This analysis of the adjusted posttest scores for the DM/DM units versus their competitors completes the analyses. In the next section, these results will be examined and interpreted in the light of the evaluation questions and the conditions of the field test.

Table 11

Analyses of Covariance on Cognitive Measures for DM/DM and Competitors

	Source	Adjusted SS	Adjusted MS	df	F	p
PERT/CPM Full Cognitive	Treatment	225.97	225.97	1	4.35	p < .05
	Error	1662.61	51.96	32		
Common Objectives	Treatment	143.12	143.12	1	3.06	--
	Error	1495.84	46.75	32		
Linear Programming Full Cognitive	Treatment	136.65	136.65	1	3.83	--
	Error	1105.41	35.66	31		
Common Objectives	Treatment	98.42	98.42	1	4.75	p < .05
	Error	642.87	20.74	31		
Queueing Theory Full Cognitive	Treatment	96.66	96.66	1	2.25	--
	Error	1114.6	42.87	26		
Common Objectives	Treatment	8.98	8.98	1	0.64	--
	Error	365.49	14.06	26		
Computer Simulation Full Cognitive	Treatment	231.17	231.17	1	6.38	p < .05
	Error	1051.41	36.26	29		
Common Objectives	Treatment	13.54	18.54	1	4.65	p < .05
	Error	115.61	3.99	29		

Table 12

Adjusted Posttest Scores on Cognitive Instruments for DM/DM Units and Competitors

	DM/DM Adjusted $\bar{y}$	Competitor Adjusted $\bar{y}$	F	d.f.
PERT/CPM				
Full Cognitive	18.50	13.41	4.35*	1, 32
Common Objectives	16.86	12.80	3.06	1, 32
Linear Programming				
Full Cognitive	13.55	9.45	3.83	1, 31
Common Objectives	11.84	8.37	4.75*	1, 31
Queueing Theory				
Full Cognitive	20.55	16.86	2.25	1, 26
Common Objectives	12.16	11.04	0.64	1, 26
Computer Simulation				
Full Cognitive	21.05	15.63	6.38*	1, 29
Common Objectives	6.64	5.11	4.65*	1, 29

* $p < .05$

Conclusions

The major conclusions of the field test will be discussed and interpreted in this section by evaluation questions, with the exception of the questions of side effects of the materials. These side effects will be discussed in a separate section of the Technical Report.

1. Do the DM/DM materials cause significant increase from pretest to posttest on tests designed to measure the attainment of instructional objectives?

Yes, for all DM/DM units the gain from pretest to posttest was statistically significant. Moreover, these increases in performance ranged from 24% to 45% of the points on the test. It appears, therefore, that studying the DM/DM units results in increased attainment of the specific instructional objectives for those units. Thus, we can conclude that learning is associated with studying the DM/DM units on operations research in educational administration.

2. Do the DM/DM materials cause significant positive changes from pretest to posttest on a questionnaire designed to measure attitude toward operations research in education?

The results are equivocal with respect to this evaluation question. The available evidence indicates that the materials changed attitudes toward using operations research in only one case. This was for "PERT/CPM" but it was derived from information obtained in the pilot test. All other available information was either negative or contradictory. Thus, we must conclude that, in general, using the DM/DM materials did not cause a significant change in attitude toward using operations research in educational administration. There is, however, some additional information that may account for this result--this is, that students responded quite positively on the pretest attitude questionnaire, so that the students apparently entered the treatment conditions with a favorable attitude rather than a negative or neutral attitude. Due to the fact that this was represented by a rating of 2 on a scale in which 1 represented the most positive attitude, there was not a great deal of latitude to detect improvement in the attitude rating. Therefore, it seems quite logical that there should be no significant improvement in attitude as measured by the questionnaire over the period of the treatment. The best that we can conclude is that the materials did nothing to discourage those who used the materials from their original positive attitude toward using operations research in educational administration.

3. <u>Are the statistically adjusted posttest scores on a test designed to measure objectives attainment for the DM/DM materials significantly better than those of its competitors?</u>

The results vary with the unit under consideration. The answer is yes for "Computer Simulation." The answer is no for "Queueing Theory" and the answer is equivocal for "PERT/CPM" and "Linear Programming." For "Computer Simulation," those using the DM/DM unit performed better than those using the competitor both on the full cognitive instrument and on the subset of common objectives. This indicates that using "Computer Simulation" caused more learning than the competitor regardless of whether or not the items concerning the computer were taken into consideration. In the case of "Linear Programming," the DM/DM unit caused better performance than the competitor on the set of common objectives but not on the full cognitive instrument. This result appears rather unusual in light of the experimental conditions for this particular set of units. These conditions were that the UI group which studied "Linear Programming" had two weeks to work on two units, while the NAU group which studied the competitor had only one week to study the same number of units. Thus, conditions independent of the unit studied should logically have had some impact favoring the DM/DM unit. Yet, this proved true for only the common objectives. This, in turn, also contradicts logic since inclusion of items relating to the computer on the full cognitive instrument would argue that if there is any difference between the DM/DM unit and its competitor, it should favor the DM/DM unit on the full cognitive instrument. Thus, for "Linear Programming" it must be concluded that the results do not conform completely to logic; however, they do favor the DM/DM unit.

In the case of "PERT/CPM" the results are much more logical. Here the DM/DM unit only caused better performance than the competitor on the full cognitive instrument. This conforms with the logic stated in the previous paragraph. From these results, it must be concluded that "PERT/CPM causes better performance than the competitor only when objectives concerning the computer are considered. When the more stringent criterion of common objectives is applied, the DM/DM unit and its competitor do equally well in causing learning.

Finally in the case of "Queueing Theory," the DM/DM unit did not appear to perform any better than the competitor under any circumstances. In this case, there may be mitigating circumstances which might have affected the outcome. "Queueing Theory" was studied by NAU students who had only one week to study two units, while its competitor was studied by UI students who had one week to study only that unit. Thus, it may be true that the performance of the students using the DM/DM unit may have been unduly negatively influenced by conditions of the particular treatment other than the materials used. That is, the time available for study may have had an important effect. Students who had less time to study the unit performed more poorly on the test. This, in turn, might account for the fact that there were no significant differences between the two materials conditions. It should be noted, however, that under detrimental conditions, the DM/DM unit performed no worse than its competitor. Therefore, the conclusion must be that students who studied "Queueing Theory" performed at least no worse than those studying its competitor, even under detrimental conditions.

It is important to note that both the DM/DM units and their competitors caused learning which was statistically significant and so these conclusions cannot be interpreted in the manner of deciding which materials worked and which did not. Rather, they imply that in several cases the DM/DM units caused greater gains in knowledge than did their competitors.

Summary

The following statement generally summarize the conclusions of this field test. The DM/DM materials as individual units did cause learning with respect to using operations research in educational administration; however, they generally did not cause a change in attitude toward using operations research in educational administration because this attitude on the part of the participants was already quite favorable. In some cases, the DM/DM units caused greater learning with respect to the instructional objectives of the DM/DM materials than did their competitors. In those cases where this was not true, the DM/DM materials caused performance at least as good as their competitors. Thus, the DM/DM materials do cause learning and they sometimes do better, and always no worse, than their likely competitors in the educational marketplace.

Side Effects of DM/DM Materials

All educational products cause outcomes that are neither expected nor planned for by the developers of that product. That is, all such products have side effects. An important part of the evaluation of an educational product is the identification of these side effects, for in order to make an effective decision, the decision maker must be aware of and able to evaluate all the outcomes of his or her decision alternatives. The purpose of this section of the summative evaluation is to identify the side effects associated with Data Management & Decision Making. It is, however, not sufficient to merely identify the associated side effects. In order to determine the worth of the side effects, it is necessary to determine if these side effects are unique to the materials and if these side effects make the materials more worthwhile than their competitors. Consequently, this section will also be concerned with how the side effects of the DM/DM materials compare with those of its competitors. In this section, then, the side effects associated with the DM/DM materials and their competitors will be enumerated and these will be compared in order to establish the relative value of the two sets of products in terms of the side effects they produce.

The process of identifying side effects of an educational product is often facilitated by the attempt to anticipate possibilities that may occur. In the case of the DM/DM materials, a number of side effects were considered possible. These were anticipated to be concerned primarily with attitudes in two areas--computers and operations research in educational administration. The following list presents these anticipated side effects.

1. Increased awareness of the utility of computers
2. Increased confidence in dealing with computers and computer personnel
3. Increased desire to use the computer as a problem solving tool
4. More negative attitude toward computers due to trouble with using the terminal
5. More negative attitude toward specific techniques due to complicated mathematics
6. Negative attitude toward operations research in educational administration due to the concentrated study required
7. Improved problem solving by school administrators
8. More group problem solving using operations research techniques
9. Higher incidence of use of operations research techniques in problem solving in educational administration
10. More widespread use of operations research as a course topic in educational administration classes at the university level
11. Lack of motivation due to no perceived immediate use of the techniques

With this list serving as a starting point, the attempt was made during the field test to determine if these side effects in fact existed and if this list was complete.

Procedures

The collection of the data concerning side effects of both the DM/DM materials and their competitors took place during the field test of the materials. Due to time restrictions involved in the development and evaluation contract, only time during and immediately after the test was used for this data collection. Hence, it was not possible to collect data on all the anticipated side effects of the materials and there may be side effects of the materials that were not observed. Only short-term side effects could be observed and no data was available concerning long-term effects.

In order to detect short-term side effects, observations were made during the field test, using two separate methods. These were self-report by the students and post-session interviews of the instructors who lead the groups. Student self-reports were collected by means of Questionnaire 3 (see page 53 for a description)--specifically from responses to questions designed to determine if subjects would recommend the materials they studied to others, what they felt were the best and worst things about the materials, and their overall reaction to the units they studied. Since the evaluator was not able to be on site, approximately one month after the conclusion of the treatments, the instructors who lead the groups were interviewed concerning their observations of the field test and were specifically questioned on side effects they noticed. In the following section the results of these procedures will be summarized.

Observed Side Effects

This section will be divided into two parts. The first part will report the results gathered from Questionnaire 3 and the second part will deal with the instructors' observations.

Student Self-Report. These results are a summary of the responses made by the students to Questionnaire 3. For purposes of reporting, these results will be reported by operations research technique.

The responses for PERT indicated that 60% of those students studying "PERT/CPM" would recommend the unit to others while the same percentage of those studying the competitor would recommend that booklet. There were no negative responses for "PERT/CPM" and two or 10% for the competitor. The rest of the students gave no response. The data gathered from the other items on Questionnaire 3 revealed very few side effects, from a small number of total responses. Those responses dealing with "PERT/CPM" indicated that the main side effect concerned the computer. Various students reported the computer as being motivating, an exciting learning experience and the best thing about the materials. Various students using the competitor materials reported that they "got some great ideas on methods of solving problems in a back home situation," and that this technique would not be much good at the school principal level.

The students that studied "Linear Programming" indicated that 55% of them would recommend the unit to others while 15% would not. For the competitor, 41% would recommend it while 7% would not. Remaining percentages are accounted for by those who did not respond. Various students using the DM, DM materials reported that they created an wareness of new administrative techniques, that they will continue to work on learning the technique but that the technique will probable be of little use at their level. For the competitor the student reports revealed such side effects (in the responses of individual students) as providing potential for all types of management problems, creating the opinion that operations research techniques should be included in doctoral programs, and the opinion that the materials give confidence and knowledge for future use--"lessens the unknown."

The responses on Questionnaire 3 for the groups using the queueing theory materials revealed that 60% of those using "Queueing Theory" would recommend the materials to others while 53% of those using the competitior were of the same opinion. The rest of the students did not respond. The predominant reported side effects for "Queueing Theory" had to do with the computer. Various students indicated that the materials made them aware of the manifold uses of the computer, increased their confidence with respect to computers, and were a good introduction to the computer and the services it can provide. Several students reported that the materials gave them a new outlook on administrative problems. A negative side effect appeared to be the perceived lack of relevancy of queueing theory. The only side effect reported for the competitor was the opinion of one person that the technique should be emphasized more in educational administration courses.

For computer simulation, the rate of recommendation was also fairly high. Seventy-five percent of the students who use "Computer Simulation" would recommend the materials to others, while 45% of those using the competitor would. The rates of negative recommendation were 6% and 15%, respectively. With respect to the side effects of the DM/DM materials, several students reported that the best thing about the materials was the computer, and that they felt more confident in dealing with it. One student reported that he planned to use the enrollment projection simulation in his own school district, and two students indicated that they were anxious to read the other materials. In the competitor condition, two students reported that the materials gave them a new perspective and that it appeared to be a highly usable technique; however, several others expressed frustration with the materials.

This completes the description of the results of Questionnaire 3 with respect to side effects. As should be evident, there were only a very few responses which indicated prevalent side effects, and not many students responded to the questions. There may be several reasons for this, including the fact that the students completed the questionnaire immediately after taking a posttest over the materials they studied and that they often had to fill out two identical forms over the two units that they had studied. The paucity of responses generally would seem to indicate two things. First, that the students were frustrated with all the testing, and vented this frustration by refusing to respond to Questionnaire 3. And second, filling out the questionnaire almost immediately after finishing the materials did not give the students the opportunity to develop a perspective on the materials and the time to form definite opinions. Thus, there appear to be very few reported side effects of the materials. The best that can be said is that for the DM/DM materials there was a consistent side effect having to do with the computer as a problem solving tool and as a fascinating machine.

Instructor Observation. The persons interviewed for the purposes of identifying side effects were those principally responsible for implementation of the field test at each test site. The side effects that they observed focused on two primary positive concerns having to do with the computer and continued interest in the materials.

The side effects having to do with computers appeared to be most predominant at UI. The principal instructor reported observing the following side effects.

1. Students gained an impression of the power and utility of the computer.
2. Students learned to use and deal with the computer as a tool.
3. Most of the students wanted the materials that dealt with the computer.
4. Students experienced som[illegible]stration with using the computer.

These side effects were detected by discussions with the students and observation of their work at the terminals.

This instructor also observed several side effects having to do with the DM/DM materials themselves. A number of students (the exact number was not specified) asked the principal instructor for other materials that they could study on a voluntary basis. In every case, these materials were the DM/DM materials. Evidence of this continued interest was also found in that students are still using the computer programs which accompanied the materials approximately one and one-half months after the completion of the field test. Another side effect was observed in another course that this person was teaching. A requirement for this course was that each student do a project in educational administration using the computer. Twelve to eighteen members of this class reported that they were using one of the operations research techniques that they had studied during the field test--primarily PERT, linear programming and computer simulation. The majority of these students were using PERT and its associated computer program. A specifi side effect of "Computer Simulation" was also reported in that two students indicated to the instructor that they had used one of the simulation programs to solve programs in their own districts. As should be evident, the instructor had some difficulty in attributing the various side effects to the specific units, but the overall outcome at this test site would seem to indicate that there were many more observable side effects for the DM/DM materials than there were for their competitors.

At the NAU test site, a smaller number of side effects were reported and there appeared to be more negative ones. It is important to note that at this test site only "Queueing Theory" and the linear programming competitor were used. At this site there were also reported several side effects having to do with computers. The instructor observed that:

1. The students learned to use the computer as a problem solving tool.
2. The students appeared to be more confident about using the computer after going through the materials.

3. Students expressed a desire for additional use of the computer beyond that required.

4. Students expressed a desire to use the computer in other classes.

5. Students were sometimes frustrated in using the computer terminals.

Since the DM/DM unit "Queueing Theory" was the unit that used the computer, it is logical to attribute these side effects to that unit.

With respect to the units themselves, several side effects were also observed. A small number of students (three) requested to go through the other DM/DM materials on a voluntary basis. Several students also suggested that the DM/DM materials be made the basis of a course in educational administration. On the other hand, some students expressed the opinion that they were "more at home" with the linear programming competitor, since they had confidence that when they made a mistake it was their fault, in contrast to the possibility of computer difficulty with the DM/DM materials. A negative side effect that was observed for both units was that many practicing administrators did not complete the materials. They reported that they had more pressing obligations, but the instructor interpreted this as a perceived lack of relevance of the materials; this, however, was not attributable to one or the other of the units studied.

Conclusions

Before drawing conclusions from this study it is important to take note of several conditions that limit the generalizability of these results. The first has to do with the computer side effects at UI. The program within which this field test took place at UI has had for some time a definite positive orientation toward the use of computers in education. In fact, the principal instructor at this test site is considered to be an expert in the area of computer applications in educational administration. Therefore, there is the possibility of a positive bias toward computers in the instructional environment and it is possible that the students have absorbed some of this bias. In addition, there might be some bias on the part of the observer, since he is strongly committed to the use of computers and operations research in education. The evaluator was aware of this possible source of bias and he attempted to structure the interview so that evidence opposed to this bias might be brought out; however, the conclusions concerning the side effects as reported at this test site must be tempered by this knowledge.

Taking this knowledge into account, it is still possible to conclude that the primary side effects of the DM/DM materials have to do with the computer, since there is confirming evidence from another test site. It would appear that the following are beneficial side effects of using the DM/DM materials.

1. Students learn to use and deal with the computer as a problem solving tool.
2. Students gain confidence in using the computer as a result of using the materials.
3. Students desire additional usage or experience with the computer.

4. Students find the use of the computer to be a motivating experience.

On the other hand, there is also a negative side effect associated with the DM/DM materials in that students become somewhat frustrated in using the computer terminal.

There appear also to be two important positive side effects of the DM/DM materials themselves. First, they are interesting and relevant enough that majorities of persons using the units would recommend them to others. Second, they appear to be sufficiently interesting so that many students will desire to learn more about other operations research techniques. A major negative side effect is that students often experience a sense of frustration with the materials which was apparently due to a number of sources, but which was in evidence for all units.

Some side effects were also reported for the competitors; however, in most cases, these were essentially duplicates of the side effects of the DM/DM materials excluding computers. Students reported that the competitors for "PERT/CPM" and "Linear Programming" provided new insights concerning the problems of the educational administrator. The one different side effect was noted at NAU for the linear programming competitor in that students felt quite "comfortable" with the materials.

In comparing the two sets of materials with respect to side effects, one result is particularly evident. The DM/DM materials are associated with a number of side effects concerning computers that the competitors simply do not have. In addition, the DM/DM materials generally evidence to a greater extent the side effect of motivation to go beyond the given material to search out new ideas in operations research. It is also true, however, that DM/DM materials demonstrated more negative side effects than their competitors, though these did not appear to be major factors in using the materials. Thus, it is reasonable to conclude that the DM/DM materials have more side effects than their competitors and that these side effects are generally positive.

Costs and Benefits of Data Management & Decision Making

This analysis of the costs and benefits of the Data Management & Decision Making materials is designed to provide information as to the costs to potential users of the DM/DM materials and how these costs compare with the benefits derivable from using the materials. The analysis will also speak to the concern of how the costs and benefits of the DM/DM materials compare with those of their competitors. The focus of the analysis will thus be on three major questions.

1. What are the costs of using the Data Management & Decision Making materials?
2. What are the benefits of using the Data Management & Decision Making materials?
3. How do the costs and benefits of the DM/DM materials compare to the costs and benefits of using their competitors?

In order to accomplish this analysis of costs and benefits, several tasks must be accomplished. It is necessary to define what is meant by costs and what is meant by benefits and what units of measure are appropriate for these outcomes. Sources of costs must be identified and the estimated costs in the given units determined. Benefits must be determined. And finally, the developed product and their competitors must be compared and conclusions drawn with respect to their relative cost-effectiveness. In the following sections each of these tasks will be addressed.

Costs

In this section, the costs of using the DM/DM materials will be examined as will the costs of using their competitors. First, however, the concept with which the section deals must be defined. Fisher (1971) defines costs as benefits lost. That is, the costs of particular decisions are, in the broadest sense, the benefits which might of have been gained by choosing other alternatives, but are lost by choosing this particular alternative. The question immediately arises, however, of how these costs can be measured. One such measure of these costs is to determine the resources that must be allocated in order to implement a decision alternative. An important measure of these resources is the monetary value of these resources--the dollar.

In this analysis, the unit of measur will be the dollar. Yet, this is not a perfect measure. It provides a poor measure of many of the intangible costs of a decision alternative, for how are such important aspects of decision alternatives as staff morale quantified in dollar terms. In spite of its inability to represent all costs of a particular decision alternative, dollar costs are of great concern to many decision makers including those in education. And thus, it will provide information of considerable use to the decision maker.

In determining the costs of using instructional materials such as the DM/DM materials, the first step is to identify the sources of costs which are involved. For the purposes of this analysis, these costs are subdivided into the areas of immediate costs, secondary costs and opportunity costs.

Immediate costs are those costs for which the decision maker must budget when choosing to use the materials. These are the resources that must be immediately allocated in order to use the instructional materials. Such costs include the cost of the instructional materials themselves. If the materials are to be used in a course or workshop setting, an instructor and all his associated costs must be considered. Cost of setting up and arranging for the workshop must be included. Personnel may have to be compensated for their time spent in studying the materials. If a computer is required, there will be the costs of computer time and equipment costs. Resources must be allocated to provide facilities for a workshop and if university credit is to be given the costs of arranging for it must be included.

Potential secondary costs are those costs which may result indirectly from using the instructional materials. In this case, the identification of cost sources is based on the assumption that a decision has been made to use one of the techniques described in the materials to solve a problem in educational administration, as a result of studying the materials. In this case, the sources of secondary costs will be a result of attempting to implement the technique. Possible sources include consultants who might be necessary to implement the finer points of the technique. Since all these techniques are based on analysis of data, an important source of cost will be the gathering of the necessary data. Also, since most of these operations research techniques require a computer, there may be costs for computer services. Finally, since personnel will be required to perform the tasks of solving the problem, it is necessary to consider the costs of using those personnel.

The final category of cost sources--opportunity costs--represent all "benefits lost" which have not been included in the previous categories. That is, these costs represent benefits lost by not making decisions other than those to use the materials. This is essentially a category with an infinite number of cost sources, since there are always an infinite number of possible decision alternatives. With respect to these materials, however, there are two major sources. The first is the opportunity costs of training in other administrative problem-solving techniques other than the four presented in these materials. The second of these are the benefits lost of the personnel in training who are not performing their normal work assignments. These are but two of the possible sources of opportunity costs, but they may be of the most immediate importance in making decisions concerning the use of the DM/DM materials.

After identifying the potential sources of costs in using the materials, the next step is to estimate the magnitude of those costs. In the following paragraphs, the costs eminating from the sources previously identified will be estimated.

Materials. The cost of the materials was assumed to be their purchase price. For the DM/DM materials, it was assumed that they were published as a single, 450 page, hardbound text by a commercial publishing company. The resulting cost as estimated by the NWREL Office of Dissemination was $12. Since the competitors were separate units of materials, their costs were estimated separately from their purchase prices. For the PERT competitor the cost was $7, for the linear programming competitor, it was $25. The queueing theory competitor was available only as part of a text which costs $8.50 and the computer simulation competitor in text form costs $4.95. Thus the cost of a set of competitors for the DM/DM materials totaled $45.45.

Instructor. For purposes of determining costs, it was assumed that the instructor for any workshop or course would be a university or college faculty member in educational administration. For a workshop it was assumed that this person would charge a fee of $200 per day or instructional session. In addition, travel expense would have to be paid. For this it was assumed that an instructor would be available within 200 miles of the workshop site. Thus, travel reimbursement was estimated at 15¢ per mile for a 400-mile round-trip, or $60 per trip. If the materials were used in a university class, there would be no additional expenses for the instructor that would not be part of his salary from the institution. It should be noted that these expenses would not depend on whether the DM/DM materials or their competitors were used.

Class Setup. Costs for class setup in using the DM/DM materials would depend on whether it was a workshop or a college class. For a college class, there would be no additional expense in using the DM/DM materials since the university provides this service regardless of the instructional content of the course. If the situation were a workshop, it might be necessary to install telephones for communicating with the computer (estimated by Pacific Northwest Bell total at $30 per phone) and there would also be operating costs for the workshop such as lunches, coffee, and so forth (estimated at approximately $3 per person per day). Finally, there would be miscellaneous costs which, for the purposes of this analysis, are estimated at $50 for a four-day workshop.

Personnel Reimbursement. If the use is in a college class, this cost will be nothing, since the university does not reimburse students for their time. If the use is in a workshop for practicing administrators, however, there may be a number of costs such as per diem and travel. An estimated figure for per diem is $20 per day, though many school districts may not pay per diem at all. If travel expenses are reimbursed, it is assumed that the participant must make no more than a 400-mile round-trip at 15¢ per mile, or $60 per participant. Group travel would make this figure less.

Computer Terminals. Since a computer terminal is a vital component of DM/DM instructional system, additional costs will be incurred when using these materials. If the institution which is sponsoring the instructional session already owns and operates the terminals, the costs for the terminals themselves will be negligible; however, if the terminals must be leased, the costs will be of concern. Assuming that the cheapest terminal available, a teletypewriter, is leased only for the time needed, it is estimated that the costs would be $5 per day per terminal.

Computer Time. Since the DM/DM materials require the use of the computer, some expenses for computer time will be incurred. Evidence from the pilot and field testing indicates that each participant would use approximately two hours of terminal time and five minutes of CPU time to work through all of the computer exercises. The literature indicates that terminal time generally costs between $4 and $9 per hour and thus the cost of terminal usage for each participant would be $8 to $18, if all the DM/DM units were studied. This same literature indicates that the CPU time required would cost from $1 to $6 per participant.

College Credit. In the case that the materials were used as a part of a college course, there would be no additional cost to the students and college beyond the usual costs of the course. The situation would be different if college credit were arranged for a workshop. In this case, the cooperating college would most likely charge a fee for granting credit. Since a four day workshop covering all the units would be the equivalent of three credit course in terms of class time, the charge would most likely be for granting three credit hours. A poll of local colleges and universities indicated that the charge is about $30 per participant per credit hour or $90 for three credits.

Facilities. Since some type of facility will be required for any group use of the materials, some facilities costs may be incurred. In the case of a college course, there will again be no additional costs beyond those incurred by the course as a whole. If a commercial facility is used for a workshop group of approximately 15 participants, it will cost in the range from $20 to $50 per day. Use of a university or college facility might fall in the range of $5 to $12 per day for comparable facilities, and use of school facilities of comparable quality would cost $25 per day.

The direct costs of using either the DM/DM materials or their competitors are fairly easy to estimate; however, the estimation of the secondary costs is much more difficult due to their lack of definition and clarity. In the next few paragraphs some cost estimates will be given and types of costs identified, though these may vary greatly from the stated figures.

Consultants. Since consultants are usually employed by the day this costs may be estimated on a per day basis. It is assumed that for most of the work a college or university faculty member can perform the consultant work. A common consulting fee charge by individuals of this type is $100 per day; however, estimates of total consulting costs cannot be estimated precisely since the number of consulting days required depends wholly on the complexity of the problem and the types of attempted solutions.

Computer. It is also impossible to give any meaningful estimate for this cost for a number of reasons. It depends once again on the scope and complexity of the problem under consideration, the type of computer available, and the skills of the persons using the computer.

Personnel. This also depends on the same factors as in the previous categories of costs. The most that can be said is that this will be generally an important category of costs in solving problems using operations research techniques.

Data Gathering. As with all previous categories, these costs are highly variable depending on the scope and complexity of the problem, in addition to the availability of data. The most that can be said for this category is that this will generally be an important non-zero expense which will include at a minimum costs for clerical personnel and keypunching.

The estimation of opportunity costs is equally as difficult as was estimating the secondary costs of using the materials. In only the very fewest cases is it possible to put dollar figures on the costs incurred; however, in the following paragraphs an attempt will be made to discuss these cost sources.

Normal Work. In training practicing administrators, there will always be a cost due to delaying or not completing the normal work done by the participants. This may be estimated by determining what the cost to the school district is for having normal work accomplished and identifying this as the benefit lost. An estimate of the average hourly salary of a practicing administrator is $11.30 (Project FACT, 1973-1974) with addition of 15% for benefits, the total comes to $13 as the average hourly worth of an administrator. If the administrator spends eight hours studying a unit instead of working on district business, it will cost the district approximately $104 in benefits lost. For a four-day workshop, this would amount to $416 in opportunity costs to a district for each participating administrator.

Other Training. Again, costs incurred in this category are benefits lost by not acquiring training in other problem solving techniques or any other training. In order to estimate this type of cost it is necessary to specify the possible decision alternatives (other training) and estimate the benefits from each of these. What little information there is on this subject does not relate to training educational administrators. Thus, the most that can be said is that this will be a cost, but its magnitude is not possible to estimate in dollar terms.

Comparing the DM/DM Materials Costs with those of its Competitors

As should be evident from the description of the alternate use of the DM/DM materials, it is not possible to arrive at a single estimate of the costs for using the materials. Nevertheless, it is useful to determine the costs of using the materials under a specific set of conditions and compare it with the costs for using its competitors. In this way, it is possible to obtain an estimate of the relative costs of using the DM/DM or its competitors.

First, let us assume a most expensive case. Here we will consider only the immediate costs since those will probably be of primary concern to most decision makers Assume that this decision maker will be responsible for all costs. Further, assume that there will be a workshop of 15 educational administrators in a workshop of four days in duration which will take place at a local commercial facility. The workshop will require an instructor who is a college or university faculty member who must travel 200 miles. It will also be necessary to assume that all terminals must be rented and that commercial computer services must be purchased.

Table 13 presents the estimated costs for this workshop using either the DM/DM materials or their competitors. It is immediately evident from

Table 13

Costs of Using Data Management & Decision Making or Competitors in High Cost Situation

Source	DM/DM	Competitor
Materials	$ 180	$ 682
Instructor		
Fee	800	800
Travel	60	60
Class Setup		
Telephone	120	--
Miscellaneous	50	50
Operating Costs	160	160
Computer		
Terminals (4)	80	--
Time		
Connect Time	208	--
CPU Time	160	--
Facilities	120	120
Immediate Cost Subtotal	$1,958	$1,892
Opportunity Cost		
Personnel Time	1,560	1,560
Total	$3,518	$3,451

the table that the total costs in this situation are essentially the same, differing by less than $100. This is preliminary evidence that there is no cost advantage in using either the DM/DM materials or their competitors, in this situation.

In order to gain additional p[illegible] elative costs of the two sets of materials, let us also con[illegible] ast expensive case. Here it is assumed that a single administrator is studying the materials on his own time. The district pays only for the materials and the computer time used on machinery that the district owns. Table 14 contains a comparison of the costs for the two sets of materials. Again, the difference between the two sets of materials is quite small, indicating that in this condition there is essentially no cost difference between using the DM/DM materials or their competitors.

Table 14

Costs of Using Data Management & Decision Making or Competitors in Low Cost Situation

Source	DM/DM	Competitor
Direct Costs		
Materials	$12	$45
Computer		
Terminals (.65 hrs.)	3	-
CPU	26	-
Direct Subtotal	41	45
Opportunity Costs		
Personnel	-	-
Total	$41	$45

Further perusal of the two comparisons reveals the reason for the lack of difference in costs between the two sets of materials. Note that in materials costs, the competitor greatly exceeds the DM/DM materials. However, it should also be noted that the competitors require no use of the computer, so that using the computer with the DM/DM materials incurs additional expenses. These expenses balance one another out, so that the overall expenses will come out essentially even under most circumstances.

The investigation of the relative costs of the DM/DM materials and their competitors has revealed no advantage for one or the other, but this does not mean that there are no differences. There may be differences in benefits derived for the same cost.

Benefits

Benefits are the "good" or desirable outcomes of choosing a particular decision alternative. The problem with determining benefits is that outcomes vary in desirability for different decision makers. For the purpose of this analysis, an assumption must be made. Here the assumption will be made that a benefit of an instructional program is the attainment of one of the goals of instruction. We will also assume that evidence already exists that attainment of these goals is desirable by some target population. In fact, this evidence does exist for the goal of the DM/DM materials in the results of the needs assessment. Thus, comparing benefits becomes generally the task of comparing goals of the materials.

The first task in considering benefits then, is to enumerate the goals of the materials. To summarize the section of this report describing the

DM/DM materials, the goals will be briefly listed. The overall goal of the materials is to create an awareness of operations research techniques in educational administrators. Within this main goal are the following subsidiary goals.

1. Acquisition of the vocabulary of each technique
2. Development of some ability with the specifics of each of the four techniques
3. Acquisition of knowledge on how to use the computer as a problem-solving tool, with respect to the four techniques
4. Development of the ability to determine appropriate uses of each of the techniques in educational administration
5. Development of the ability to make decisions based on the results of using each of the techniques
6. Creation of a more positive attitude toward operations research in education

Since the competitors were chosen to reflect essentially the same goals as the DM/DM materials, this list substantially represents the goals of the competitor materials as well.

In order to make the most rigorous comparison between the costs and benefits for each of the sets of materials, it is necessary to quantify these benefits in dollar terms. This quantification, however, is extremely difficult if not impossible. First, accomplishing the goals only provide the potential for better problem solving in educational administration, and this potential is realizable in a great number of ways. In turn each of these ways implies benefits in dollar terms such as cost savings depending almost entirely on the individual situation. Theoretically, it should be possible to determine an average dollar benefit by observing a great number of situations in which these techniques are used; however, no such evidence presently exists and it is beyond the scope of this evaluation to carry out those observations. Thus the best that can be done in examining the benefits of these sets of materials in this evaluation is to enumerate their benefits and leave it to the decision maker to decide the relative importance of these benefits.

In comparing the benefits of the two sets of materials it seems most obvious to compare the goals they apparently profess. Table 15 summarizes this comparison. This table shows that the DM/DM materials profess three more important goals than their competitors, with the exception of linear programming. Of these, there was evidence in the field test that two were accomplished or at least partially attained. The DM/DM materials did not appear to change attitudes; consequently, while this goal was professed, it was not attained. In sum, it would appear that the DM/DM materials have two benefits that the competitors do not have relating to computer usage and problem identification in educational administration.

It should be noted that this treatment of the benefits of the DM/DM materials and their competitors took place at a very general level. There may be specific goals of either the DM/DM materials or their competitors which were not taken into account in this analysis. On the whole, however,

Table 15

Comparison of Apparent Goals of DM/DM and Competitors

Goal	DM/DM	Competitor
1. Create an awareness of operations research techniques in educational administrators.	Yes	Yes
2. Acquisition of the vocabulary of each technique	Yes	Yes
3. Development of some facility with the specifics of each of the four techniques	Yes	Yes
4. Acquisition of knowledge on how to use the computer as a problem-solving tool with respect to the four techniques	Yes	No (3) Yes (1)
5. Development of the ability to determine appropriate uses of each of the techniques in educational administration	Yes	No
6. Development of the ability to make decisions based on the results of using the tecnhiques	Yes	Yes
7. Creation of a more positive attitude toward operations research in educational administration	Yes	No

this should not contradict the conclusion stated above. There are a number of small differences in the instructional goals of the two sets of materials. For example, in the linear programming competitor, an attempt is made to impart a simple pictorial understanding of an optimum solution while this is not done in "Linear Programming." In no instance are these differences so major, however, as to substantially alter the list of goals as given in Table 15 and in no case do they change the attribution of goals.

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Conclusion

This cost and benefits analysis of the DM/DM materials and their competitors has revealed two important results. First, there is essentially no difference in cost of using the DM/DM materials or their competitors. Second, using the DM/DM materials results in two more benefits than using the competitors. The conclusion of this analysis must be that if the decision maker considers it important to learn about using the computer as a problem solving tool in educational administration and to identify types of educational problems which may be solved by four operations research techniques, as well as to create an awareness of operations research techniques in educational administrators, then he will gain more benefit by using the <u>Data Management & Decision Making</u> materials.

CONCLUSIONS AND RECOMMENDATIONS

The summative conclusion of this Technical Report is that <u>Data Management & Decision Making</u> is a validated product with respect to its use as instructional materials in college courses. This has been concluded for the following reasons. In the needs assessment, it was demonstrated that among at least two of the three target groups for these materials, students of educational administration, administrators, and professors of educational administration, there is a need for training materials in the four operations research techniques of concern in the materials. In the pilot test, it was demonstrated that the DM/DM materials can cause learning about operations research techniques in that students evidenced increased attainment of the instructional objectives after working through the materials. This pilot test also showed that using the DM/DM materials could change some attitudes towards operations research in education in a positive direction. In the field test, it was again demonstrated that the DM/DM materials cause learning. Moreover, it was demonstrated that in some but not all cases it causes significantly more learning than its most likely competitors, and in all cases it does no worse than the competitors. It also demonstrated that apparently no changes were evidenced in an overall measure of attitude towards operations research in education no matter whether the materials were DM/DM or their competitors. This is not a negative conclusion, since this attitude was generally quite positive when the students entered the course. As a result of the field test, it was also demonstrated that the DM/DM materials apparently had several positive side effects having to do with using the computer and increased motivation to learn about operations research techniques. When these were compared with the competitors, it was evident that the competitors had fewer positive side effects and did not have any of the minor negative side effects of the DM/DM materials. Finally in the costs and benefits analysis, it was revealed that for a cost approximately equal to that of its competitors, the DM/DM materials could deliver a greater number of benefits to the user. If the decision maker considers favorable experiences with computers and greater motivation toward learning about operations research to be valuable benefits, then Data Management & Decision Making is more cost-effective than its competitors.

For the reasons stated above, Data Management & Decision Making is a validated product with respect to learning, both cognitive and affective, cost and benefits, and side effects. Since it meets a need and is a validated product that meets an empirically established need, it is a worthwhile product. Finally, because it compares favorably with its likely competitors, it has relatively more worth in the educational marketplace.

Based on these conclusions, it is recommended that dissemination of this product be initiated and that a publisher be sought for this product.

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APPENDIX A

OBJECTIVES OF THE DATA MANAGEMENT & DECISION MAKING UNITS

OBJECTIVES FOR INTRODUCTION TO "OPERATIONS RESEARCH"

1. General Objective: The student will know and comprehend the concept of Decision Context.
   a. Behavioral Objective: The student will be able to define the term decision context. (p. 4)[1]
   b. Behavioral Objective: The student will list and define the three components of a decision context. (pp. 4-5)
   c. Behavioral Objective: The student will be able to identify the three components of a decision context given a specific problem in educational administration. (pp. 5-6)
2. General Objective: The student will know and comprehend the concept of decision strategy.
   a. Behavioral Objective: The student will be able to define the term decision strategy. (p. 8)
   b. Behavioral Objective: The student will be able to list and describe the four characteristic components of a decision strategy. (pp. 8-10)
3. General Objective: The student will know and comprehend the concept of payoff.
   a. Behavioral Objective: The student will be able to define the concept of payoff. (p. 10)
   b. Behavioral Objective: The student will be able to identify possible payoffs in an educational administration problem situation. (pp. 10-11)

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[1] Page numbers in parentheses refer to pages in the text where the objective is addressed. The text are the units accompanying this report.

4. General Objective: The subject will know the meaning of the term operations research and will be familiar with four techniques of operations research.

a. Behavioral Objective: The student will be able to define the term operations research. (p. 12)

b. Behavioral Objective: The student will be able to list four operations research techniques and briefly describe to what type of educational administration problem each technique is most applicable. (pp. 12-18)

OBJECTIVES FOR "PERT/CPM"

1. General Objective: The student will know, comprehend, and apply the concept of PERT/CPM as a problem-solving tool in educational administration.

   a. Behavioral Objective: The student will be able to define the PERT/CPM terms project (p. 5), activity (pp. 5-6), event (p. 8) and network (p. 7).

   b. Behavioral Objective: The student will be able to describe the three uses of dummy activities in PERT/CPM networks. (pp. 12-15)

   c. Behavioral Objective: The student will be able to define the terms: Earliest Start, Latest Start, Earliest Finish, Latest Finish, and Slack Time. (pp. 17-23)

   d. Behavioral Objective: The student will be able to construct a PERT/CPM network, given a list of activities for a project and each activity's immediate predecessors. (pp. 7-15)

   e. Behavioral Objective: The student will be able to define the concept of critical path in a PERT/CPM network. (pp. 23-25)

   f. Behavioral Objective: The student will be able to translate the times given in a complete PERT/CPM chart into calendar dates specifying the earliest start date and latest completion date for the activities in a project. (pp. 33-38)

2. General Objective: The student will be able to use the computer program GCPATH.

a. Behavioral Objective: The student will be able to cause the proper execution of the computer program GCPATH by entering the appropriate response to the interactive questions asked by the program. (p. 30)

c. Behavioral Objective: The student will be able to find the critical path in a PERT/CPM network using the computer program GCPATH. (p. 31)

d. Behavioral Objective: The student will be able to correctly interpret each item of information given in the output from GCPATH. (p. 31)

3. General Objective: The student will be able to use PERT/CPM as a decision-making tool with reference to specific problems in educational administration.

a. Behavioral Objective: The student will be able to identify at least five educational administration projects for which PERT/CPM is applicable. (p. 4)

b. Behavioral Objective: The student will be able to describe the use of PERT/CPM as a communications tool. (pp. 33-38)

c. Behavioral Objective: The student will be able to choose between two or more decision alternatives and justify his choice by referring to the principles of PERT/CPM, given a specific project planning problem in educational administration. (Not directly approached but dealt with by exercises on pp. 27 and 38.)

d. <u>Behavioral Objective:</u> The student will be able to list seven advantages and four disadvantages of PERT/CPM. (pp. 39-41)

OBJECTIVES FOR "LINEAR PROGRAMMING"

1. General Objective: The student will know, comprehend, and apply the concept of linear programming as a problem-solving tool in educational administration.

   a. Behavioral Objective: The student will be able to define the terms constraint (pp. 5-6), controllable variable (p. 5), object function (p. 5), and measure of effectiveness (p. 5).

   b. Behavioral Objective: The student will be able to contruct a mathematical model (constraints, controllable variables and object function) for a simple problem in linear programming (pp. 4-8).

   c. Behavioral Objective: The student will be able to distinguish between possible and optimal solutions to a linear programming problem. (pp. 12-13).

   d. Behavioral Objective: The student will be able to outline the general steps necessary in solving a linear programming problem. (pp. 30-36)

2. General Objective: The student will be able to use the computer program LINPRG.

   a. Behavioral Objective: The student will be able to construct and enter the proper DATA statements, given a specific mathematical model of a linear programming problem. (pp. 17-20)

   b. Behavioral Objective: The student will be able to cause a proper execution of the computer program LINPRG by entering the appropriate response to the interactive questions asked by the program. (pp. 20-24)

c. Behavioral Objective: The student will be able to correctly interpret the output of LINPRG as the solution of the linear programming problem. (pp. 24-25)

3. General Objective: The student will be able to use linear programming as a decision-making tool with reference to specific problems in educational administration.

a. Behavioral Objective: The student will be able to describe the general type of problem to which the technique of linear programming is applicable. (p. 3, 31-32)

b. Behavioral Objective: The student will be able to list two reasons why the technique of linear programming has only recently been used in educational administration. (pp. 29-30)

c. Behavioral Objective: The student will be able to list five typical resources to be allocated in educational problems and five quantities which could be used as measures of effectiveness. (pp. 31-32)

d. Behavioral Objective: The student will be able to list five advantages and two disadvantages of using the technique of linear programming in problems of educational administration. (pp. 86-87).

e. Behavioral Objective: The student will be able to choose between two or more decision alternatives and to justify his choice by referring to the results of a linear programming analysis, given a problem situation in educational administration which requires optimization. (All of Part IV: pp. 38-85).

OBJECTIVES FOR "QUEUEING THEORY"

1. General Objective: The student will know, comprehend, and apply the concept of queueing theory as a problem-solving tool.

   a. Behavioral Objective: The student will be able to outline the basic conditions which problems must satisfy before queueing theory can give useful results. (pp. 8-12)

   b. Behavioral Objective: The student will be able to define the queueing terms: source field, customer, service facility, arrival rate, service rate, idle time and waiting time. (pp. 5-6; 16)

   c. Behavioral Objective: The student will be able to list the queueing statistics that can be derived from the basic information about a waiting line situation. (p. 25)

   d. Behavioral Objective: The student will be able to identify in a specific queueing problem which parts of the problem function as constraints, controllable variables and payoff. (p. 33; 40)

   e. Behavioral Objective: The student will be able to explain the general effects on length of waiting line, waiting time, and probability of service facility idleness as the number of service facilities or the arrival rate, or the service rate varies. (pp. 37-38; 43; 47-48; 54)

   f. Behavioral Objective: The student will be able to identify the source field, customers, service facilities, arrival rate and service rate for a specific queueing problem. (pp. 6-7 and numerous examples in entire booklet)

2. General Objective: The student will be able to use the computer program QUEUE.

a. Behavioral Objective: The student will cause proper execution of the computer program QUEUE by entering the appropriate problem parameters in response to the interactive questions asked by QUEUE. (First example: pp. 24-28).

b. Behavioral Objective: The student will be able to correctly interpret the output of QUEUE with respect to the queueing statistics that it yields. (p. 27 and other numerous examples throughout the text)

3. General Objective: The student will be able to use queueing theory as a decision-making tool with reference to specific problems in educational administration.

a. Behavioral Objective: The student will be able to choose between two or more decision alternatives and justify his choice by referring to the results of a Queueing Theory analysis, given a problem situation in educational administration to which Queueing Theory is applicable. (Present in all examples of booklet, beginning with first example on p. 21).

b. Behavioral Objective: The student will be able to list four advantages and four disadvantages in using queueing theory for problems in educational administration. (p. 55)

OBJECTIVES FOR "COMPUTER SIMULATION"

1. General Objective: The student will know, comprehend, and apply the concept of simulation as a problem-solving tool.

   a. Behavioral Objective: The student will be able to define simulation. (p. 3)

   b. Behavioral Objective: The student will be able to list the four components of a simulation. (pp. 6-7)

   c. Behavioral Objective: The student will be able to name at least two uses of simulation in an educational setting. (Numerous examples throughout booklet)

   d. Behavioral Objective: The student will be able to list and describe the three classes and two types of simulations. (pp. 7-11)

   e. Behavioral Objective: The student will be able to list and explain the four purposes of simulation. (pp. 11-12)

2. General Objective: The student will be able to use the computer program BUSRUT which simulates bus routing problems.

   a. Behavioral Objective: The student will be able to construct and enter the proper DATA statements required for the program BUSRUT, given a map with the pickup locations, coordinate axes and number of children to be picked up at each stop. (pp. 14-18).

   b. Behavioral Objective: The student will be able to cause the proper execution of the computer program BUSRUT by entering the required information in the required sequence. (pp. 18-21)

c. <u>Behavioral Objective:</u> The student will be able to correctly interpret the output of the computer program BUSRUT as the solution of the bus routing problem. (pp. 21-24)

d. <u>Behavioral Objective:</u> The student will be able to choose between two or more decision alternatives and justify his choice by referring to the output of the BUSRUT program, given a problem situation involving the routing of buses. (First example, p. 25; others: pp. 26-30).

3. <u>General Objective:</u> The student will be able to use the computer simulation ENRPRO, which simulates school enrollment and provides projections.

a. <u>Behavioral Objective:</u> The student will be able to construct and enter the proper DATA statements required for the program ENRPRO, given a table of enrollment data over, at least, a five year period. (pp. 38-39)

b. <u>Behavioral Objective:</u> The student will be able to cause the proper execution of the program ENRPRO by entering the required information in the required sequence. (pp. 40-44)

c. <u>Behavioral Objective:</u> The student will be able to correctly interpret the output of the program ENRPRO with respect to projected enrollments, year-to-year comparisons, and projected versus actual enrollment. (pp. 44-52)

d. <u>Behavioral Objective:</u> The student will be able to choose between two or more decision alternatives and justify his choice by referring to an enrollment projection produced by the program ENRPRO, given a problem situation in educational administration involving enrollment projections. (pp. 60-67)

APPENDIX B

NEEDS ASSESSMENT INSTRUMENT

Northwest Regional Educational Laboratory
Lindsay Building · 710 S.W. Second Avenue
Portland, Oregon 97204 · Telephone (503) 224-3650

May 10, 1974

Dear

The Northwest Regional Educational Laboratory is presently engaged in planning for the development of instructional materials which are intended to focus on some of the techniques of modern management and which are targeted for educational administrators. In preparation for this work, practitioners, professors and students of educational administration are being surveyed. The purpose of this survey is to determine if the topics that are being considered for inclusion in the materials are, in fact, considered important by persons involved in educational administration.

The short questionnaire that you will find included with this letter consists of a listing of possible administrative problems which are solvable by the techniques under consideration for inclusion in the materials. We would greatly appreciate it, if you would respond to this questionnaire from two points of view--how often the problems occur and how important they are. Responses in the lefthand column should reflect the frequency with which you encountered the listed problems. Please use the righthand column to indicate the importance of training to help administrators deal with each of the listed problems.

Enclosed you will also find a self-addressed, stamped envelope. After filling out the questionnaire, please put it in the envelope and drop it in the mail. It would be helpful if you could fill out this questionnaire and return it within 10 days. We realize that your time is strictly budgeted but the few moments necessary to complete this form would be greatly appreciated. Thank you very much for your time and effort.

Sincerely,

Stuart M. Speedie

Stuart M. Speedie
Computer Technology Program

SMS/n
Enclosures

Please check only one box. Please check only one box.

Often	Sometime	Hardly Ever		Needed Very Much	Needed But Not Essential	Not Needed
☐	☐	☐	1. Understanding the decision-making process	☐	☐	☐
☐	☐	☐	2. Planning projects	☐	☐	☐
☐	☐	☐	3. Analyzing ongoing procedures for efficiency	☐	☐	☐
☐	☐	☐	4. Minimizing costs	☐	☐	☐
☐	☐	☐	5. Analyzing the efficiency of school district services	☐	☐	☐
☐	☐	☐	6. Allocating time for the accomplishment of tasks	☐	☐	☐
☐	☐	☐	7. Minimizing the waiting time for a particular service	☐	☐	☐
☐	☐	☐	8. Understanding the interaction of school district systems	☐	☐	☐
☐	☐	☐	9. Routing school buses	☐	☐	☐
☐	☐	☐	10. Scheduling activities so as to meet a deadline	☐	☐	☐
☐	☐	☐	11. Simultaneously minimizing costs while maintaining quality of an activity	☐	☐	☐
☐	☐	☐	12. Maximizing the utilization of service facilities	☐	☐	☐
☐	☐	☐	13. Predicting changes in school enrollment	☐	☐	☐
☐	☐	☐	14. Identifying options in decision making	☐	☐	☐
☐	☐	☐	15. Allocating budgetary resources efficiently	☐	☐	☐
☐	☐	☐	16. Simultaneously satisfying a number of different goals	☐	☐	☐
☐	☐	☐	17. Determining the probable outcome of a particular decision without actually implementing the decision	☐	☐	☐

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ID: ____________________
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Date: ____________________

For each applicable item circle the letter of the best answer.

Form: I P

1. A <u>decision context</u> is:

   a. a choice between two different options
   b. the administrator's environment
   c. a problem for which a decision is needed
   d. the school district of the administrator

2. List and briefly define the three components of the decision context:

   Component

   1 ________________ Dfn: ____

   ____

   2 ________________ Dfn: ____

   ____

   3 ________________ Dfn: ____

   ____

3. Suppose that you are a school superintendent. Your school board has just adopted the policy that all children should have at least 18 weeks of career education by the time they reach the seventh grade. Only grades 4, 5, 6 are to be involved and the sum of $50,000 has been allocated. You have the freedom to assign any number of teachers for any number of hours and to hire as many consultants as necessary provided you do not exceed the authorized amount.

   I. The sum of $50,000 is:

   a. a perceived need
   b. a constraint
   c. none of these
   d. a controllable variable

   II. The number of teachers assigned is:

   a. a controllable variable
   b. a perceived need
   c. a constraint
   d. none of these

III. To develop a plan for career education in the upper elementary grades is:

a. none of these
b. a controllable variable
c. constraint
d. a perceived need

4. A <u>decision strategy</u> is:

a. the process by which a decision is made
b. a problem for which a decision is needed
c. the choice between a number of options
d. the process of implementing a decision

5. The four components of a decision strategy are:

a. perceived need, constraints, controllable variables, generation of possible solutions
b. analysis of the decision context, decision on criteria for the best solution, perceiving the appropriate need, testing possible solutions against criteria for best solution
c. analysis of the decision context, decision on criteria for the best solution, generation of possible solutions, testing possible solutions against criteria for best solution
d. finding controllable variables, decision on criteria for the best solution, generation of possible solutions, testing possible solutions against criteria for best solution

6. A <u>payoff</u> is:

a. the situation which requires a decision
b. the process of making a decision
c. a decision with respect to a specific context
d. the result of a specific decision

7. Suppose that you have the responsibility for constructing the school district's budget for the next fiscal year. You have available to you a full-time secretary, all previous years' budgets and budget estimates from each of your district's schools. The most important payoff of decision making in this case is:

a. budget length
b. time
c. money
d. line item costs

8. _______________ is a set of powerful decision strategies for large and complex administrative problems.

a. operations research
b. linear programming
c. mathematical modeling
d. queueing theory

9. List four important operations research techniques and match them with administrative applications for which they are most useful (Any operations research technique may be applicable to more than one problem).

a. _______________ _____planning and analyzing project stages
b. _______________ _____analyzing waiting line problems
c. _______________ _____analyzing a working model of the decision context
d. _______________ _____problems in which the constraints and payoff can be stated mathematically
_____problems involving service facilities

10. A project is:

a. an organizational unit with finite beginnings and endings
b. a set of interrelated activities, each with a beginning and ending
c. a set of activities which require a mix of human and material resources
d. a finite, complex organizational unit dedicated to the attainment of a goal

11. An action or set of actions designed to attain a specific goal is:

a. an activity
b. an event
c. a project
d. a network

12. An event

a. is a set of large and complex activities
b. marks only the beginning of an activity
c. has a definite duration of time
d. marks the beginning or ending of an activity

13. A diagram which depicts a project as a set of relationships among activities by arrows and circles is:

a. a tree diagram
b. a network
c. a project layout
d. a project picture

14. Which of the four listed below is not a use of dummy activities:

I. Indicating activity precedence without intervening activities.
II. Indicating the precedence of activities when two activities begin with the same event.
III. Providing single starting and termination events for projects with multiple starts or finishes.
IV. Eliminating the possibility that two activities will start and end with the same events.

a. IV
b. III
c. II
d. I

15. Match the following words with their definitions:

_____Earliest start	a. earliest latest start of all immediate successors
_____Latest start	b. earliest finish of all immediate predecessors
_____Earliest finish	c. latest finish - slack time
_____Latest finish	d. earliest start time + duration of activity
_____Slack time	e. latest finish - duration of activity
	f. latest start time - earliest start time

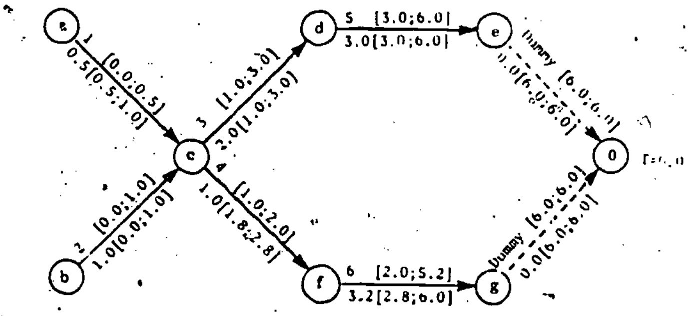
16. Construct a PERT/CPM network from the information given below. Identify each activity arrow by its number.

Activity	Predecessor(s)
1	
2	
3	
4	1,2,3
5	1,2,3
6	5
7	4,6

17. The Critical Path in a PERT/CPM network is the path which:

a. has the least amount of slack
b. has the greatest amount of slack
c. is the shortest path through the network
d. contains the most activities

18. Below is a PERT/CPM Network



I. Which of the paths below is the Critical Path?

a. 1,3,5
b. 1.4,6
c. 2,4,6
d. 2,3,5

II. Below is a calendar for the month of May

S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

19. Which dates are the Earliest Start and Latest Finish dates for the above project if the project may not begin before May 7 and must be finished by May 18. (Assume a five day work week)

a. May 7,14
b. May 11,18
c. May 7,18
d. May 9,16

20. If activity 7 took 2 weeks and was preceded by activities 5 and 2, the correct DATA statement for program GCPATH would be:

a. 2000 DATA 7,14,5,2
b. 2000 DATA 7,2,-1
c. 2000 DATA 7,5,2,-1
d. 2000 DATA 7,2,5,2,-1

21. Below is a sample output from program GCPATH

EARLIEST COMPLETION TIME FOR THE ENTIRE PROJECT = 15.5

	EARLIEST		LATEST			
JOB	START	FINISH	START	FINISH	SLACK	
1	0	5	0	5	0	*CP*
2	5	8	5.5	8.5	.5	
3	8	10	8.5	10.5	.5	
4	10	11	10.5	11.5	.5	
5	5	11	5	11	0	*CP*
6	11	11.5	11	11.5	0	*CP*
7	11.5	12.5	12.5	13.5	1	
8	12.5	14.5	13.5	15.5	1	
9	11.5	15.5	11.5	15.5	0	*CP*

DONE

I. Which path is the Critical Path?

a. 1,5,6,9
b. 1,2,3,4,7,8
c. 1,2,3,4,9
d. 1,5,6,7,8

II. What is the Earliest Start, Latest Finish and Slack Time for Activity 4?

a. 10,11.5,.5
b. 10,15.5,.5
c. 10,11,.5
d. 10.5,11.5,.5

22. List 5 educational applications of PERT/CPM

a. ____________________

____

b. ____________________

____

c. ____________________

____

d. ____________________

____

e. ____________________

____

23. PERT/CPM is a useful communications tool because:

a. it tells the activity supervisor exactly what he must do.
b. it displays a project with complex relationships of activities in a simple and direct manner.
c. it informs the manager of his management responsibilities.
d. it provides a picture of the project as a set of decision events in a simple and direct manner.

24. Suppose that you are a school district superintendent. You are planning a school census. You have analyzed this project using PERT/CPM. Your analysis tells you that the Critical Path is 7 months long. It is now April 1, 1973. Your survey must be finished by August 1, 1974. Which is the latest period in which you can initiate the project?

a. April 1, 1973 to April 30, 1973
b. October 1, 1973 to July 31, 1974
c. September 1, 1973 to September 15, 1973
d. April 1, 1973 to September 30, 1973

25. Give a reason based on PERT/CPM for your answer:

____

____

____

26. Give one advantage and one disadvantage of PERT CPM:

Advantage: ______________________________

____

____

Disadvantage: ______________________________

____

____

ID: ____________________
(last 4 digits of your SS no.)

Date: ____________________

For each applicable item circle the letter of the best answer.

Forms: II.P

1. The situation which creates the need for a decision is the:

a. decision context
b. perceived need
c. decision strategy
d. constraints

2. List and briefly define the three components of the decision context.

Component

1 __________ Dfn. __________

2 __________ Dfn. __________

3 __________ Dfn. __________

3. Suppose that you are an assistant superintendent. You have been assigned the task of establishing a busing program which will result in racial balance within your school system. Your district has allocated $100,000 for busing using its fleet of 75 buses. You may adjust the number of students on any bus, the route any bus will follow and the school or schools to which it delivers. The plan is to be ready to use at the beginning of school this fall.

I. The school or schools to which a bus delivers is:

a. none of these
b. a constraint
c. a perceived need
d. a controllable variable

II. To establish a busing program is

a. a controllable variable
b. perceived need
c. none of these
d. a constraint.

III. The 75 buses in the school district fleet represent:

a. a perceived need
b. a controllable variable
c. a constraint
d. none of these

4. The process by which the administrator makes a decision with respect to the decision context is the:

a. perceived need
b. decision context
c. analysis of the decision context
d. decision strategy

5. The following four activities
- analysis of the decision context
- decision on criteria for best solution
- generation of possible solutions
- testing of possible solutions against criteria for best solution

are components of the

a. decision strategy
b. controllable variables
c. decision context
d. decision variables

6. The result or outcome of a specific decision is

a. a decision context
b. a payoff
c. what happens
d. a decision strategy

7. Suppose that you are responsible for choosing a new reading series for the elementary schools in your district. The decision must be made by the spring of this year and you have been allocated $25,000. What is the most important payoff for this decision?

a. reading achievement
b. total time to prepare
c. number of texts
d. manhours used

8. Operations Research is

a. a method for the scientific study of management or administrative functions
b. a method of research designed to study business operations
c. a set of powerful decision contexts for large and complex administrative problems
d. a set of powerful decision strategies for large and complex administrative problems

9. List four important operations research techniques and match them with administrative applications for which they are most useful (any operations research technique may be applicable to more than one problem).

a. ________	_____planning and analyzing project stages
b. ________	_____analyzing waiting line problems
c. ________	_____analyzing a working model of the decision context
d. ________	_____problems in which the constraints and payoff can can be stated mathematically
	_____problems involving service facilities

10. A complex organizational unit which involves a set of finite related actions and requires a mix of human and material resources is:

a. an activity
b. a project
c. a set of events
d. an event

11. An <u>activity</u> is:

a. an action or set of actions designed to attain a goal
b. a set of complex and interrelated actions
c. a complex organizational unit which requires a mix of human and material resources
d. the beginning or ending of a set of actions

12. That which marks the beginning or ending of an activity is:

a. a time
b. a project
c. an event
d. a network

13. A <u>network</u> is a diagram which depicts:

a. a project as a set of interrelated events by means of arrows
b. an activity as a set of interrelated events by means of arrows
c. an event as a set of interrelated activities by means of circles and arrows
d. a project as a set of interrelated activities by means of circles and arrows

14. Which three of these listed below are the uses of a dummy activity:

I. Indicating the precedence of activities when two activities end with the same event.
II. Eliminating the possibility that two activities will start and end with the same events.
III. Indicating activity precedence without intervening activities.
VI. Providing single starting and termination events for projects with multiple starts and/or finishes.

a. I, II, III
b. I, II, IV
c. I, III, IV
d. II, III, IV

15. In each of the following items choose the term which matches the definition

I. Earliest start time and duration of the activity
a. earliest start
b. earliest finish
c. slack time
d. latest start

II. Earliest latest start of all immediate predecessors
a. slack time
b. earliest finish
c. latest start
d. latest finish

III. Earliest finish of all immediate predecessors
a. earliest start
b. earliest finish
c. latest start
d. latest finish

IV. Latest start time - earliest start time
a. slack time
b. earliest start
c. latest start
d. latest finish

V. Latest finish - duration of the activity
a. earliest start
b. earliest finish
c. latest start
d. slack time

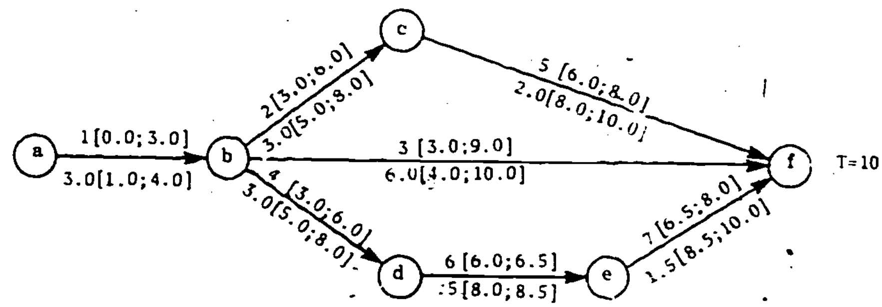
16. Construct a PERT/CPM network from the information given below. Identify each activity arrow by its number.

Activity	Predecessors
1	
2	1
3	1
4	3
5	4
6	2
7	5,6
8	5,6

17. The longest path through the network in terms of time is:

a. the path with the most activities
b. the path with the fewest activities
c. the critical path
d. the most slack path

18. Below is a PERT/CPM network



I. Which of the paths below is the Critical Path?

a. 1,2,5
b. 1,3
c. 1,4,6,7
d. 1,3,6,7

II. Below is a calendar for the month of September

S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

If the above project must start by Sept. 18 and be finished by Sept. 29 its Earliest Start and Latest Finish times are:

a. Sept. 20,29
b. Sept. 18,29
c. Sept. 18,28
d. Sept. 19,29

19. If activity 14 takes 3 days to complete and is preceded by activities 13, 9, 5, the correct DATA statement for program GCPATH would be:

a. 2000 DATA 14,3,13,9,5,-1
b. 2000 DATA 14,3,13,9,5
c. 2000 DATA 14,13,9,5,3
d. 2000 DATA 14,13,9,5,3,-1

20. Below is a sample output from program GCPATH

EARLIEST COMPLETION TIME FOR THE ENTIRE PROJECT = 25

JOB	EARLIEST START	EARLIEST FINISH	LATEST START	LATEST FINISH	SLACK	
1	0	3	1	4	1	
2	3	4	4	5	1	
3	0	3	0	3	0	*CP*
4	3	5	3	5	0	*CP*
5	5	13	5	13	0	*CP*
6	13	19	13	19	0	*CP*
7	19	23	19	23	0	*CP*
8	23	25	23	25	0	*CP*
9	19	22	22	25	3	
10	19	19.3	24.7	25	5.7	

I. Which path is the Critical Path?

a. 1,2,5,6,7,8
b. 1,2,5,6,9
c. 3,4,5,6,7,8
d. 3,4,5,6,9

II. What is the Earliest Start, Latest Finish and Slack Time for activity 4.

a. 3,5,3,5,0
b. 5,12,5,13,0
c. 2,3,4,5,1
d. 3,5,3,5,1

21. List 5 educational applications of PERT/CPM

a. ____

____

b. ____

____

c. ____

____

d. ____

____

e. ____

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____

22. Because PERT/CPM displays a project with complex interrelationships of activities in a simple and direct manner it is a useful:

a. communication tool
b. decision-implementing tool
c. project monitoring tool
d. project evaluation tool

23. Suppose that you are an assistant superintendent of a large school district. You have the responsibility to make enrollment predictions for the next five years. Using PERT/CPM you have analyzed this project and found that your critical path is 3 months long. It is now July 1, 1973 and the project must be completed by May 1, 1974. How long can you delay the starting of this project and still finish safely?

a. September 1, 1973
b. March 1,1974
c. October 1, 1973
d. February 1, 1974

24. Give a reason based on PERT/CPM for your answer.

____

____

____

25. Give one advantage and one disadvantage of PERT/CPM:

Advantage: ______________________________

____

____

Disadvantage: ______________________________

____

____

ID:____________________
(last 4 digits of your SS no.)

Date:____________________

For each applicable item circle the letter of the best answer.

Form: I L

1. A decision context is:

   a. a choice between two different options
   b. the administrator's environment
   c. a problem for which a decision is needed
   d. the school district of the administrator

2. List and briefly define the three components of the decision context.

   Component

   1______________ Dfn: ______________________________

   ____

   2______________ Dfn: ______________________________

   ____

   3______________ Dfn: ______________________________

   ____

3. Suppose that you are a school superintendent. Your school board has just adopted the policy that all children should have at least 18 weeks of career education by the time they reach the seventh grade. Only grades 4, 5, 6 are to be involved and the sum of $50,000 has been allocated. You have the freedom to assign any number of teachers for any number of hours and to hire as many consultants as necessary provided you do not exceed the authorized amount.

   I. The sum of $50,000 is:

   a. a perceived need
   b. a constraint
   c. none of these
   d. a controllable variable

   II. The number of teachers assigned is:

   a. a controllable variable
   b. a perceived need
   c. a constraint
   d. none of these

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III. To develop a plan for career education in the upper elementary grades is:

a. none of these
b. a controllable variable
c. constraint
d. a perceived need

4. A decision strategy is:

a. the process by which a decision is made
b. a problem for which a decision is needed
c. the choice between a number of options
d. the process of implementing a decision

5. The four components of a decision strategy are:

a. perceived need, constraints, controllable variables, generation of possible solutions
b. analysis of the decision context, decision on criteria for the best solution, perceiving the appropriate need, testing possible solutions against criteria for best solution
c. analysis of the decision context, decision on criteria for the best solution, generation of possible solutions, testing possible solutions against criteria for best solution
d. finding controllable variables, decision on criteria for the best solution, generation of possible solutions, testing possible solutions against criteria for best solution

6. A payoff is:

a. the situation which requires a decision
b. the process of making a decision
c. a decision with respect to a specific context
d. the result of a specific decision

7. Suppose that you have the responsibility for constructing the school district's budget for the next fiscal year. You have available to you a full-time secretary, all previous years' budgets and budget estimates from each of your district's schools. The most important payoff of decision making in this case is:

a. budget length
b. time
c. money
d. line item costs

8. _______________ is a set of powerful decision strategies for large and complex administrative problems.

   a. operations research
   b. linear programming
   c. mathematical modeling
   d. queueing theory

9. List four important operations research techniques and match them with administrative applications for which they are most useful (Any operations research technique may be applicable to more than one problem).

   a. _______________ _____planning and analyzing project stages
   b. _______________ _____analyzing waiting line problems
   c. _______________ _____analyzing a working model of the decision context
   d. _______________ _____problems in which the constraints and payoff can be stated mathematically
   _____problems involving service facilities

10. A constraint is:

a. a quantity that we wish to either maximize or minimize
b. the measure of how successful we are at either maximizing or minimizing
c. a restriction on one or several controllable variables
d. a direct restriction on the measure of effectiveness

11. A variable whose value can be manipulated in order to get an optimum result is:

a. a controllable variable
b. an optimized variable
c. a measure of effectiveness
d. a constraint

12. An object function is:

a. a restriction on one or more controllable variables
b. a mathematical expression of the measure of effectiveness
c. the quantity we want to either maximize or minimize
d. a mathematical expression of the problem's constraints

13. The quantity which we wish to either maximize or minimize in a linear programming problem is:

a. an object function
b. a controllable variable
c. a constraint
d. measure of effectiveness

14. Suppose that you are responsible for deciding how many reading books to buy for the first grades in your district. You have decided on purchasing two series---series A and series B. (t_1 is the total number of series A books, t_2 is the total number of series B books) Series A books costs $2.50 each and last for 2 years. Series B books cost $4.95 each and last 4.5 years. You have $5,000 to spend and you must purchase at least 100 of each series. The goal is to purchase the books so that they last the maximum amount of time. Determine the following for this problem:

I. Controllable variables: ______________________

II. Constraints: ______________________

____

____

III. Object Function: ______________________

15. Which of the statements below describes the relationship between a <u>feasible</u> solution and an <u>optimal</u> solution?

a. the optimal solution is the best of all feasible solutions

b. the feasible solution is the best of all optimal solutions

c. a feasible solution satifies all the constraints while the optimal solution does not.

d. there may be a great many optimal solutions but only one feasible solution.

16. List the seven steps necessary in solving a linear programming problem:

____

____

____

____

____

____

____

17. Below is a model for a linear programming problem. Write down the DATA statements in the correct order for using the computer program LINPRG.

Object function: $7t_1 + 5.3t_2 = C$

Constraints: $t_1 > 50$
$t_2 < 30$
$3000\ t_1 + 5000\ t_2 < 20{,}000$

____

____

____

____

____

18. Below is an output listing from the program LINPRG.

```
LINPRG

 * LINEAR PROGRAMMING *

HAVE YØU ENTERED YØUR DATA STATEMENTS?
(YES='1', NØ='0')
?1

IF MAXIMIZING THE ØBJECT FUNCTIØN, TYPE '1';
IF MINIMIZING THE ØBJECT FUNCTIØN, TYPE '-1'.
?1

NUMBER ØF CØNSTRAINTS?
?3

NUMBER ØF VARIABLES?
?2

NUMBER OF LESS-THAN CØNSTRAINTS?
?1

NUMBER ØF EQUALITY CØNSTRAINTS?
?0

NUMBER ØF GREATER-THAN CØNSTRAINTS?
?2

**************************************************


ANSWERS:

THE MAXIMUM VALUE ØF THE ØBJECT FUNCTIØN IS 556.4
THIS ØCCURS WHEN:
    VARIABLE   1      =  13.04
    VARIABLE   2      =  4

ANY VARIABLES NØT LISTED HAVE VALUE 0

DØNE
```

Object function: $35t_1 + 25t_2 = C$

Constraints: $t_1 < 22$; $t_2 > 4$; $\$500t_1 + \$370t_2 < \$8000$

t_1 represents the number of Type A science centers ($500@) and t_2 represents the number of Type B science centers ($370@). The object function attempts to maximize the number of children served by science centers.

I. How many Type A centers should be purchased? ______________
II. How many Type B centers should be purchased? ______________
III. How many children will be served by these centers? __________

19. Linear programming is primarily useful in dealing with problems where:

a. one is able to quantify the variables involved in the problem
b. resources are allocated so as to optimize some result
c. resources are allocated so as to maximize some quantity
d. resources are allocated so as to minimize some quantity

20. Which of the following alternatives represent two reasons why the technique of linear programming has only recently been used in education:

a. Important educational variables are difficult to quantify. Linear programming is applicable to only a small number of educational problems.
b. Linear programming was developed only recently. There has not been much time to develop educational applications.
c. The necessary mathematicians and computers are not generally available to educators. It is necessary to have specialized training to use linear programming.
d. Important educational variables are difficult to quantify. Few educators are aware of the existence of linear programming.

21. List five typical resources to be allocated in educational problems.

a. ____
b. ____
c. ____
d. ____
e. ____

22. Which of the following four is not an advantage of using the technique of linear programming in solving problems in educational administration?

a. provides fast answers at little cost
b. provides a rational basis for decision making
c. provides a method for quantifying goals
d. provides a means for simulating changes and observing the results

23. Which of the following is a disadvantage of using the technique of linear programming?

a. linear programming provides data but does not make decisions
b. the technique is too sophisticated to use for educational problems
c. it requires mathematical sophistication to use the technique
d. linear programming often does not provide a best answer

ID:______________________

(last 4 digits of your SS no.)

Date:______________________

For each applicable item circle the letter of the best answer.

Form: II L

1. The situation which creates the need for a decision is the:

   a. decision context
   b. perceived need
   c. decision strategy
   d. constraints

2. List and briefly define the three components of the decision context.

   Component

   1 ______________ Dfn. ______________________________
   ____

   2 ______________ Dfn. ______________________________
   ____

   3 ______________ Dfn. ______________________________
   ____

3. Suppose that you are an assistant superintendent. You have been assigned the task of establishing a busing program which will result in racial balance within your school system. Your district has allocated $100,000 for busing using its fleet of 75 buses. You may adjust the number of students on any bus, the route any bus will follow and the school or schools to which it delivers. The plan is to be ready to use at the beginning of school this fall.

   I. The school or schools to which a bus delivers is:

   a. none of these
   b. a constraint
   c. a perceived need
   d. a controllable variable

   II. To establish a busing program is

   a. a controllable variable
   b. perceived need
   c. none of these
   d. a constraint

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III. The 75 buses in the school district fleet represent:

a. a perceived need
b. a controllable variable
c. a constraint
d. none of these

4. The process by which the administrator makes a decision with respect to the decision context is the:

a. perceived need
b. decision context
c. analysis of the decision context
d. decision strategy

5. The following four activities
- analysis of the decision context
- decision on criteria for best solution
- generation of possible solutions
- testing of possible solutions against criteria for best solution

are components of the

a. decision strategy
b. controllable variables
c. decision context
d. decision variables

6. The result or outcome of a specific decision is

a. a decision context
b. a payoff
c. what happens
d. a decision strategy

7. Suppose that you are responsible for choosing a new reading series for the elementary schools in your district. The decision must be made by the spring of this year and you have been allocated $25,000. What is the most important payoff for this decision?

a. reading achievement
b. total time to prepare
c. number of texts
d. manhours used

8. Operations Research is

   a. a method for the scientific study of management or administrative functions
   b. a method of research designed to study business operations
   c. a set of powerful decision contexts for large and complex administrative problems
   d. a set of powerful decision strategies for large and complex administrative problems

9. List four important operations research techniques and match them with administrative applications for which they are most useful (any operations research technique may be applicable to more than one problem).

   a. ________   _____planning and analyzing project stages
   b. ________   _____analyzing waiting line problems
   c. ________   _____analyzing a working model of the decision context
   d. ________   _____problems in which the constraints and payoff can can be stated mathematically
                    _____problems involving service facilities

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10. A restriction on one or more controllable variables is:

    a. a controllable variable
    b. a measure of effectiveness
    c. an object function
    d. a constraint

11. A <u>controllable</u> variable is:

    a. a quantity we wish to either maximize or minimize
    b. a variable which can be manipulated in order to get an optimum result
    c. a mathematical expression of the restrictions on certain variables
    d. the mathematical expression for the measure of affectiveness

12. A mathematical expression of the measure of effectiveness is:

    a. the object function
    b. a controllable variable
    c. a constraint
    d. an optimizer

13. The <u>measure of effectiveness</u> is:

    a. the quantity we wish to either maximize or minimize.
    b. a variable which can be directly manipulated.
    c. a restriction on one or more controllable variables.
    d. a mathematical expression for the controllable variables.

14. Suppose that you are responsible for deciding how many science centers to buy for your new school. You have a choice of two types S, Z. Type S costs \$750 and serves 20 students. Type Z costs \$475 and serves 25 children. (t_1 is the total number of type S centers; t_2 is the total number of type Z centers) You have \$10,000 to spend and you wish to maximize the number of children served. You must buy at least 3 of each type. Determine the following for this problem:

    I. Controllable variables: ______________________________

    II. Constraints: ______________________________

    ____

    ____

    ____

III. Object Function : ______________________________

15. The ____________ solution is ______________ of all ____________ solutions.

a. feasible, the best, optimal
b. optimal, one, feasible
c. optimal, the best, feasible
d. feasible, one, optimal

16. List the seven steps necessary in solving a linear programming problem.

____

____

____

____

____

____

____

17. Below is a model for a linear programming problem. Write down the DATA statements in the correct order for using the computer program LINPRG

Object Function: $90t_1 + 75t_2 = C$

Constraints: $5t_1 + 3t_2 = 250$
$t_1 < 30$
$t_2 > 50$

____

____

____

____

____

18. Below is the listing for a linear programming problem solved by the computer program LINPRG.

```
LINPRG

 * LINEAR PRØGRAMMING *

HAVE YØU ENTERED YØUR DATA STATEMENTS?
(YES='1', NØ='0')
?1

IF MAXIMIZING THE ØBJECT FUNCTIØN, TYPE '1';
IF MINIMIZING THE ØBJECT FUNCTIØN, TYPE '-1'.
?1

NUMBER ØF CØNSTRAINTS?
?3

NUMBER ØF VARIABLES?
?2

NUMBER ØF LESS-THAN CØNSTRAINTS?
?1

NUMBER ØF EQUALITY CØNSTRAINTS?
?0

NUMBER ØF GREATER-THAN CØNSTRAINTS?
?2

**************************************************


ANSWERS:

THE MAXIMUM VALUE ØF THE ØBJECT FUNCTIØN IS 1243.42
THIS ØCCURS WHEN:
    VARIABLE   1     =  50
    VARIABLE   2     =  584.211

ANY VARIABLES NØT LISTED HAVE VALUE 0

DØNE
```

Object function: $1.5t_1 + 2t_2 = L$

Constraints: $t_1 > 50$, $t_2 > 75$, $\$4.50\ t_1 + \$4.75\ t_2 < 3000$

t_1 represents the number of textbook S (\$4.50 @) and t_2 represents the number of textbook Z (\$4.75 @). The object function attempts to maximize the cumulative length of time that the textbooks will last.

I. How many S textbooks should be purchased? ____________________

II. How many Z textbooks should be purchased? ____________________

III. What is the cumulative length of time the textbooks will last? ____________________

19. Linear programming is useful for solving problems in which ____________ are allocated so as to ____________ some result.

   a. quantities, maximize
   b. resources, minimize
   c. quantities, maximize
   d. resources, optimize

20. Which of the following choices give two valid reasons why linear programming is presently used so little in education:

   a. Important educational variable are difficult to express numerically. It is necessary to have specialized training to use linear programming.
   b. It is difficult to express important educational variables numerically. Few educators are aware of the existence of linear programming.
   c. There has not been much time to develop educational applications. It is necessary to have specialized training to use linear programming.
   d. The necessary mathematicians and computer are not generally available to educators. Linear programming was developed only recently.

21. List five typical resources to be allocated in educational problems.

   a. ____________
   b. ____________
   c. ____________
   d. ____________
   e. ____________

22. List five measures of effectiveness in educational problems.

   a. ____________
   b. ____________
   c. ____________
   d. ____________
   e. ____________

23. Which of the following four is not an advantage of using the technique of linear programming in solving problems in educational administration?

a. provides the criteria for decision making.
b. encourages identification of goals
c. provides a format for systematic analysis of a problem.
d. provides fast answers at little cost

24. Which of the following four is a disadvantage of using the technique of linear programming.

a. the technique is too sophisticated to use for educational problems
b. the technique is slow and costly to use
c. it is necessary to be sophisticated mathematically to use Linear Programming
d. Many real-world situations are difficult to formulate mathematically

ID:________________________
(last 4 digits of your SS no.)

Date:_______________________

Materials Used:____

For each applicable item circle the letter of the best answer.

Form: I S

1. A decision context is:

   a. a choice between two different options
   b. the administrator's environment
   c. a problem for which a decision is needed
   d. the school district of the administrator

2. List and briefly define the three components of the decision context.

   Component

   1____________ Dfn: ____

   ____

   2____________ Dfn: ____

   ____

   3____________ Dfn: ____

   ____

3. Suppose that you are a school superintendent. Your school board has just adopted the policy that all children should have at least 18 weeks of career education by the time they reach the seventh grade. Only grades 4, 5, 6 are to be involved and the sum of $50,000 has been allocated. You have the freedom to assign any number of teachers for any number of hours and to hire as many consultants as necessary provided you do not exceed the authorized amount.

   I. The sum of $50,000 is:

   a. a perceived need
   b. a constraint
   c. none of these
   d. a controllable variable

   II. The number of teachers assigned is:

   a. a controllable variable
   b. a perceived need
   c. a constraint
   d. none of these

III. To develop a plan for career education in the upper elementary grades is:

a. none of these
b. a controllable variable
c. constraint
d. a perceived need

4. A decision strategy is:

a. the process by which a decision is made
b. a problem for which a decision is needed
c. the choice between a number of options
d. the process of implementing a decision

5. The four components of a decision strategy are:

a. perceived need, constraints, controllable variables, generation of possible solutions
b. analysis of the decision context, decision on criteria for the best solution, perceiving the appropriate need, testing possible solutions against criteria for best solution
c. analysis of the decision context, decision on criteria for the best solution, generation of possible solutions, testing possible solutions against criteria for best solution
d. finding controllable variables, decision on criteria for the best solution, generation of possible solutions, testing possible solutions against criteria for best solution

6. A payoff is:

a. the situation which requires a decision
b. the process of making a decision
c. a decision with respect to a specific context
d. the result of a specific decision

7. Suppose that you have the responsibility for constructing the school district's budget for the next fiscal year. You have available to you a full-time secretary, all previous years' budgets and budget estimates from each of your district's schools. The most important payoff of decision making in this case is:

a. budget length
b. time
c. money
d. line item costs

8. _______________ is a set of powerful decision strategies for large and complex administrative problems.

a. operations research
b. linear programming
c. mathematical modeling
d. queueing theory

9. List four important operations research techniques and match them with administrative applications for which they are most useful (Any operations research technique may be applicable to more than one problem).

a. _______________ _____planning and analyzing project stages
b. _______________ _____analyzing waiting line problems
c. _______________ _____analyzing a working model of the decision context
d. _______________ _____problems in which the constraints and payoff can be stated mathematically
_____problems involving service facilities

10. Simulation is

    a. making reality easier to understand
    b. role playing
    c. representing reality by using a computer
    d. giving the effect or appearance of reality

11. Which of the following is not a component of a simulation?

    a. Object system
    b. Controller
    c. Model
    d. Output

12. Name two uses of simulation in education.

    a. ______________________________

    ____

    ____

    b. ______________________________

    ____

    ____

13. Which of the following is not one of the three classes of simulation?

    a. computer-computer
    b. man-model
    c. All-computer
    d. man-computer

14. Which of the below is not a type of simulation?

    a. deterministic
    b. stochastic
    c. organic

15. Which of the following is not a purpose of simulation?

    a. Copy reality exactly.
    b. Predict future behavior of the system.
    c. Describe the object system.
    d. Teach about the object system.

16. When a human being interacts with a computer to provide inputs to the model controlled by the computer, it is a ______________ simulation.

    a. man-model
    b. all-computer
    c. man-computer
    d. computer-computer

17. When a simulation has exact rules for relating each possible input to a specific output, the simulation is ________ as opposed to ________.

    a. stochastic, deterministic
    b. deterministic, stochastic
    c. organic, deterministic
    d. logarithmic, stochastic

18. Assume that you are constructing DATA statements for the BUSRUT simulation program. The stop that you are working on now is number 12. It is in the 16th row and 2nd column and there are 7 children to pick up. Write the proper DATA statement on the line below.

    ____

19. Below is the output from the BUSRUT simulation. Read through the listing and answer the questions below.

```
ENTER THE SCHOOL COORDINATES, SEPARATED BY A COMMA.
THE VERTICAL COORDINATE SHOULD BE FIRST
?15,17
WANT TO CHANGE BUS CAPACITIES? YES=1, NO=0
?1
YOU WILL BE ABLE TO ENTER THE CAPACITY OF EACH VEHICLE
TYPE.  WHEN ENTERING, REMEMBER THAT THE COMPUTER WILL
RUN ROUTES IN THE ORDER ENTERED.  ENTER ONE AT A TIME
WHEN A QUESTION MARK APPEARS, UP TO 5 ENTRIES.  ENTER
0 IF NO MORE ARE DESIRED.
CAPACITY  1
?36
CAPACITY  2
?0
WANT TO CHANGE NUMBERS OF BUSES? YES=1, NO=0
?1
ENTER THE NUMBER OF 36   PASSENGER BUSES
?5
ENTER THE AVERAGE RATE OF TRAVEL IN MPH
?5
ENTER THE NUMBER OF GRID LINES PER MILE.
   FOR EXAMPLE, IF A QUARTER-MILE GRID IS USED, ENTER 4
?12
ENTER COST PER MILE TO OPERATE BUSES
?.40

ROUTE 1
STOP          STUDENTS        MINUTES
 23              7              8.5
 20              4             17.1
 21             10             18.1
 22              8             19.6
 S                             34.8
THE COST BASED ON $ .4          PER MILE IS $ 1.16
BUS CAPACITY 36   TOTAL STUDENTS 31
```

I. In what column and row is the school located?

__________ column and __________ row

II. How many students will a type 1 bus carry? __________

III. How many type 1 buses are available? __________

IV. What is the average rate of travel? __________

V. How many grid lines are there to a mile? __________

VI. What is the cost per mile to operate the buses? __________

VII. How many minutes does the first bus take to run its route? __________

VIII. What is the total cost of this bus run? __________

20. The DATA for the school year 1969-70 is listed below.

Age 0 - 608	Gr 1 - 572	Gr 7 - 618
Age 1 - 658	Gr 2 - 579	Gr 8 - 576
Age 2 - 708	Gr 3 - 571	Gr 9 - 588
Age 3 - 736	Gr 4 - 615	Gr 10 - 632
Age 4 - 739	Gr 5 - 584	Gr 11 - 571
Kind - 763	Gr 6 - 582	Gr 12 - 581

Write the DATA statements for this data to be used in the ENRPRO simulation on the lines below.

____

____

____

21. Below is a portion of the projected enrollment report from the program ENRPRO. Study this figure and then answer the items below.

SCHOOL DISTRICT 1
PAST CENSUS AND ENROLLMENT DATA

AGE OR GRADE	1967 TO 1968	1968 TO 1969	1969 TO 1970	1970 TO 1971	1971 TO 1972
GR 1	595	605	572	595	564
GR 2	550	588	579	569	550
GR 3	604	606	571	590	552

AGE OR GRADE	1972 TO 1973	1973 TO 1974	1974 TO 1975	1975 TO 1976	1976 TO 1977
GR 1	554	526	526	492	436
GR 2	540	530	504	506	471
GR 3	539	529	[illegible]	494	[illegible]

I. The enrollment in Grade 2 in the '69-'70 school year is__________.

II. The projected enrollment in Grade 2 five years later is__________.

III. The data indicate that there is a(n)______________trend in the data for the projected years.

a. increasing
b. decreasing

22. Below is a portion of the year-to-year percent change report. Study it and then answer the following items.

SCHOOL DISTRICT 1

PAST CENSUS AND ENROLLMENT DATA PLUS YR TO YR % CHANGES
(ALL DECIMAL FIGURES ARE PERCENTS)

	1967 TO 1968		1968 TO 1969		1969 TO 1970		1970 TO 1971		1971 TO 1972		PROJECTED 1972 TO 1973
4	598		589		615		574		585		551
		-1.51		4.41		-6.67		1.92		-5.81	
		-2.17		-.35		-.98		.7		-.4	
5	607		[illegible]		554		609		574		552

I. What was the enrollment in grade 4 in the 1968-'69 school year?__________

II. What was the enrollment in grade 5 for the same year?__________

III. What was the percent change from 1968-'69 to 1969-'70 for grade 4?__________

IV. What is the percent change in those group of students who were in grade 5 in 1967-'68, in the period from 1967-'68 to 1968-'69?__________

23. Below is a portion of the comparison report. Study it and then answer the items below.

SCHOOL DISTRICT 1

ACTUAL VS PROJECTED ENROLLMENTS FOR 1972
BASED ON DATA FROM 1967 THROUGH 1971

	ACTUAL ENROLL	PROJECTED ENROLL	ACTUAL - PROJECTED	% ERROR (A-P)/A
GR 4	565	551	14	2.48
GR 5	558	582	-24	-4.3
GR 6	572	572	0	0

I. What was the actual enrollment in grade 5? ________________

II. What was the projected enrollment for grade 6? ________________

III. What is the absolute error in prediction for grade 4? ________________

IV. What is the percent error for grade 5? ________________

24. Assume that you are in charge of bussing for your district. For one school you must decide whether to use one 48 passenger bus or two 24 passenger mini-buses. Below is the printout for each of the two cases. Choose one of the following alternatives based on this data.

```
CAPACITY  1
?24
CAPACITY  2
?0
WANT TØ CHANGE NUMBERS ØF BUSES? YES=1, NØ=0
?1
ENTER THE NUMBER ØF 24   PASSENGER BUSES
?2
ENTER THE AVERAGE RATE ØF TRAVEL IN MPH
?20
ENTER THE NUMBER ØF GRID LINES PER MILE.
   FØR EXAMPLE, IF A QUARTER-MILE GRID IS USED, ENTER 4
?2
ENTER CØST PER MILE TØ ØPERATE BUSES
?2.00

RØUTE 1
STØP        STUDENTS        MINUTES
 8             3              21.6
 7            10              29.3
 6             9              32.3
 5                            45.2
THE CØST BASED ØN $ 2    PER MILE IS $ 30.12
BUS CAPACITY 24    TØTAL STUDENTS 22

RØUTE 2
STØP        STUDENTS        MINUTES
 4             4               6.2
 5             4              16.7
 3             2              23.4
 2            10              24.9
 5                            28.2
THE CØST BASED ØN $ 2    PER MILE IS $ 18.83
BUS CAPACITY 24    TØTAL STUDENTS 20

STØPS WHERE STUDENTS WERE NØT PICKED UP
STØP       STUDENTS
 1            5

THE TØTAL CØST FØR ALL RØUTES IS $ 48.95
THE TØTAL TIME FØR ALL RØUTES IS 73.4        MINUTES
 42    STUDENTS PICKED UP 5     NØT PICKED UP
```

```
CAPACITY  1
?48
CAPACITY  2
?0
ENTER THE NUMBER ØF 48   PASSENGER BUSES
?1
ENTER THE AVERAGE RATE ØF TRAVEL IN MPH
?20
ENTER THE NUMBER ØF GRID LINES PER MILE.
   FØR EXAMPLE, IF A QUARTER-MILE GRID IS USED, ENTER
?2
ENTER CØST PER MILE TØ ØPERATE BUSES
?3.00

RØUTE 1
STØP        STUDENTS        MINUTES
 1             5               3
 4             4               9.2
 5             4              19.7
 8             3              30.5
 7            10              38.1
 6             9              41.1
 3             2              49.9
 2            10              51.4
 5                            54.8
THE CØST BASED ØN $ 3    PER MILE IS $ 54.75
BUS CAPACITY 48    TØTAL STUDENTS 47

STØPS WHERE STUDENTS WERE NØT PICKED UP
STØP       STUDENTS
NØNE

THE TØTAL CØST FØR ALL RØUTES IS $ 54.75
THE TØTAL TIME FØR ALL RØUTES IS 54.8        MINUTES
 47    STUDENTS PICKED UP 0     NØT PICKED UP
```

a. Use two smaller buses because they cost less.
b. Use one larger bus because it takes less cumulative time.
c. Use two smaller buses because they take less clock time.
d. Use one larger bus because it picks up all students.

25. Below are the predictions of enrollment for a junior high school for the next five years. Which of the conclusions about this data is correct?

SCHOOL DISTRICT 1
FUTURE ENROLLMENT PROJECTIONS

AGE OR GRADE	1972 TO 1973	1973 TO 1974	1974 TO 1975	1975 TO 1976	1976 TO 1977
GR 7	642	626	618	579	554
GR 8	597	636	620	612	573
GR 9	666	649	691	674	665

a. Over the next five years space needs will remain the same for the seventh grade.
b. The need for teachers will continue to decline in the 8th grade.
c. The space needs for the 9th grade will be fairly consistent over the next 5 years.
d. There should be surplus staff in the 9th grade by 1974.

ID:________________________
(last 4 digits of your SS no.)

Date:________________

For each applicable item circle the letter of the best answer.

Form: II S

1. The situation which creates the need for a decision is the:

   a. decision context
   b. perceived need
   c. decision strategy
   d. constraints

2. List and briefly define the three components of the decision context.

   Component

   1____________ Dfn. ________________________

   ____

   2____________ Dfn. ________________________

   ____

   3____________ Dfn. ________________________

   ____

3. Suppose that you are an assistant superintendent. You have been assigned the task of establishing a busing program which will result in racial balance within your school system. Your district has allocated $100,000 for busing using its fleet of 75 buses. You may adjust the number of students on any bus, the route any bus will follow and the school or schools to which it delivers. The plan is to be ready to use at the beginning of school this fall.

   I. The school or schools to which a bus delivers is:

      a. none of these
      b. a constraint
      c. a perceived need
      d. a controllable variable

   II. To establish a busing program is

      a. a controllable variable
      b. perceived need
      c. none of these
      d. a constraint

III. The 75 buses in the school district fleet represent:

a. a perceived need
b. a controllable variable
c. a constraint
d. none of these

4. The process by which the administrator makes a decision with respect to the decision context is the:

a. perceived need
b. decision context
c. analysis of the decision context
d. decision strategy

5. The following four activities

- analysis of the decision context
- decision on criteria for best solution
- generation of possible solutions
- testing of possible solutions against criteria for best solution

are components of the

a. decision strategy
b. controllable variables
c. decision context
d. decision variables

6. The result or outcome of a specific decision is

a. a decision context
b. a payoff
c. what happens
d. a decision strategy

7. Suppose that you are responsible for choosing a new reading series for the elementary schools in your district. The decision must be made by the spring of this year and you have been allocated $25,000. What is the most important payoff for this decision?

a. reading achievement
b. total time to prepare
c. number of texts
d. manhours used

8. Operations Research is

   a. a method for the scientific study of management or administrative functions
   b. a method of research designed to study business operations
   c. a set of powerful decision contexts for large and complex administrative problems
   d. a set of powerful decision strategies for large and complex administrative problems

9. List four important operations research techniques and match them with administrative applications for which they are most useful (any operations research technique may be applicable to more than one problem).

   a. ________ ______planning and analyzing project stages
   b. ________ ______analyzing waiting line problems
   c. ________ ______analyzing a working model of the decision context
   d. ________ ______problems in which the constraints and payoff can can be stated mathematically
   ______problems involving service facilities

10. ______________________ is giving the effect or appearance of reality.

a. stochastic
b. simulation
c. deterministic
d. role playing

11. Which of the following is not a component of a simulation?

a. processes
b. object system
c. outputs
d. model

12. Name two uses of simulation in education.

a. ____

____

____

b. ____

____

____

13. Which of the following is not one of the three classes of simulations?

a. man-computer
b. man-model
c. computer-based
d. model-computer

14. Which of the below is not a class of simulations?

a. stochastic
b. logarithmic
c. deterministic

15. Which of the following is not a purpose of simulation?

   a. Teach about the object system
   b. Replace the object system
   c. Predict future behavior of the object system
   d. Explain past behavior of the object system

16. When the computer represents all aspects of a simulation, i.e., both providing input and operating the model, it is a ____________ simulation.

   a. man-computer
   b. man-model
   c. computer-based
   d. computer-computer

17. When some random element is part of a simulation so that random processes relate input to output, the simulation is:

   a. stochastic
   b. deterministic
   c. logarithmic

18. Assume that you are constructing DATA statements for the BUSRUT simulation program. The stop that you are working on now is number 27. It is in the 19th row and 33rd column and there are 3 children to pick up. Write the proper DATA statement on the line below.

____

19. Below is the output from the BUSRUT simulation. Read through the listing and answer the questions below.

```
ENTER THE SCHOOL COORDINATES, SEPARATED BY A COMMA.
THE VERTICAL COORDINATE SHOULD BE FIRST
?6,11
YOU WILL BE ABLE TO ENTER THE CAPACITY OF EACH VEHICLE
TYPE.  WHEN ENTERING, REMEMBER THAT THE COMPUTER WILL
RUN ROUTES IN THE ORDER ENTERED.  ENTER ONE AT A TIME
WHEN A QUESTION MARK APPEARS, UP TO 5 ENTRIES.  ENTER
0 IF NO MORE ARE DESIRED.
CAPACITY  1
?20
CAPACITY  2
?0
ENTER THE NUMBER OF 20   PASSENGER BUSES
?8
ENTER THE AVERAGE RATE OF TRAVEL IN MPH
?40
ENTER THE NUMBER OF GRID LINES PER MILE.
   FOR EXAMPLE, IF A QUARTER-MILE GRID IS USED, ENTER 4
?1
ENTER COST PER MILE TO OPERATE BUSES
?.25

ROUTE 1
STOP          STUDENTS       MINUTES
 11              9             47.1
 18             10             57.6
 5                             96.9
THE COST BASED ON $ .25         PER MILE IS $ 16.14
BUS CAPACITY 20   TOTAL STUDENTS 19
```

I. In what column and row is the school located?
column ____________ and row ____________.

II. How many students will a type 1 bus carry? ____________

III. How many type 1 buses are available? ____________

IV. What is the average rate of travel? ____________

V. How many grid lines are there to a mile? ____________

VI. What is the cost per mile to operate the buses? ____________

VII. How many minutes does it take the first bus to run its route? ____________

VIII. What is the total cost of this bus run? ____________

20. The data for the school year 1967-'68 is listed below.

Age 0 - 686	Gr 1 - 595	Gr 7 - 555
Age 1 - 725	Gr 2 - 650	Gr 8 -- 569
Age 2 - 771	Gr 3 - 604	Gr 9 - 589
Age 3 - 774	Gr 4 - 598	Gr 10 - 602
Age 4 - 816	Gr 5 - 607	Gr 11 - 540
Kind - 819	Gr 6 - 576	Gr 12 - 470

Write the DATA statements for this data to be used in the simulation ENRPRO on the lines below.

____________________ ____________________

____________________ ____________________

____

21. Below is a portion of the projected enrollment report from the program ENRPRO. Study this figure, and answer the following items.

SCHOOL DISTRICT 1
PAST CENSUS AND ENROLLMENT DATA

AGE OR GRADE	1967 TO 1968	1968 TO 1969	1969 TO 1970	1970 TO 1971	1971 TO 1972
GR 7	555	582	618	607	603
GR 8	569	550	76	597	613
GR 9	589	602	588	642	647

SCHOOL DISTRICT 1
FUTURE ENROLLMENT PROJECTIONS

AGE OR GRADE	1972 TO 1973	1973 TO 1974	1974 TO 1975	1975 TO 1976	1976 TO 1977
GR 7	609	586	572	557	545
GR 8	597	603	583	586	551
GR 9	666	649	655	632	637

I. The enrollment in Grade 9 in 1970-'71 school year is__________.

II. The projected enrollment in Grade 9 five years later is__________.

III. The data indicate that there is a(n)__________ trend in the data for the projected years.

a. decreasing
b. increasing

22. Below is a portion of the year-to-year comparison report. Study it and answer the following items.

SCHOOL DISTRICT 1

PAST CENSUS AND ENROLLMENT DATA PLUS YR TO YR % CHANGES
(ALL DECIMAL FIGURES ARE PERCENTS)

	1967 TO 1968		1968 TO 1969		1969 TO 1970		1970 TO 1971		1971 TO 1972	PROJECTIONS 1972 TO 1973
A0	686		649		608		586		562	
		-5.39		-6.32		-3.62		-4.1		
		.29		1.39		3.43		5.46		8.12
A1	725		688		658		641		618	585

I. What was the number of children at age 0 in 1971-'72?__________

II. What was the number of children at age 1 in the same year?__________

III. What was the percent change from 1970-'71 to 1971-'72 for age 0?__________

IV. What was the percent change in those groups of children who were at age 0 in 1969-'70, in the period from 1969-'70 to 1970-'71?__________

23. Below is a portion of the projected versus actual enrollment report. Study it and then answer the items below.

SCHOOL DISTRICT 1

ACTUAL VS PROJECTED ENROLLMENTS FOR 1972
BASED ON DATA FROM 1967 THROUGH 1971

	ACTUAL ENROLL	PROJECTED ENROLL	ACTUAL - PROJECTED	% ERROR (A-P)/A
KIND	699	683	16	2.29
GR 1	544	554	-10	-1.84
GR 2	530	540	-10	-1.89
GR 3	532	539	-7	-1.32

I. What was the actual enrollment in grade 3? ______________

II. What was the projected enrollment for grade 1? ______________

III. What is the absolute error in prediction for grade 1? ______________

IV. What is the percent error for grade 2? ______________

24. Assume that you are in charge of bussing for your district. You must decide which load factor (number of students per seat) to use for bussing to certain schools. Using BUSRUT try out several different load factors. The results are given in the table below.

Load Factor	No. of Routes	Total Cost	Total Time
1 1/2	9	$ [illegible]5.26	63.5 minutes
2	8	83.50	77.2 minutes
2 1/2	8	74.30	79.0 minutes
3	8	70.19	83.0 minutes

Choose the best load factor, consider the data available.

a. 1 1/2
b. 2
c. 2 1/2
d. 3

25. Below is the actual versus predicted enrollment report for a high school. How would you evaluate the accuracy of your predictions?

SCHOOL DISTRICT I

ACTUAL VS PROJECTED ENROLLMENTS FOR 1972
BASED ON DATA FROM 1967 THROUGH 1971

	ACTUAL ENROLL	PROJECTED ENROLL	ACTUAL - PROJECTED	% ERROR (A-P)/A
GR 10	627	655	-28	-4.47
GR 11	570	635	-65	-11.4
GR 12	563	570	-7	-1.24

a. The predictions for grades 10 and 12 are fairly accurate but it is off for grade 11.
b. The predictions of enrollment for all the grades are quite accurate.
c. The errors in prediction for all three grades exceed one classroom in magnitude.
d. Only the prediction for grade 12 is accurate.

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For each applicable item circle the letter of the best answer.

Form: I Q

1. A decision context is:

   a. a choice between two different options
   b. the administrator's environment
   c. a problem for which a decision is needed
   d. the school district of the administrator

2. List and briefly define the three components of the decision context.

   Component

   1 ______________ Dfn: ____

   ____

   2 ______________ Dfn: ____

   ____

   3 ______________ Dfn: ____

   ____

3. Suppose that you are a school superintendent. Your school board has just adopted the policy that all children should have at least 18 weeks of career education by the time they reach the seventh grade. Only grades 4,5,6 are to be involved and the sum of $50,000 has been allocated. You have the freedom to assign any number of teachers for any number of hours and to hire as many consultants as necessary provided you do not exceed the authorized amount.

   I. The sum of $50,000 is:

   a. a perceived need
   b. a constraint
   c. none of these
   d. a controllable variai

   II. The number of teachers assigned is:

   a. a controllable variable
   b. a perceived need
   c. a constraint
   d. none of these

III. To develop a plan for career education in the upper elementary grades is:

a. none of these
b. a controllable variable
c. constraint
d. a perceived need

4. A <u>decision strategy</u> is:

a. the process by which a decision is made
b. a problem for which a decision is needed
c. the choice between a number of options
d. the process of implementing a decision

5. The four components of a decision strategy are:

a. perceived need, constraints, controllable variables, generation of possible solutions
b. analysis of the decision context, decision on criteria for the best solution, perceiving the appropriate need, testing possible solutions against criteria for best solution
c. analysis of the decision context, decision on criteria for the best solution, generation of possible solutions, testing possible solutions against criteria for best solution
d. finding controllable variables, decision on criteria for the best solution, generation of possible solutions, testing possible solutions against criteria for best solution

6. A <u>payoff</u> is:

a. the situation which requires a decision
b. the process of making a decision
c. a decision with respect to a specific context
d. the result of a specific decision

7. Suppose that you have the responsibility for constructing the school district's budget for the next fiscal year. You have available to you a full-time secretary, all previous years' budgets and budget estimates from each of your district's schools. The most important payoff of decision making in this case is:

a. budget length
b. time
c. money
d. line item costs

8. ______________ is a set of powerful decision strategies for large and complex administrative problems.

   a. operations research
   b. linear programming
   c. mathematical modeling
   d. queueing theory

9. List four important operations research techniques and match them with administrative applications for which they are most useful (Any operations research technique may be applicable to more than one problem).

   a. ______________ ______planning and analyzing project stages
   b. ______________ ______analyzing waiting line problems
   c. ______________ ______analyzing a working model of the decision context
   d. ______________ ______problems in which the constraints and payoff can be stated mathematically
   ______problems involving service facilities

10. Which of the following are <u>not</u> basic conditions which must be satisfied in order for queueing theory to give useful results?

a.. The system must be in equilibrium
b. There must be at least one customer in the queue
c. Service times are independent
d. Customers do not leave the queue until they are serviced
e. The arrival and departure rates are independent of each other
f. First come, first served
g. Arrival rate must be less than the service rate
h. Arrivals of customers are random and independent

11. A <u>source field</u> is

a. The area where customers of a facility come from
b. The population of customers
c. The population of possible service facilities for customers
d. The population of potential customers

12. The users of a service facility are:

a. Employers
b. Waiters
c. Arrivals
d. Customers

13. A <u>service facility</u> is:

a. A location at which a service is rendered
b. A building where customers are serviced
c. The place where the queue is located
d. The potential pool of customers for the queue

14. The average number of customers arriving at the service facility during a unit of time is the:

a. Service rate
b. Departure rate
c. Arrival rate
d. Customer rate

15. The average number of customers that can be serviced by one service facility during a unit of time assuming no idle time is the:

a. Arrival rate
b. Service rate
c. Queue rate
d. Departure rate

16. The amount of time that a service facility is not servicing a customer is the:

a. Idle time
b. Queueing time
c. Waiting time
d. Service time

17. The waiting time is the time:

a. between the beginning and ending of service for a customer
b. that a customer spends in the source field before he joins the queue
c. the total time that a customer spends in the queue and service facility
d. between when the customer joins the queue and when he gets serviced

18. Which of the statistics listed below are not statistics derived from queueing theory?

a. expected waiting time of an arrival
b. expected number of customers waiting for service or being serviced
c. probability that a customer will be serviced within time T
d. expected number of customers waiting for service
e. probability that the facility is idle
f. mean number of customers being serviced
g. probability that N users are being serviced or are waiting for service
h. probability that more than L users are being serviced or are waiting

19. As the number of service facilities increases, the length of the queue ________, the waiting time ________ and the probability of a service facility being idle ________.

  a. decreases, increases, decreases
  b. decreases, decreases, increases
  c. increases, decreases, decreases
  d. increases, increases, increases

20. As the arrival rate decreases, the length of the queue ________, the waiting time ________, and the probability of the service facility being idle ________.

  a. decreases, decreases, increases
  b. increases, decreases, decreases
  c. increases, increases, increases
  d. decreases, increases, decreases

21. As the service rate decreases, the length of the queue ________, the waiting time ________, and the probability of the service facility being idle ________.

  a. decreases, decreases, increases
  b. increases, increases, increases
  c. increases, increases, decreases
  d. increases, decreases, decreases

22. Your local high school has a printshop for vocational education. They do large printing jobs for the school district. The instructor has made a request for a second printing press. He claims that the class cannot keep up with the number of requests they receive. The shop receives an average of three orders each week. It takes an average of one and one-half days to complete a job.

Answer the follow questions about this queueing theory problem.

  I. The source field is ________________.

  II. The customers are ________________.

  III. The service facility is ________________.

  IV. The arrival rate is ________________.

  V. The service rate is ________________.

23. Below is the output of program QUEUE for a queueing theory problem. Use this to answer the questions below.

```
ENTER SØURCE FIELD
     O=INFINITE PØPULATIØN
     M = FINITE PØPULATIØN ØF SIZE M
     -1 TØ QUIT
?0
F - NUMBER ØF SERVICE FACILITIES
?2
A - AVERAGE NUMBER ØF ARRIVALS PER UNIT TIME
?12
S - AVERAGE NUMBER ØF CUSTØMERS SERVED PER UNIT TIME
?8

PRØBABILITY THAT THE FACILITY IS IDLE - P(O) =  .142557
EXPECTED NUMBER EITHER BEING SERVICED ØR WAITING - E(N) = 3.42857
EXPECTED NUMBER WAITING - E(W) =  1.92857
EXPECTED WAITING TIME ØF AN ARRIVAL - E(T) =  .160714
IF YØU WISH P(N), THE PRØBABILITY THAT N USERS ARE BEING
     SERVICED ØR WAITING, ENTER THE NUMBER FØR N.  IF NØT,
     ENTER -1
?5
P( 5     )=       6.78013E-02
ENTER ANØTHER N ØR -1 TØ QUIT
?-1
IF YØU WISH P(N>L), THE PRØBABILITY THAT THE NUMBER ØF
     USERS BEING SERVICED ØR WAITING EXCEEDS SØME NUMBER L,
     ENTER THE NUMBER FØR L.  IF NØT, ENTER -1
?3
P(N> 3     ) =   .290179
ENTER ANØTHER L ØR -1 TØ QUIT
?-1
```

I. The probability that the number waiting and being serviced is greater than 3 is____________.

II. Average number of arrivals is____________.

III. The number of service facilities is____________.

IV. The probability that the facility is idle is____________.

V. The probability that five customers are waiting or being serviced is____________.

VI. Average number of customers being serviced is____________.

VII. The expected number waiting is____________.

VIII. How long should an arrival expect to wait?____________.

IX. What is the expected number in the queue or being serviced?________

X. The average service rate is ____________.

24. In item 23 you were given a printout which reflects the following queueing theory problem. An office presently has two typists. They are contemplating adding a third typist. Using the printout from item 23 plus the one given below, you must decide whether or not to hire an extra secretary. The time unit is days.

A poll of users has shown that they will not tolerate a wait of more than 1 day.

```
ENTER SØURCE FIELD
     0=INFINITE PØPULATIØN
     M = FINITE PØPULATIØN ØF SIZE M
     -1 TØ QUIT
?0
F - NUMBER ØF SERVICE FACILITIES
?3
A - AVERAGE NUMBER ØF ARRIVALS PER UNIT TIME
?12
S - AVERAGE NUMBER ØF CUSTØMERS SERVED PER UNIT TIME
?8

PRØBABILITY THAT THE FACILITY IS IDLE - P(0) =  .210526
EXPECTED NUMBER EITHER BEING SERVICED ØR WAITING - E(N) = 1.73684
EXPECTED NUMBER WAITING - E(W) =  .236842
EXPECTED WAITING TIME ØF AN ARRIVAL - E(T) = 1.97368E-02
```

a. Hire one, because the average number waiting or being serviced will be reduced to less than the number of secretaries.
b. Do not hire one because the expected waiting time is only reduced from 1/3 to 1/100 of a day.
c. Hire one because the average number waiting will be reduced more than 80%.
d. Do not hire one, because each typist will then be idle more than 1/5 of the time.

25. Which of the following is/are <u>not</u> advantage(s) of queueing theory?

a. Provides a method for simulating changes in the queueing system and observing the results.
b. Provides criteria for determining the "best" solution to a problem.
c. Provides a means for analyzing most problems which involve waiting in lines.
d. Provides data which may suggest possible changes in the queueing system.
e. Provides a framework for studying the queueing system.

26. Which of the following is/are <u>not</u> disadvantages of queueing theory?

a. The results from queueing theory are averages, not exact results.
b. Problems must satisfy certain conditions in order to be analyzed using queueing theory.
c. Queueing theory is very limited when dealing with small populations.
d. Queueing theory yields data and does not make decisions.
e. The results of a queueing theory analysis are too abstract and difficult to understand.

[illegible] Used: ______________________

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last 4 digits of SS#.

Date: ______________

Questionnaire No. 2a

Below are a series of questions concerning scientific management techniques. Some of these statements you may agree with and with others you may not agree. Please indicate your degree of agreement by circling SA (Strongly Agree), A (Agree), N (Neutral), D (Disagree), or SD (Strongly Disagree) for each item. If you are not presently an administrator, please assume an administrator's point of view when responding to the items.

1.	Mathematics is a useful administrative tool.	SA	A	N	D	SD
2.	There are a number of scientific management methods for solving administrative problems in education.	SA	A	N	D	SD
3.	I find mathematics useful in my work as an educational administrator.	SA	A	N	D	SD
4.	I know of at least four scientific management techniques for solving administrative problems in education.	SA	A	N	D	SD
5.	Few of the problems I encounter in my work can be solved by scientific management methods.	SA	A	N	D	SD
6.	I will use scientific management techniques for solving many of the problems in my work.	SA	A	N	D	SD
7.	I know of at least one scientific management technique for solving administrative problems in education.	SA	A	N	D	SD
8.	I plan to seldom use scientific management methods in solving the problems I encounter in my work.	SA	A	N	D	SD
9.	I feel comfortable using scientific management techniques in my work.	SA	A	N	D	SD
10.	I want to use scientific management techniques in my work.	SA	A	N	D	SD

Below are some questions concerning the materials you studied. Please respond as you did to the previous information.

11.	The problem solving technique that I studied will be very useful in solving educational administrative problems.	SA	A	N	D	SD
12.	The materials I studied were easy to understand.	SA	A	N	D	SD
13.	Using the computer made these materials more interesting.	SA	A	N	D	SD
14.	I learned enough from these materials to use them in my work as an administrator.	SA	A	N	D	SD
15.	I will not use the technique I studied in my work as an administrator.	SA	A	N	D	SD
16.	I am generally satisfied with the materials I studied.	SA	A	N	D	SD
17.	More direction from the instructor was needed.	SA	A	N	D	SD
18.	The computer is an essential part of these materials.	SA	A	N	D	SD

Materials Used: ______________________

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1. What is your positi ______________

2. What degree do you hold? ______________

3. How many years of administrative experience have you had? ______________

4. How many hours did you spend on the materials? ______________

5. Did you work by yourself or with a group? Do you prefer that way?

6. Did you have enough time to finish the unit? If you did not, why not?

7. Did you have any difficulties using the computer?

8. What was the best thing about these materials?

9. What was the worst thing about these materials?

10. What could be improved in the booklet you just read?

11. Do you have any specific criticisms of the materials?

12. Please state the difficulty of the materials from your point of view.

13. Would you recommend to others the materials you studied? Why or Why not?

14. Please summarize your overall feeling about the materials.