AN EXPERIMENTAL STUDY OF THE EFFECTS OF QUANTITATIVE MANAGEMENT INFORMATION ON THE GENERATION AND SELECTION OF ALTERNATIVE ACTIONS IN INDIVIDUAL DECISION MAKING UNDER UNCERTAINTY

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ABSTRACT

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By

Charles Alexander Davis

Administrators of colleges and universities are experiencing increased pressure from legislators, trustees, taxpayers, and faculty to improve the management of the resources of higher education institutions. University administrators have responded by attempting to adapt computer-based tools and techniques of management technology, based on industrial models, to the operation of their institutions. All of these computer-based tools and techniques and their associated data bases were characterized as Management Information Systems (MIS) in this study.

Early experience with MIS in higher education institutions revealed considerable difficulty integrating new management technology into the established management structure. Available literature has made valuable contributions to explaining the problem of implementation, but reveals little evidence of basic research aimed at understanding the effect of new management systems and technology on the individual manager.

The present research was intended to explore the effects of quantitative management information on the individual manager in the performance of one of his most crucial functions--decision making. Because of the lack of research results directly related to individual decision making in the current literature, this study was considered exploratory.

The problem addressed by this research was the effect of quantitative management information about the state of an uncertain environment on the generation and selection of alternative actions in the individual decision-making process in that environment. An uncertain environment is one in which all possible actions, the outcomes of possible actions, and the possibilities of such outcomes are not known to the decision maker.

The background for the present research was established by reviewing literature related to MIS applications in higher education. A brief review of the history of decision making was presented and a model, based on decision-making theory, was developed to establish the theoretical framework for the study.

Five basic research questions were formulated relative to the effects of quantitative management information on the individual decision maker in an uncertain environment. An experiment was designed to provide the data from which answers to the research questions could be derived.

Subjects used in the experiment were chosen from seniors and graduate students in the College of Business at Western Michigan University. Subjects were randomly assigned to treatment groups to minimize the effect of confounding uncontrolled variables with the information treatment. Orthogonal planned comparisons of the mean number of alternatives generated and selected and nonparametric analysis of the distribution of alternatives generated and selected were used to extract information from the raw data.

The methodology used in the study was experimentation. Internal validity was controlled by choice of sample size, confidence levels, and random assignment of subjects to treatment groups. Generalization of the results of a single experiment, a single decision problem, and a given population to all decision situations is not the claim of the researcher. It is hoped that a contribution has been made to understanding individual decision making in an uncertain environment.

Findings of the study were:

1. Quantitative management information had no effect on the number of alternatives generated by individual decision makers in an uncertain environment.

2. There was no evidence that quantitative management information had any effect on the number of alternative actions selected by individual decision makers in an uncertain environment.

3. The number of alternatives generated showed high positive correlation with the number of alternatives selected by the same individual except when the information treatment was quantitative management information.

4. The distribution of alternatives selected by individual decision makers in an uncertain environment was affected by the combination of quantitative and nonquantitative management information when compared to the use of quantitative management information alone in an uncertain environment.

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CHAPTER I

INTRODUCTION

Introductory Statement

> Higher education institutions will be difficult to manage even with the availability of the best planning and management systems information. Without such information, good management at a complex institution may be virtually impossible.[1]

The foregoing statement by Huff and Manning reflects the opinion of a new breed of management scientists whose mission is the application of the tools and techniques of management technology to higher education. The central element in most proposed applications is the electronic data processing capability of the computer. No standardized terminology has yet emerged, but the more highly recognized approaches to scientific management techniques are identified by the terms Management by Objectives, Program Planning and Budgeting Systems, Management Information Systems, Computer-Based Planning Models, and Educational Simulation Systems.

Despite the overlapping descriptions used to identify current approaches, all management tools and techniques are linked by one common denominator: a supportive, quantitative data base. This data base is most often associated with MIS, which Nelson defined as

[1] R. A. Huff and C. W. Manning, Higher Education Planning and Management Systems (Boulder, Colorado: National Center for Higher Education Management Systems, 1972), p. 17.

> . . . that configuration of men, machines and methods which supports management in the collection, storage, processing, and transmission of information for operation, control, evaluation and planning of a university.[2]

Robinson defined MIS in terms of its objectives: "The major objective of a management information system, therefore, is to provide useful, relevant information to management in the form and at the time when it will be most useful."[3] The term MIS is used in this study to characterize all of the tools and techniques of management technology and their associated data bases.

While management scientists are adapting their technology to the management problems of higher education, there is increased pressure from public agencies to make higher education institutions more manageable. Farmer described the financial pressure:

> For many years higher education has presented the bill for higher education to the public for support, and it usually was paid. Now, however, bond authorizations are frequently defeated at the polls, and state governments are drastically reducing per student funds. Although higher education used only 2.2 percent of the gross national product in 1965-67, the expenditures totaled $15.2 billion. By 1980 higher education will be consuming 2.5% of the GNP, some $32.5 billion. The public now has a large number of social programs--hunger, housing, medical care, transportation and pollution--competing for public funds. Educators are being asked to specifically describe their objectives, measure their performance, and determine costs.[4]

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[2]C. A. Nelson, "Management Planning in Higher Education--Concepts, Terminology and Techniques," Management Controls, January 1971, p. 5.

[3]D. D. Robinson, "Some Observations on the New Management for College and University," Management Controls, October 1970, p. 220.

[4]J. Farmer, Why Planning, Programming, Budgeting Systems for Higher Education? (Boulder, Colorado: Western Interstate Commission for Higher Education, 1970).

Robinson wrote of college administrators' growing awareness of the need for sound management:

> There is, above all else, a growing realization that good management is important in an institution of higher learning. This may sound self-evident, but the fact is that up until recently most academic administrators believed (or certainly behaved as if they believed) that colleges were not subject to the same kinds of management rules as are other organizations; that through some sort of marvelous beneficence, they were exempt from all or most of the consequences of bad management. This revelation, this insight, this slow coming of age has finally made possible the rational consideration of the need to fashion tools that will assist in meeting the management problems of colleges and universities.[5]

Rourke and Brooks pointed out the political utility of a computer-based MIS:

> Finally, beyond considerations of efficiency and internal control, the computer plays an important role as a showpiece to impress the outside world with the modernity of university administration. As the struggle for legislative appropriations grows intense, most universities must draw upon any and all available strategies to insure economic survival. One such strategy is to give the public and the state legislature every possible reason to believe that the university is being operated with maximum efficiency.[6]

The concentration of pressures from public agencies, faculty, students, and even some university administrators on the administrative structure of colleges and universities to "do something" to improve the management of their resources has generated the awareness of an acute need to change the traditional methods by which universities have been operated in the past. This acute need, coincident with the desire of management scientists to apply management technology to higher

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[5]Ibid., p. 217.

[6]F. E. Rourke and C. E. Brooks, "Computers and University Administration," Administrative Science Quarterly, December 1966, p. 600.

education administration, has led to the rapid and sometimes unfortunate introduction of MIS on college campuses.

Early experience with MIS applications in complex organizations such as institutions of higher learning has led some observers to point out problems of such systems. Ackoff criticized the assumptions on which MIS designs are usually based:

> Contrary to the impression produced by the growing literature, few computerized management information systems have been put into operation. Of those I've seen that have been implemented, most have not matched expectations and some have been outright failures. I believe that these near-and-far misses could have been avoided if certain false (and usually implicit) assumptions on which many systems have been erected had not been made.[7]

Thompson raised some thorny questions about the impact of such systems in the university resource allocation process:

> After the initial resource allocation pattern has been fixed by legislative action, it is at this point that nonelected officials take over the responsibility for successive reallocations down to the smallest organizational components affected. But will PPBS data necessarily affect the long established practices of organizational bureaucracy as they apply to this type of budgeting? Will the process ever be free from successful attempts to once again introduce internal and external political considerations capable of affecting the eventual outcome? And will the eventual reaction of the agencies budgeted to the final pattern of resource allocation be any different than the present if they perceive the decision-making process as being basically unchanged, but merely dressed up with some new computerized budgeting gimmick?[8]

Argyris discussed some of the emotional problems that arose when a MIS was introduced into the management of a complex organization

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[7]R. A. Ackoff, "Management Misinformation Systems," Management Science 14 (December 1967): 147.

[8]D. L. Thompson, "PPBS: The Need for Experience," Journal of Higher Education 42 (January 1972): 686.

by a team of MIS technologists.[9] Observation of the technologists' attempts to increase the rationality of management behavior revealed an intensification of the emotional responses of the management personnel. Argyris reported that the technologists deviated from the rational philosophy of their professional training under the stress of the corporate environment. The technologists tended toward the same emotional behavior exhibited by the managers of the complex organization.

Ackoff, Thompson, and Argyris all addressed a broad general problem: the effect of quantitative data-based MIS on the established practices of managing complex organizations.

Higher education institutions, among the most complex of modern organizations, are not exempt from the requirement to effectively integrate new management technology into their established patterns of administration.

There has been considerable deliberation of the problem of implementing new management systems. Churchman and Schainblatt summarized the various opinions about how the efforts of researchers in management science should be implemented into traditional management structures.[10] They identified four alternative positions with respect to the relationship between the management scientist and the manager:

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[9]C. Argyris, "Management Information Systems: The Challenge to Rationality and Emotionality," Management Science 17 (February 1971): 275-291.

[10]C. W. Churchman and A. W. Schainblatt, "The Researcher and the Manager: A Dialectic of Implementation," Management Science 11 (February 1965): 69-87.

1. Separate function position--management and management research are viewed as separate functions. Implementation consists of specifying the physical changes that must take place in an organization in order for it to accommodate the optimal mathematical solution.

2. Communication position--emphasizes the need for creating better lines of communication between manager and the management scientist. The communication is direct and independent of the personality of the manager. The manager's understanding of the scientist is viewed as critical.

3. Persuasion position--emphasis is placed on the scientist's understanding enough about the manager to persuade the manager to accept recommended changes.

4. Mutual understanding position--embraces the position that management and management science cannot be separated. If science is to become a method of managing, then management must become the method of science.

Argyris used the strategy of placing a member of line management on the MIS team to act as a liaison in the implementation process, but reported less than desirable results.[11] He implied that implementation strategies based on rational solutions such as education and structural change alone would not work, and suggested emphasis on the utilization of behavioral science technology to increase interpersonal competence. Mitchell, Farmer, Nowbray, and Levine analyzed the implementation of various management science tools in higher

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[11]Ibid.

education institutions.[12] Halter and Dean discussed the relationship between the analyst and the decision maker in complex agricultural situations.[13]

Although it has made valuable contributions to explaining the implementation problem, the available literature reveals little evidence of basic research aimed at understanding the effects of new management systems and technology on the individual manager, or how individual managers use such systems and technology.

Functions of the Administrator in Higher Education

Although various writers have described the functions of managers and administrators differently, few disagree with Corson's statement that:

> The administration of any enterprise involves the making and subsequently the execution of a succession of decisions. In a manufacturing concern, these decisions involve the hiring of workers, the purchasing of raw materials, the determination of methods of production and volume of output, the setting of prices, and a myriad of related decisions of greater and lesser significance to the accomplishments of the enterprise. In a government bureau, the decisions involve the proposal of legislation, the hiring and promotion of civil servants, the contracting with industry, the adjudication of cases, the formulation of budgets and work programs and the determination of what shall be said to the public in speeches and reports.
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> In a university similar decisions are made and executed. Faculty members, administrators, coaches, secretaries, and

[12] E. E. Mitchell, "PPBS: Panacea or Pestilence," AEDS Monitor, February 1970, pp. 4-13; J. Farmer, An Approach to Planning and Management Systems Implementation (Los Angeles, California: California State Colleges Publications, 1971); G. Mowbray and J. B. Levine, "The Development and Implementation of CAMPUS: A Computer Based Planning and Budgeting System for Universities and Colleges," Educational Technology, March 1971.

[13] A. Halter and G. Dean, Decisions Under Uncertainty (Chicago: Southwestern Publishing Co., 1971), p. 139.

> various other persons are hired and promoted--or not promoted. A curriculum is formulated and reformulated; courses are added and dropped.[14]

A distinguishing characteristic of complex enterprises or organizations is the process by which decisions are made and implemented. A manager or administrator seldom makes decisions without the involvement of both subordinates and superiors. Simon argued that:

> It should be perfectly apparent that almost no decision made in an organization is the task of a single individual. Even though the final responsibility for taking a particular action rests with some definite person, we shall always find, in studying the manner in which the decision was reached, that its various components can be traced through the formal and nonformal channels of communication to many individuals who have participated in forming its premises.[15]

A major concern of administrators or managers in a complex organization is the maintenance and structuring of the decision-making process. One could argue further that a major responsibility of the administrator in a complex organization is to fulfill his role in the decision-making process of the organization. The definition of that role depends on the particular organization. Most research on complex organizations and the decision processes has been centered on government, business, and industrial firms. Administrative theorists and administrators are concerned that the results of such studies are not wholly applicable to colleges and universities. Millett, a leading spokesman for this viewpoint, declared that "Ideas drawn from business

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[14] J. Corson, Governance of Colleges and Universities (New York: McGraw-Hill, 1960), p. 118.

[15] H. A. Simon, Administrative Theory (New York: Macmillan Co., 1961), p. 221.

and public administration have only a very limited applicability to colleges and universities."[16]

Litchfield, a spokesman for the opposing view, believed that "Administration and the administrative process occur in substantially the same generalized form in industrial, commercial, civil, educational, military and hospital organization."[17]

The similarities and differences between the management of universities and government, business, and industry was pointed out by Baldridge, using two models of the university.[18] If the university is viewed as a bureaucracy, as described by Weber, a great similarity with business and industry can be claimed.[19] Among the shared features are:

1. The university is a complex organization chartered by the state.
2. The university has a formal hierarchy, with offices and a set of bylaws that specify the relationships between these offices.
3. There are formal channels of communication that must be respected.

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[16]J. D. Millett, The Academic Community (New York: McGraw-Hill, 1962), p. 4.

[17]E. H. Litchfield, "Notes on a General Theory of Administration," Administrative Science Quarterly 1 (January 1956): 28.

[18]J. V. Baldridge, Academic Governance (Berkeley: McCutchan Publishing Co., 1971).

[19]M. Weber, The Theory of Social and Economic Organizations, trans. T. Parsons and A. Henderson (New York: The Free Press, 1947).

4. There are definite bureaucratic authority relations, with some officials exercising authority over others.
5. Formal policies and rules govern much of the institution's work.
6. Decision processes are often highly bureaucratic, especially when rather routine types of decisions are at stake.

If the university is viewed as a "collegium" or "community of scholars," some distinct differences between the university and business and industry can be observed. Prominent features are:

1. Participation of all members of the academic community--especially faculty--in the management of the university.
2. Emphasis on authority based on "technical competence" rather than the "official competence" resulting from one's office holding in the bureaucratic hierarchy.
3. A utopian prescription for humanism in the educational process, unlike the impersonalism of the bureaucracy.

Baldridge pointed out that an analysis of the decision process implied by these two views of the university reveals weaknesses in both:

1. The bureaucratic model does not deal adequately with nonformal types of power and influence.
2. The bureaucratic model explains formal structure but does not deal adequately with the processes that give dynamism to the structure.

3. The collegial model does not deal adequately with the problem of conflict. The argument that major decisions are made primarily by consensus ignores power plays, conflict, and the politics of a large university.

It appears decision theorists should initiate research efforts aimed at understanding the university as a complex organization, different than business and industrial firms.

Baldridge conducted a research project to study the decision-making process in a large American university.[20] Results indicated that most members of the university community claimed some participation in the decision-making process at some level. Many people were involved in decision making at the department level, but only a small number participated in college or all-university decisions. Further analysis indicated that decision-making influence was fragmented, with different groups being strong in different spheres of influence and no single group dominating everything. The groups defined in the study were trustees, central administration, deans, college faculty, department faculty, and individual faculty members. One finding of the study was that trustees had very little influence on decision making in curriculum matters, whereas deans had great influence in decision making where faculty promotion was concerned.

In another study of 115 colleges and universities in the United States, Baldridge reported a strong association between increasing institution size and the following:

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[20] J. V. Baldridge, Power and Conflict in the University (New York: John Wiley and Sons, 1971).

1. a center specialized in mediating those external relations that are crucial to the maintenance and development of institutional legitimacy and material support.
2. a powerful faculty senate and subject matter departments with more autonomy over matters of particular concern to them.[21]

The results of these research efforts imply that the large university is a loose federation of administrative units with wide participation in decision making at the lower levels and a centralized officialdom at the upper level involving very few persons in the decision process.

It appears that the administrator in an institution of higher education is more likely to be in the role of mediation or consensus formulation than is his counterpart in business and industry. As Baldridge so wisely observed, however, the "collegial consensus" is often nothing more than the ascendancy of one group over another. In such situations, even at the departmental level, the administrator often decides which group will prevail. In large universities, at higher levels, the decision-making process involves few individuals and, to a large extent, administrative officials participate in the decision making with recommendations from committees or councils. If one is to make a research contribution to the effective implementation of quantitative management information systems in complex organizations such as higher education institutions, such research

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[21]Baldridge, Academic Governance, p. 58.

might best study the effect of such systems on the decision-making process. One approach would be to investigate the effect of MIS on collegial consensus at the department level in the university. Another approach would be to investigate the effect of MIS on decision making by administrators in higher education functioning in the absence of consensus. The administrative role in such situations is more nearly like that of an administrator in business or industrial organizations. The present study takes the latter approach.

Statement of the Problem

The problem addressed by the present research was derived from the previously mentioned need to integrate quantitative management information systems and techniques into the traditional management patterns of complex organizations such as higher education institutions. Investigation of the problem focuses on the decision-making activities of individuals in an uncertain environment.

The problem investigated was the effect of quantitative management information about the state of an uncertain environment on the generation and selection of alternative actions in the individual decision-making process in that environment.

The theoretical framework for the investigation is embodied in the Bayesian model derived from decision-making theory, as discussed in Chapter II of this dissertation. Soelberg's research, based on an expanded model of Simon's characterization of the decision process, indicated that early activity focused on the search for alternative actions and the reduction to two or more acceptable alternatives before termination of the search.[22] In this activity the decision maker examines the environment to obtain information about present and possible states of nature, and tests hypotheses about the probability of likely states of nature in the environment as a result of the decision to be made.

Purpose of the Study

The purpose of the study was to seek answers to five basic questions about individual decision making under uncertainty and the effects of quantitative management information on the generation and selection of alternatives. The questions were:

1. Is there any difference in the number of alternative actions generated by the individual decision maker in an uncertain environment as a result of quantitative management information as compared to nonquantitative management information or no management information?

2. Is there any difference in the number of alternative actions selected by the individual decision maker in an uncertain environment as a result of quantative management information as compared to nonquantitative management information or no management information?

3. Is there any difference in the number of alternative actions generated by an individual decision maker under uncertain

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[22] P. Soelberg, "Unprogrammed Decision Making," in Studies in Managerial Process and Organization Behavior, ed. J. H. Turner, A. C. Filley and R. J. House (Glenview, Ill.: Scott, Foresman and Co., 1972).

conditions as a result of the combination of quantitative and nonquantitative management information when compared to the use of either type separately?

4. Is there any difference in the number of alternative actions selected by an individual decision maker in an uncertain environment as a result of the combination of quantitative and nonquantitative management information as compared to either type when used separately?

5. Is there any difference in the distribution of alternative actions selected by individual decision makers in an uncertain environment as a result of quantitative management information when compared to nonquantitative management information or no management information, when the distribution variate is a randomly ordered nominal set of alternatives representative of a referenced distribution?

These questions were addressed to a small part of the problem of the effects of management information on individual decision making: the generation and selection of alternatives. It is hoped that furthering the understanding about this part of individual decision-making activity will contribute to the knowledge base from which future researchers may draw some guidance.

Methodology

So little research has been published on the subject of individual decision making under uncertainty that this study must be considered exploratory. For this reason, the research hypotheses were stated in the form of questions rather than major null hypotheses.

The question framework for stating research hypotheses allows the researcher more flexibility to explore whatever results the data might reveal.

The methodology for the study was experimentation as opposed to field observation or a case study. The use of the experimental method in research has long been accepted in the physical and biological sciences, but still evokes debate among researchers in the social and behavioral disciplines. Decision making under uncertainty is a complex process involving many variables. The researcher must exert some control over variables believed to be related to the research question if valid knowledge is to be derived from his work. The experimental method allows the experimenter to control some variables and minimize the effect of others through randomization. This enhances the internal validity of the experiment. Another advantage of the experimental method is that the researcher must state explicitly the conditions under which the results were obtained. The results can then be generalized to other situations in which similar conditions are observed. This enhances the external validity of the results of the experiment.

Another issue that had to be resolved was the population from which subjects would be drawn. Cummings and Harnett cited several studies that supported the reasoning that students can be used as subjects in managerial decision-making studies and that their responses will be essentially the same as those of active managers.[23] In this

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[23]L. L. Cummings and D. L. Harnett, "Managerial Problems and the Experimental Method," Business Horizons, April 1968, p. 41.

study there was the added requirement that the subject population be familiar with the format for presenting quantitative management information, such as charts, graphs, tables, percentages, and proportions. The population used in this study was college students in a single university; they were chosen from the College of Business, before instrumentation of the study. The rationale for selection of this population was that the students' backgrounds indicated the aforementioned familiarity with the style and format of quantitative management information. It was expected such familiarity would minimize response variance resulting from misinterpretation of the information, thus increasing the precision of the experiment.

A large resource group was identified, which represented a cross-section of the population. Subjects were randomly selected from the larger resource group. A total of 80 subjects was used in the experiment. Twenty students were assigned to each treatment group. The criteria for participation of students in the study were:

1. Subjects must voluntarily agree to participate in the experiment.
2. Participants must possess sufficient knowledge of the problem situation of the study to be considered usable subjects.
3. Subjects must be accessible to the researcher to facilitate the collection of data and completion of the study within a reasonable time, and thus minimize the effects of history and external influence on the responses.

Definition of Terms

Management information: Management information is that information necessary to support the management of an institution in (a) planning what should be done, (b) operationalizing plans to get things done, (c) controlling operations to determine whether plans are being operationalized, and (d) evaluating whether planned outcomes have been achieved.

Management information systems: An earlier reference was made to the lack of standardization in the terminology of management technology and its application to higher education institutions. In this study, MIS is used as a general descriptor of all of the tools and techniques of management technology and their associated supportive data bases.

Decision: Most of the literature on decision making in the journals of psychology, economics, and statistical mathematics avoids specific definitions of a "decision." Eilon quoted a definition given by Ofstad:

> To say that a person has made a decision may mean (1) that he has started a series of behavioral reactions in favor of something, or it may mean (2) that he has made up his mind to do a certain action, which he has no doubts that he ought to do. But perhaps the most common use of the term is this: "To make a decision" means (3) to make a judgment regarding what one ought to do in a certain situation after having deliberated on some alternative courses of action.[24]

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[24] S. Eilon, "What Is a Decision?" Management Science 16 (December 1966): 172.

Knezevich stated that "A decision can be defined as a conscious choice from among a well defined set of often competing alternatives."[25]

Although many decision theorists would argue that decisions are often made with considerable doubt and that choices are not always well defined, there would be general agreement that a decision involves at least two alternatives, and that after deliberation a conscious choice is made from the alternatives. For purposes of this study, the following definition was used: Decision--a conscious choice of an alternative after deliberate consideration of at least two competing alternatives.

Decision making: The majority of decision theorists tend to focus on the decision-making process. Knezevich said, "Decision making is a sequential process culminating in a single decision or a series of decisions."[26]

Blankenship and Miles wrote:

> Decision making may be visualized as a complex process in which an individual or a group of individuals moves through a series of interrelated substeps including (1) the recognition of a problem requiring some response, (ii) the investigation of the problem and its environment in an effort to collect relevant information and to generate solutions, and (iii) the selection of a course of action based on an analysis of the available information and solutions.[27]

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[25] S. J. Knezevich, Administration of Public Education (New York: Harper and Row, 1969), p. 10.

[26] Ibid., p. 32.

[27] L. V. Blankenship and R. E. Miles, "Organizational Structure and Managerial Decision Making," Administrative Science Quarterly 13 (June 1968): 107.

These two definitions represent the simplistic and the complex extremes of the concept of the decision-making process. The present study used the definition of decision making proposed by Blankenship and Miles. This preference is further demonstrated by the decision activity model discussed in Chapter III.

Quantitative management information: Management information systems have generally been defined to include the tools and techniques of management technology and their supportive data bases. This definition is adequate for purposes of discussion, but for designing the experiment, quantitative management information must be more precisely defined. A search of the literature failed to uncover any definition of these terms, so definitions are formulated here for purposes of this study. Quantitative management information must meet two basic criteria:

1. The variables on which data measurements are made must, in principle, be naturally quantifiable.
2. The format in which data are presented must not alter the information content.

Any management information not meeting these two criteria is defined as nonquantitative management information.

The first criterion differentiates between those variables that are naturally quantifiable and those on which quantitative scales are artificially imposed for purposes of measurement. Naturally quantifiable variables include dollars available for program support, number of student credit hours, number of jobs available, size of faculty, and projected size of the student body. Variables that might be artificially quantified are satisfaction of graduates, unity of faculty, power of the student body, intelligence of students, and quality of programs.

The second criterion is intended to distinguish between structuring the data format for purposes of presentation to user and altering the information content by interpretation, inference, personal judgment, or axiological perturbation. The format for quantitative management information is generally void of prose and makes use of graphs, charts, statistical analyses, and tables.

The second criterion does not prohibit ordinary statistical analyses such as determination of the mean, variance, mode, maximum and minimum values. Qualitative statistical analyses would violate the condition for quantitative management information. Techniques such as rank ordering, categorical grouping, and statistical inference convey information about the values and perceptions of individuals as well as the quantitative data.

These two criteria were applied in the selection of management information to be used in the research instrument.

Uncertain environment: The theories of decision making are related to the environment in which the decision is made. An uncertain environment is one in which all possible actions available to the decision maker are not known, the outcomes of such actions are not completely known, and the probabilities of known outcomes are in doubt.

In summary, the following definitions were used in this study:

Management information--that information necessary to support the management of an institution in planning what should be done, operationalizing plans to get things done, controlling operations to determine whether plans are being operationalized and evaluating whether planned outcomes have been achieved.

Management information systems--all of the tools and techniques of management technology and their associated supportive data bases.

Decision--a conscious choice of an alternative after deliberate consideration of at least two competing alternatives.

Decision making--a complex process in which an individual or a group of individuals moves through a series of interrelated substeps including the recognition of a problem requiring some response, the investigation of the problem and its environment in an effort to collect relevant information and to generate solutions, and the selection of a course of action based on an analysis of the available information and solutions.

Quantitative management information--management information that meets the following criteria:

1. The variables on which data measurements are made must, in principle, be naturally quantifiable.
2. The format in which data are presented must not alter the information content.

Uncertain environment--one in which all possible actions available to the decision maker are not known, the outcomes of possible actions are not completely known, and the probabilities of known outcomes are in doubt.

Limitations of the Study

This study investigated only a portion of the decision-making activity of individuals in an uncertain environment--the generation and selection of alternative actions. It does not deal with the culminating decision activity, a final choice from selected alternatives.

This study was experimental; as such, one must recognize the limitations of experimental studies in terms of validity and generalizability of the results. Careful selection of the population and randomization minimized the influence of variables other than the information treatment effects. A further limitation of the study was the use of students rather than university administrators as subjects in the experiment. The ability of such students to artificially assume the role of administrators for experimental purposes has been verified by management scientists but in any given decision situation, generalization of the results might be limited.

Since the study was exploratory, the results are not expected to be the end but rather the means by which future research might be guided. Research questions were investigated. It was not expected that conclusions would come from this study, but that directions would be indicated for future investigation of the complex process of individual decision making under uncertainty and the effects of quantitative management information on that process.

Importance of the Study

Two factors have contributed to the increased application of computer-based management technology to the administration of higher education institutions. Those factors are pressure from public agencies on higher education to be more accountable for the management of public resources and the eagerness of management scientists to adapt the tools and techniques that have proven successful in industry to higher education management problems. The problem now is one of "implementation"--the introduction of quantitative-data-oriented technology into the highly judgmental decision process of traditional educational administration. We must investigate the effects of such quantitative data on the process of decision making under uncertainty, to discover whether and how the introduction of such data contributes to more effective management. Research should start with the individual decision maker. Unless we increase our knowledge of decision making and the utility of new technology for improving it, the benefit that can be gained from the successful implementation of computer-based management information systems in colleges and universities will be lost. The present study is an attempt to contribute to that knowledge.

Overview of the Dissertation

Chapter I provided an introduction to the role of management information systems in higher education, a statement of the problem to be investigated in this study, and the purpose, methodology, and limitations of the study. Definitions of selected terms used in the dissertation were also presented.

Chapter II contains a review of literature and related research on management information systems and the decision-making theory on which the study was based.

A description of the model that forms the theoretical basis for the study, the design of the experiment, and the methods of analysis of the data are found in Chapter III.

The raw data and the analysis of the data are presented in Chapter IV.

Chapter V contains a summary of the results of the study, conclusions and recommendations for future investigation, and reflections on the conduct of the study and its results.

CHAPTER II

SELECTED REVIEW OF LITERATURE

The literature review of this study can be categorized in two distinct areas: (1) current quantitative management information systems and (2) decision theory. The review of current quantitative management information systems provides the background necessary to comprehend the kinds of data, formats, structures, and variables administrators in higher education institutions are likely to encounter now and in the near future in their search for information to assist them in decision making.

Decision theory forms the theoretical base for the model used in the study. From decision theorists in psychology, statistics, economics, management, and business administration have come reports of research studies related to individual decision making under uncertainty. The results of some of those studies are presented in this chapter.

Current Management Information Systems

Reference was made in Chapter I to the lack of a standardized terminology of management technology and its application to higher education institutions. In this dissertation, MIS is used as a general descriptor of all the tools and techniques of management technology and the associated supportive data bases. This general usage causes some confusion when one tries to talk about the state of the art of MIS in higher education, for it becomes difficult to categorize and survey the literature.

Rourke and Brooks, in a survey of 436 institutions of post-secondary education to determine use of computerized systems in their administration, established four general areas of heavy usage: (1) student affairs, (2) financial management, (3) physical plant management, and (4) general policy planning.[1] Student affairs activities included registration, grading records, admissions, testing, and student records. Financial administration included payroll, general accounting, budget preparation, investment records, and general inventory. Physical plant management included space inventory, space cost analysis, classroom assignment, and office space assignment. Policy planning included long-range planning, institutional research, and simulation of institutional operations. In the overall operation of the university, none of these areas is totally independent of the other.

Rourke and Brooks further analyzed the use of computerized systems in the four areas according to level of sophistication: routine, programmed procedures, management information, advanced programmed analysis, and nonprogrammed decision making.[2] The interest in decision making under uncertainty, which will be discussed in detail in Chapter III, leads to more interest in those applications of MIS at the level of advanced analysis and nonprogrammed decision making, as defined by

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[1]F. E. Rourke and C. E. Brooks, "Computers and University Administration," Administrative Science Quarterly, December 1966, p. 600.

[2]Ibid.

Rourke and Brooks, while still recognizing the necessity of lower level operating data systems to support higher level activities.

No overall survey of the state of the art of MIS applications is attempted as a part of this study. In the words of Nelson,

> Discussions of the state of the art are often unsatisfactory because of the very different interests and perspectives of the participants. What are we talking about: Higher education planning? Computer applications to university operations? Program planning and budgeting? Management information systems? Model building?[3]

A survey of literature to date leads one to believe that no university has a totally integrated MIS operating today. This review discusses the major characteristics of some of the more publicized systems dealt with in the literature, to give the reader some idea of the kinds of information being made available to the manager to assist in decision making.

Most designers of MIS for higher education institutions view the university as a system as shown in Figure 1.

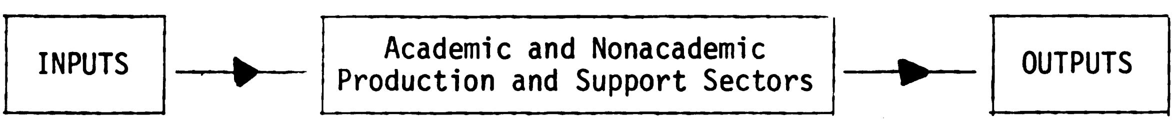

Figure 1.--The university as a system.

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[3]C. A. Nelson, "Management Planning in Higher Education--Concepts, Terminology and Techniques," Management Controls, January 1971, p. 6.

Vaj Wijk and Young defined inputs to include:

1. Student input--a description or measure of the student (or student body) being introduced into the system.
2. Financial input--a measure of resources being sent from the environment to the system to perpetuate its existence.

The outputs they defined included:

1. Student output--the behavioral change in the student input brought about as a consequence of the institution.
2. Nonstudent output--the impact of the educational process on the environment.[4]

Tables 1 and 2 show quantitative measures for input and output variables suggested by Hartley.[5] Figure 2 shows the typical academic and nonacademic production and support structure of a university proposed by Van Wijk and Young.[6] The three major functions--instruction, research, and public service--espoused by most university administrators are maintained by systems designers in their conceptual models of the university.

One of the agencies that has been very active in the design, development, and implementation of management technology in higher

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[4]A. P. Van Wijk and B. J. Young, Objectives, Program Structure and Evaluation in Higher Education: An Introduction, Research Report of the Institute for Policy Analysis (Toronto, Canada: Institute for Policy Analysis, 1971), p. 19.

[5]H. J. Hartley, Educational Planning, Programming and Budgeting: A Systems Approach (Englewood Cliffs, New Jersey: Prentice-Hall, 1968), p. 222, adapted from A. Astin, Who Goes Where to College? (Englewood Cliffs, New Jersey: Prentice-Hall, 1965), p. 26.

[6]Ibid., p. 15.

Table 1.--Student input characteristics.

Student Input Variable	How It Could Be Measured
A. Past achievement in high school	
- academic	- high school grades, high school rank
- scientific	- placing in a scientific contest
- artistic	- art awards, exhibitions of own art work
- musical	- ratings in music contests
- literary	- awards for writing, number of own works published in literary magazines
- oral	- oratory awards, participation in plays
- social	- awards for leadership, offices held in school
B. Education & vocational aspirations	
- highest degree planned	- graduate work, Ph.D. degree, professional degree
- probable major field of study	- open
- decided or undecided about studies	
C. Socio-economic background	
- parents' educational level	- primary, secondary, college graduate, post-graduate
- father's occupation	- open
- number of parents living	
- ethnic origin	
- size of high school class	- median high school class size
D. Sex	

Table 2.--Output measurement.

Variables	How They Could Be Measured
Student Output	
Quantity and quality	- standardized test results: performance of students on standardized tests given in the freshman and senior years and on graduate admissions tests
	- number and type of degree granted
	- the number of seniors admitted to graduate schools
	- questionnaires filled out by alumni giving a personal history after receiving their degrees, listing positions, salaries, participation in community affairs and graduate studies
Nonstudent Output	
Community involvement	- expressed in terms of lectures, cultural events, art exhibits & urban and community projects
Library growth	- the number of books in the library
Research and scholarly publications	- expressed in terms of research grants and research publications
Economic benefits	- economic implications of investment in education

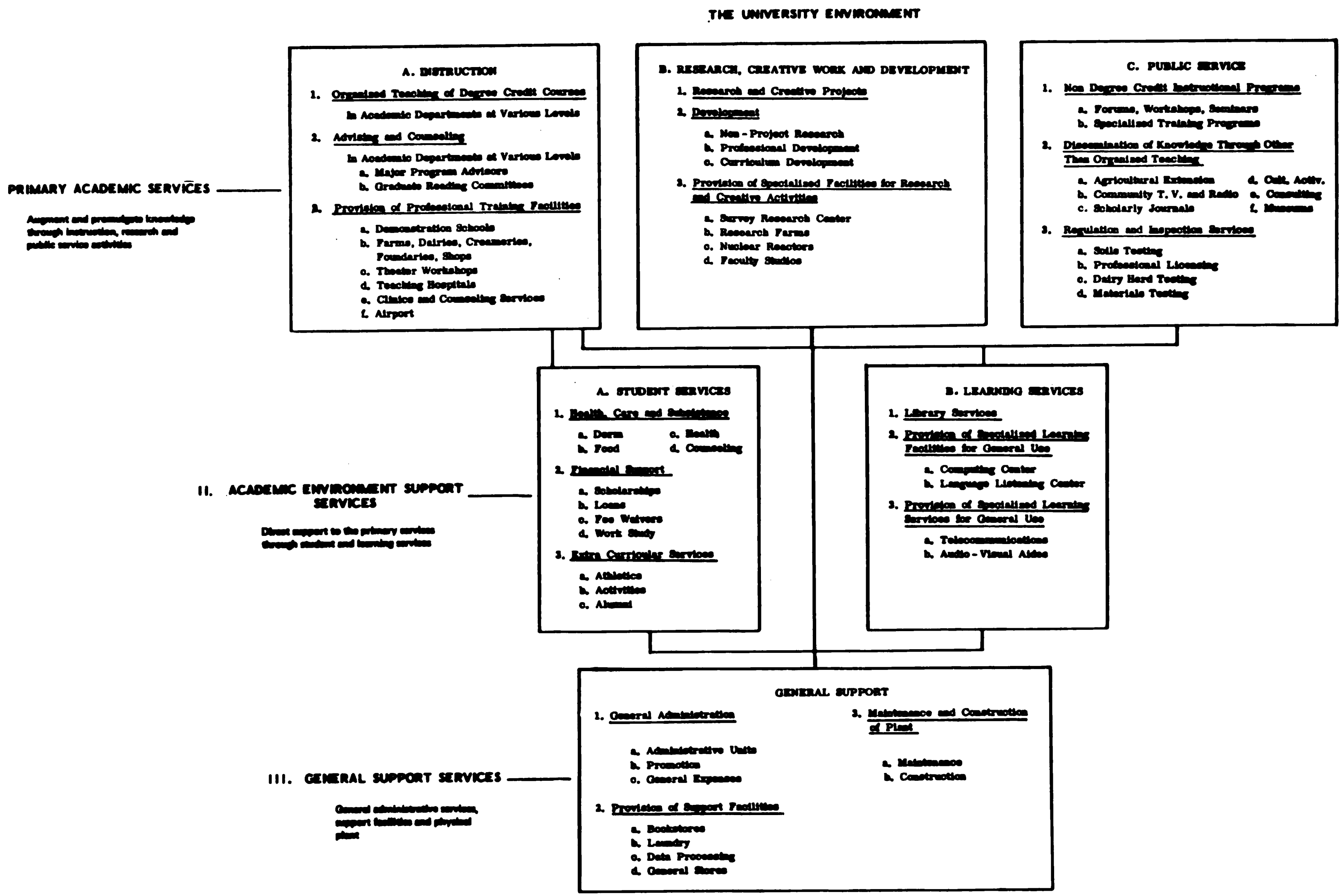


Figure 2.--Typical academic and nonacademic production sectors.

education is the National Center for Higher Education Management Systems at Boulder, Colorado. The collection of tools and techniques offered by NCHEMS is in two general categories:

1. those that are used to gather historical data, and
2. those that use the historical data as a point of departure to project future costs and assist in planning for future operation.

Specific instruments are Program Classification Structure (PCS), Information Exchange Procedures (IEP), Student Flow Model, Induced Course Load Matrix (ICLM), Cost Simulation Model (CSM), Faculty Activity Analysis (FAA), Cost Estimation Model (CEM), Cost Finding Principles (CFP), and Resource Requirements Prediction Model (RRPM). Figure 3 shows how some of these instruments might be used in a systematic way. Raw data are organized according to the program classification structure chosen. Output data from PCS are used to allocate support costs to departments. Course requirements for each instructional major are determined and displayed, according to the department responsible for providing the courses, in the ICLM. Department support costs and planning parameters, PCS data, and ICLM data are used to calculate costs for each program. Costs for each major can be converted to costs per graduate or cost per credit in any major. Planning and budgeting costs based on desired outputs are calculated for planned programs based on the input data. The output data of Figure 3 would be calculations of the costs required to support the programs planned, based on the input data.

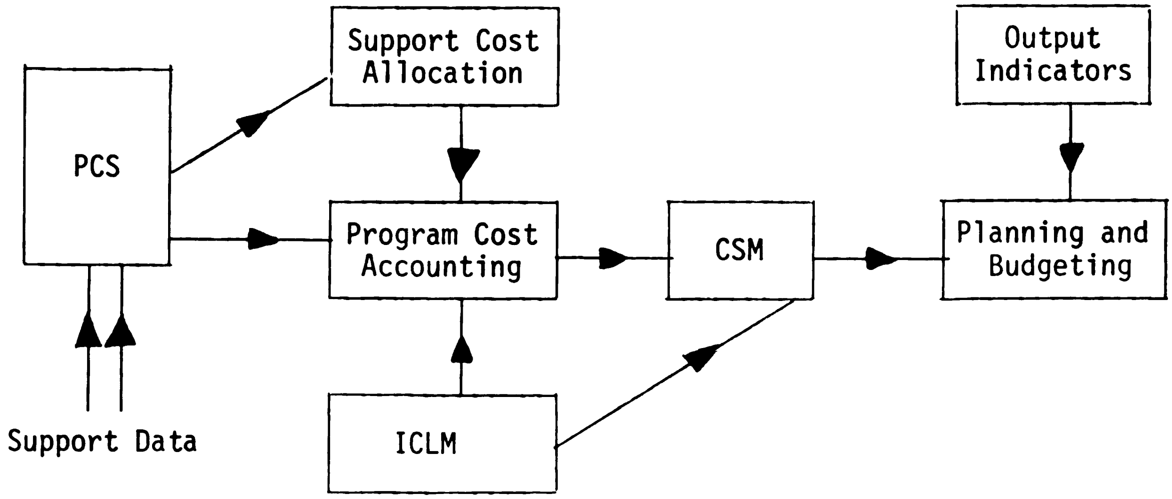


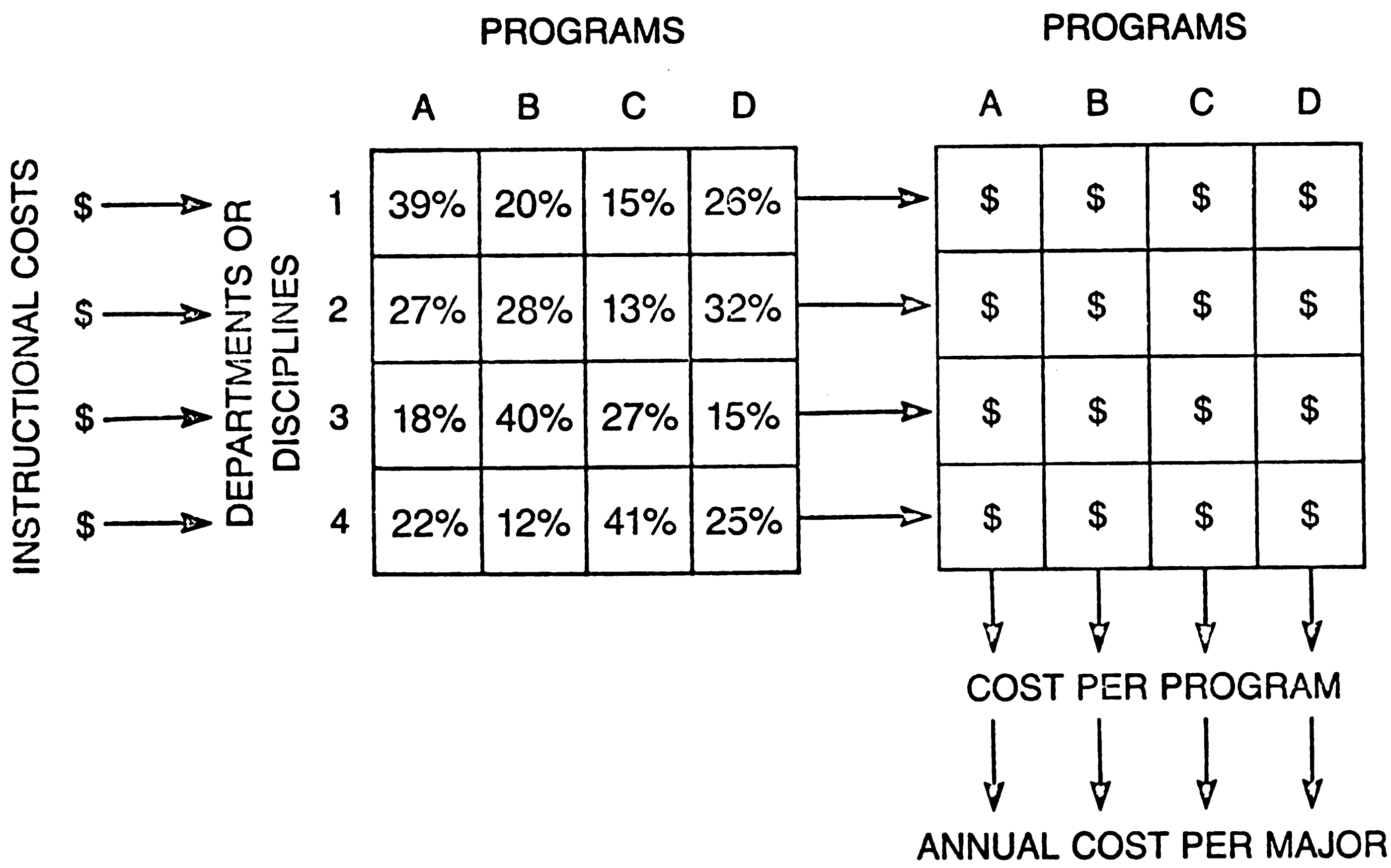
Figure 3.--Sample use of NCHEMS instruments.

Figures 4, 5, and 6 show specific data and formats for some of the above-named instruments.

Although NCHEMS offers the user a collection of tools and techniques, several commercial computerized packaged systems perform the same functions. Typically, a computer software option is sold or leased to the user. The program is controlled from a computer teletype terminal. The user interacts with the computer by supplying requested input data and specifying the outputs.

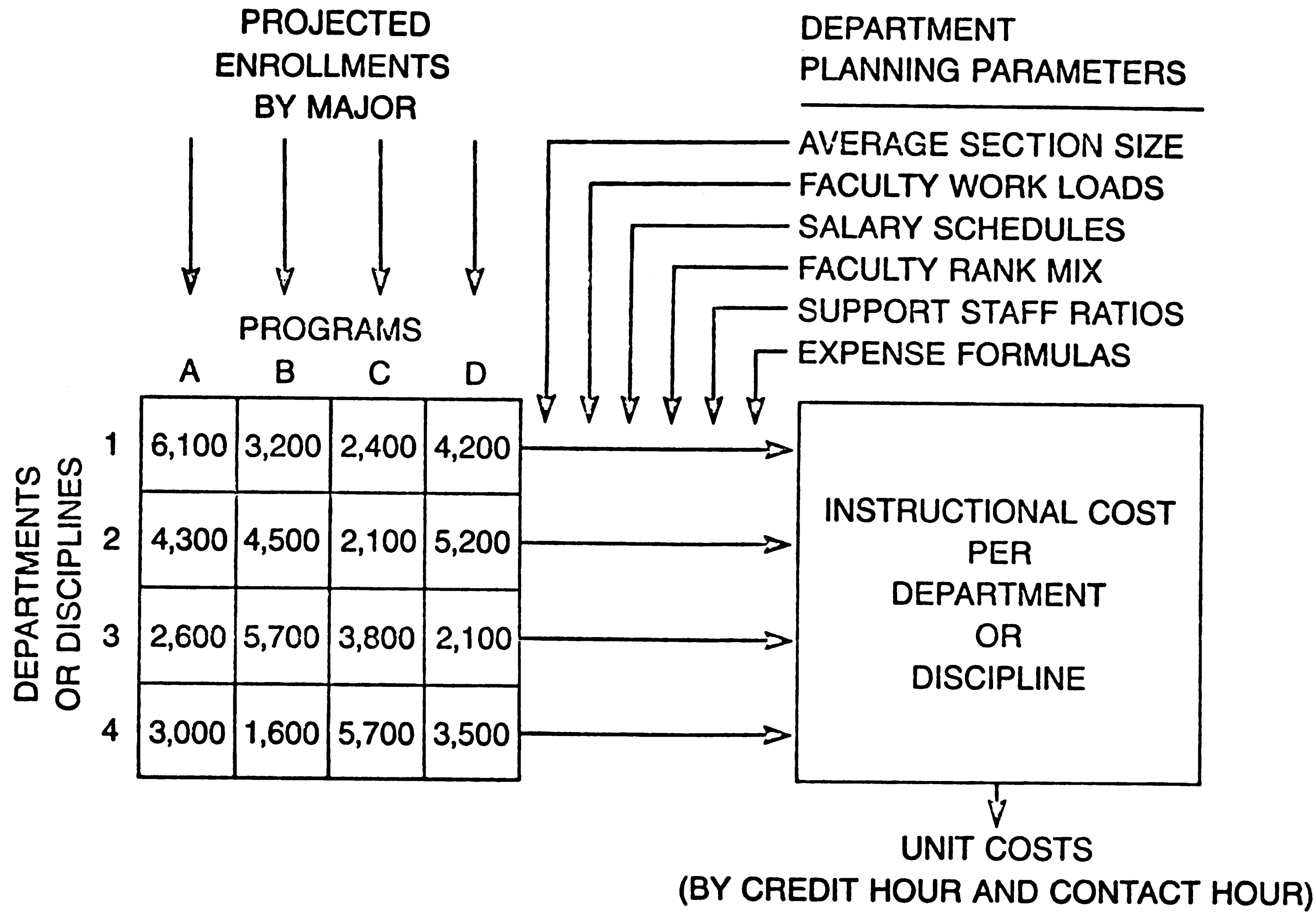
One such commercial package is CAMPUS VII, designed by Systems Research Group of Toronto, Canada. Table 3 shows the data the user puts into the system. Table 4 shows the information the user might request as output.

Another commercial package is PLANTRAN II, designed by Midwest Research Institute of Kansas City, Missouri. This software package allows the user the flexibility of structuring his own model of the



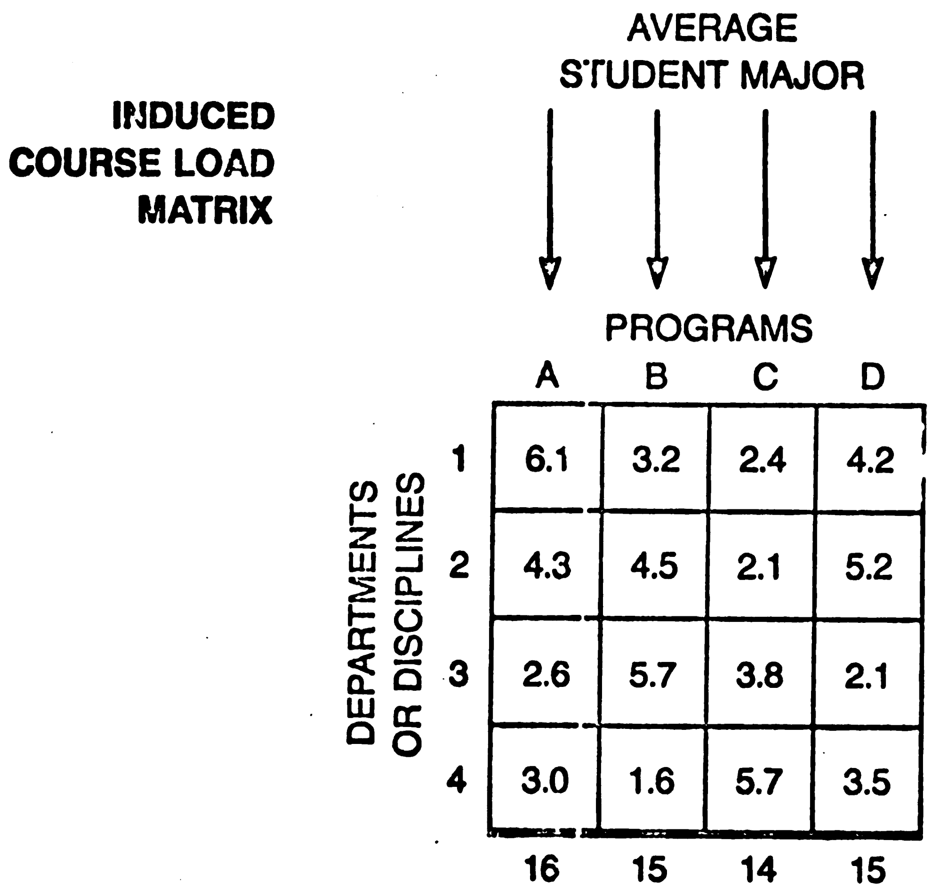
Source: R. A. Huff and C. W. Manning, Higher Education Planning and Management Systems (Boulder, Colorado: National Center for Higher Education Management Systems, 1972).

Figure 4.--NCHEMS CSM data format.



Source: R. A. Huff and C. W. Manning, Higher Education Planning and Management Systems (Boulder, Colorado: National Center for Higher Education Management Systems, 1972).

Figure 5.--NCHEMS CSM data format.



Source: R. A. Huff and C. W. Manning, Higher Education Planning and Management Systems (Boulder, Colorado: National Center for Higher Education Management Systems, 1972).

Figure 6.--Typical NCHEMS ICLM data format.

Table 3.--What you put into CAMPUS VII.

On degree programs

The enrollment, course load per student and transition rates for each year (achievement level).

The cross-loading or induced course load matrix, distributing students with each program among the disciplines or departments that teach them, by percentage of discipline/department load.

On departments or disciplines

Faculty assumptions and characteristics--how staff members are assigned to teach, hours per week, distribution of ranks in hiring, salary rates per rank.

Characteristics of courses in these disciplines or teaching departments--number offered, average section size, average hours per week per section, student credits per course, distribution of enrollments by course type, teaching staff and space for each type of course.

Departmental/discipline functional computations--rules for computing support staff needs in the teaching departments, and needs for supplies, fringe benefits, etc.

On administrative units (or programs)

All of the supportive resources that the staff in administrative work require is entered, including expense and revenue items--e.g., salaries, fringe benefits, secretarial staff, and institutional revenue items such as tuition; bases on which these are to be computed.

Source: George Mowbray, member of the Systems Research Group, presentation to the Conference on Management Science in Education, Michigan State University, East Lansing, Michigan, August 2, 1972. (Unpublished.)

Table 4.--What you get out of CAMPUS VII.

<u>Single-year reports for each simulation year</u>

Program enrollment for each year of the program

Program loading on the teaching departments

Departmental/discipline contact hours

Teaching staff requirements

Teaching space requirements (sq. ft. & stations)

Departmental/discipline support resources needed

Administrative support resources needed in nonteaching departments and units

<u>Multi-year reports for simulation period</u>

Enrollment, total costs and cost per student for each year in each <u>program</u>; division between teaching and administrative costs; cost to graduate; class and lab space required, in total and per student.

For each teaching <u>department</u>, costs of salaries, support staff and other resources; revenue generated, if any; number of staff and other personnel required; square feet of classroom, laboratory, office and support space needed; FTE enrollment and total student courses; total cost per student; faculty cost per student; total space per student and teaching space per student; student/faculty ratio; and aggregate costs per academic year of student.

For each administrative department or unit, approximately the same information as above, for teaching departments.

Summary reports for all teaching departments and all administrative departments or units.

Source: George Mowbray, member of the Systems Research Group, presentation to the Conference on Management Science in Education, Michigan State University, East Lansing, Michigan, August 2, 1972. (Unpublished.)

university. Figure 7 shows a typical input data set and Figure 8 a typical output data set.

Peat, Marwick, Mitchell and Co. markets a system called SEARCH. Casasco reported that

> SEARCH is a generalized simulation of a college or university as an interactive system. It encompasses students, programs, faculty, facilities and finances, functionally relating each of these aspects to the others so that it can simulate the behavior of a college as an operating system. Beginning with the actual present state of the institution, it simulates its future state by yearly intervals for up to ten years, based on a continuation of present operating policies and decisions as well as alternative policies and decisions the planner wishes to explore.[7]

Figure 9 is a sample of the projected data format.

These current MIS tools were reviewed to demonstrate the kinds of quantitative data requirements the systems need to operate and the data that are provided the manager to aid in making decisions. No attempt was made to describe each system in detail.

It can generally be said that the computerized systems take raw data from the operating systems of the university, manipulate them according to programmable decision rules, simulate the operation of the university, and calculate the new values of selected variables at specific time intervals.

Brief History of Decision Theory

The situation with which decision theory deals is this: Given two perceived states, A and B, into either one of which an individual may place himself, the individual chooses A in preference to B (or

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[7]J. A. Casasco, Planning Techniques for University Management (Washington, D.C.: American Council on Education, 1972).

ANY UNIVERSITY
DEPARTMENTAL
RUN

ANALYSIS OF MATRIX
FOR A
6 PERIOD FORECAST

CURRENT DATE
BASE YR. 1972

LINE	DESCRIPTION	BASE	METHOD OF COMPUTATION
1	WEEKLY STUDENT CONT HRS	7250	DATA7270,7280,7295,7300,7290,7275
2	AVERAGE SECTION SIZE	35	INCREASE 1 BEGINNING IN 3RD YEAR
3	AVE FACULTY TCH LD(WSCH)	9.2	PERCENT DECREASE OF .5 BEGIN IN 5TH YEAR
4	FTE FACULTY REQUIRED	22.5	EQUATION: L1 / (L2 * L3)
9	AVERAGE FACULTY SALARY	15650	PERCENT INCREASE OF 2.5 PER YEAR
5	PCT RANKED FACULTY	70	INCREASE .5 PER YEAR
6	PCT TEACHING ASSISTANTS	30	EQUATION: 100-L5
7	FTE RANKED FACULTY	15.75	EQUATION: L4*.01L5
8	TEACHING ASSISTANTS	10	EQUATION: L4* .01 L6 / .67
10	AVERAGE TCH ASSIST SAL	4800	INCREASE 200 PER YEAR
11	FACULTY SALARIES	246488	EQUATION: L7 * L9
12	TCH ASSISTANT SALARIES	48000	EQUATION: L8 * L10
13	SUPPORT STAFF	7.2	EQUATION: 2 + .33 L7

Source: An Introduction to Plantran II (Kansas City, Mo.: Midwest Research Institute, 1972).

Figure 7.--Typical PLANTRAN II input data sheet.

ANY UNIVERSITY
DEPARTMENTAL

BUDGET REQUIPREMENTS

CURRENT DATE
RUN

LINE NO.	PLANNING ITEM	1973	1974	1975	1976	1977	1978
11	FACULTY SALARIES	255332.31	263934.19	265415.63	266732.13	269032.44	271340.44
12	TCH ASSISTANT SALARIES	49704.51	50886.44	50593.93	50188.52	49890.63	49519.29
15	SUPPORT STAFF SALARIES	37170.00	38333.16	38752.00	39160.04	39678.51	40204.70
16	TOTAL SALARIES	342206.82	353153.78	354761.55	356080.68	358601.57	361064.43
28							
18	SUPPORT BUDGET	8276.96	8347.13	8189.25	8029.14	8660.56	9269.34
28							
19	DIRECT EXPENSE	350493.75	361500.88	362950.69	364109.75	367262.06	370333.69
28							
20	INDIRECT COSTS	167373.31	172727.50	173513.81	174159.00	175392.00	176596.56
28							
21	TOTAL DEPT EXPENSE	517857.06	534228.38	536464.50	538268.75	542654.06	546930.25

Source: An Introduction to Plantran II (Kansas City, Mo.: Midwest Research Institute, 1972).

Figure 8.--Typical PLANTRAN II output data sheet.

	YEAR					
	1970	1971	1972	1973	1974	1975
STUDENTS ENROLLED	770	815	832	856	856	856
FRESHMAN	293	293	293	293	293	293
SOPHOMORE	194	234	234	234	234	234
JUNIOR	158	147	174	174	174	174
SENIOR	125	141	131	155	155	155
NO OF FACULTY--TOTAL	55	55	55	55	55	55
PROFESSORS	9	9	9	9	9	9
ASSOCIATES	16	16	16	16	16	16
ASSISTANTS	23	23	23	23	23	23
INSTRUCTORS	7	7	7	7	7	7
ADJUNCT	0	0	0	0	0	0
COURSES	158	158	158	158	158	158
FRESHMAN	25	25	25	25	25	25
SOPHOMORE	25	25	25	25	25	25
JUNIOR	51	51	51	51	51	51
SENIOR	57	57	57	57	57	57
SECTIONS	226	226	226	226	226	226
FRESHMAN	64	64	64	64	64	64
SOPHOMORE	51	51	51	51	51	51
JUNIOR	52	52	52	52	52	52
SENIOR	59	59	59	59	59	59
FACULTY LOAD (HRS/YR)	26	26	26	26	26	26
STU-FAC RATIO	14	14	15	15	15	15
CREDIT HOURS PRODUCED	21741	24983	25530	26226	26226	26226
AVE CLASS SIZE	17	16	17	17	17	17
TUITION INCOME	1305	1407	1437	1479	1479	1479
INSTRUCTION EXPENSE	708	708	713	716	719	724
INSTR COST/CRED HR	26	28	27	27	27	27

Figure 9.--Typical SEARCH data format.

vice versa). Throughout the history of social research, great minds have sought to understand the behavior of individuals in such situations. Bodies of theory have been accumulated throughout the years under such varying names as decision theory, value theory, utility theory, theory of chance, theory of decision making, and others.

Kauder credited Aristotle with creating the concept of value in use, and cited readings from one of the great philosopher's best-known works, The Topics, as evidence of Aristotle's well-developed theory of utility in human choice.[8] Aristotle's theory dealt primarily with the economic marginal utility of goods, wherein marginal utility was based on the value of the last piece of goods exchanged. Aristotle's thoughts about utility theory, like most of his other works, lay dormant for over one thousand years. In the thirteenth century, growing debate over market forms and just prices led medieval doctors to revive the Aristotelian theories. Urged on by philosophers such as Thomas Aquinas, Henry of Ghant, and Johannes Buridanus, a value theory developed that was a mixture of economic cost and subjective value; utility was based on the general welfare of the community and not the pleasure of the individual. Kauder traced the threads of Aristotelian influence through the centuries to the young Italian economist, Abbé Galiani,[9] who developed a value theory based entirely on subjective estimation, wherein value was defined as the

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[8] E. Kauder, "Genesis of the Marginal Utility Theory," Economic Journal 63 (September 1953): 638.

[9] Ibid., p. 644.

ratio of utility and scarcity. For the first time, value had meaning for something other than economic goods.

About the same time that Galiani was developing his subjective theory, a young English minister, Thomas Bayes, was developing his solution to some of the problems of the doctrine of chance, based on the mathematical work of Bernoulli.[10] In an introduction to his essay, Bayes wrote:

> . . . that his design at first in thinking on the subject of it was to find out a method by which we might judge concerning the probability that an event has to happen, in given circumstances, upon supposition that we know nothing concerning it but that, under the same circumstances, it has happened a certain number of times, and failed a certain number of times.[11]

The key to Bayes' mathematical work was the proposition that preceding an experiment, the chance of an event occurring could be estimated to lie within a probability interval based on the number of times the event had happened or failed to happen under similar circumstances in the past. The relationship of Bayes' essay to the theory of choice is demonstrated by his proposition 2:

> If a person has an expectation depending on the happening of an event, the probability of the event is to the probability of its failure as his loss if it fails to his gain if it happens.
>
> Suppose a person has an expectation of receiving N, depending on an event the probability of which is P/N. Then the value of his expectation is P, and therefore if the event fails, he loses that which is in value P; and if it happens he receives N, but his expectation ceases. His gain therefore is N-P. Likewise, since the probability of the event is P/N, that of its failure is (N-P)/N. But P/N is to (N-P)/N as P is to N-P, i.e.,

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[10] T. Bayes, "Essay Towards Solving a Problem in the Doctrine of Chances," Philosophical Transactions of the Royal Society 53 (December 1763): 370; reprinted in Biometrika 45 (1963): 293.

[11] Ibid.

> the probability of the event is to the probability of its failure as his loss if it fails to his gain if it happens.[12]

Bayes' concept of probability as determined by the frequency of occurrence of events formed the basis for the classical approach to the mathematical theory of chance that dominated thinking during the eighteenth and nineteenth centuries.

The first half of the twentieth century saw the development of the classical decision theorists. This classical approach can be described as empirical, an attempt to justify propositions on the basis of data. The key to the expected success of the classical approach was the empirical verification of utility. Edwards expressed the view of that period:

> People choose the alternative, from among those open to them, that leads to the greatest excess of positive over negative utility. This notion of utility maximization is the essence of the utility theory of choice.[13]

Classical theorists used utility theory to establish the nature of the demand for various goods. Assuming that the utility of any good is a monotonically increasing, negatively accelerating function of the amount of that good, theorists expected to show that the amounts of most goods a consumer would buy are decreasing functions of price--functions that are precisely specified once the shape of the utility curves is known.

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[12]Ibid.

[13]W. Edwards, "The Theory of Decision Making," Psychological Bulletin 51 (April 1954): 381.

Edwards reviewed the numerous attempts by classical theorists to derive empirical marginal utility functions and some of the complexities that led to the eventual abandonment of the approach.[14]

A new era in decision theory began with the publication in 1944 of Von Neumann and Morgenstern's book, Theory of Games and Economic Behavior.[15] The authors modified the classical approach to utility by requiring that an individual can completely order probability combinations of states. This simple modification led to the concept of expected utility. For example, suppose an individual is indifferent between a certainty of $5.00 and a 60-40 chance of winning $7.00. It can be assumed that these two alternatives have the same utility. If the utility of $0.00 is defined as 0 utiles (units of utility) and the utility of $7.00 as seven utiles, we have assigned the two arbitrary constants in a linear utility transformation. Then the utility of $5.00 can be calculated by using the following concept of expectation:

$$\begin{aligned} U(\$5.00) &= 0.6\ U(\$7.00) + 0.4\ U(\$0.00) \\ &= 0.6(7) + 0.4(0) \\ &= 4.2 \end{aligned}$$

By varying the odds and using the linear transformation already determined, it is possible, in principle, to determine the utility of any other amount of money. In a classical paper on decision theory, Edwards, Lindman, and Savage characterized the Von Nuemann and

[14] Ibid.

[15] J. Von Nuemann and O. Morgenstern, Theory of Games and Economic Behavior (Princeton, N.J.: Princeton University Press, 1944).

Morgenstern theory as the "decision-theoretic formulation of statistical inference," and reviewed some of the scientists, such as Wald, Neyman, and Pearson, who championed that theory.[16] The mood of decision theorists during that period was to act on the basis of a decision determined from a point estimate of a parameter such as the expected value, $\bar{x}$, of a variable. The decision-theoretic approach was often successful in predicting human choice where money was the exchange, but suffered deficiencies when other commodities were tested. Like most decision theory before that time, predictions were more successful in risky situations than in uncertain situations. The inaccuracy of the theories is generally attributed to the failure to consider personal or subjective probability.

The most controversial new decision theory since about 1960 is grounded in Bayesian statistical inference. Bayesian statistics is said to have begun in 1959 with the publication of Probability and Statistics for Business Decisions by Robert Schlaifer. Edwards and his associates claimed that Bayesian statistics was a "reversion to the statistical spirit of the eighteenth and nineteenth centuries." Paradoxically, Bayesian statistics should not be confused with the theoretical viewpoint of the man for whom it is named, Thomas Bayes.

[16] W. Edwards, H. Lindman, and L. Savage, "Bayesian Statistical Inference for Psychological Research," Psychological Review 70 (May 1963): 193; A. Wald, "On the Principles of Statistical Inference," Notre Dame Mathematical Lectures, Vol. I (Ann Arbor: Edwards Brothers Press, 1942); J. Neyman, "Outline of a Theory of Statistical Estimation Based on the Classical Theory of Probability," Philosophical Transactions of the Royal Society 236 (1937): 333-380; E. Pearson and L. Savage, The Foundations of Statistical Inference: A Discussion (New York: John Wiley and Sons, 1962).

Edwards et al. stated that: "Bayesian statistics is so named for the rather inadequate reason that it has many more occasions to apply Bayes' Theorem than classical statistics has."[17]

The elements embraced by modern Bayesian decision theory, which distinguish it from earlier theory, are

1. the definition of probability as a particular measure of opinions of ideally consistent people,
2. the view of statistical inference as a modification of those opinions in light of evidence, with Bayes' Theorem specifying how such modifications should be made, and
3. the implication that the rules governing when data collection stops are irrelevant to data interpretation.

This thought represents a radical departure from the classical concept of probability as the limit of the frequency of occurrence of events, the classical approach to hypothesis testing based on the outcome of an experiment without regard to prior probabilities, and classical experimental design in which data collection is carefully planned and terminated before interpreting the data. This new philosophic attitude opens the door to consideration of subjective or personal probability, at least a priori. The potential for a workable theory of individual decision making under uncertainty is increased.

The mathematical sophistication and experimental testing of this new approach to decision theory are still undeveloped. Classical statisticians now recognize this new approach, even though it has

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[17]Ibid.

not received unanimous endorsement.[18] Neither the Bayesian approach nor any other decision theory to date adequately predicts human behavior in individual decision making under uncertainty.

Enthusiasm for the success of decision-making theory in economic goods or consumer choice situations tends to obscure some of the apprehensions of behavioral scientists about the validity of expected utility, personal probability, and significance when value determinants are nonmonetary. Basic questions still remain, such as numerical combinations of probabilities and values, the assumption that individuals are always seeking to maximize utility, the psychological impact of risk and uncertainty on human behavior, and the cost of incorrect decisions.

This section presented a brief review of the chronological development of formal decision theories from the time of Aristotle, 400 B.C., to the present. The impact of economic choice is obvious throughout the history of decision theory. Although several publications in the behavioral sciences, such as psychology, have been cited, the gain-loss variable in decision theory has still been mainly economic goods. The next section focuses on the assumptions of the theories of individual decision making.

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[18] R. Kirk, Experimental Design: Procedures for the Behavioral Sciences (Belmont, California: Brooks/Cole Publishing Co., 1968), p. 32; W. Hays, Statistics (New York: Holt, Rinehart and Winston Publishers, 1963).

Theories of Individual Decision Making

The method of theorists concerned with the theory of decision making was characterized by Edwards as the "armchair method."[19] They make assumptions and from them deduce theorems that presumably can be tested. One such theory is The Theory of Riskless Choices, sometimes called the theory of economic man. It is assumed that anyone who makes a decision to which this theory applies is an economic man. The properties of an economic man are:

1. He is completely informed about all courses of action open to him and what the outcome of each action will be.

2. He is infinitely sensitive. It is assumed that the alternatives available to him are continuous and infinitely divisible, and that prices are also infinitely divisible.

3. He is rational. Rationality implies two things--that the decision maker can weakly order the states of nature and that he makes his choices in order to maximize something. This property of rationality has led to a bulk of formal theorizing in economics, psychology, and management science. The theory of utility has developed in an effort to lend structure to the ordering of preferences. Sophisticated techniques, such as linear programming, have developed to facilitate maximization.

The Theory of Risky Choices is thought to have originated with Von Neumann and Morgenstern's Theory of Games and Economic Behavior,

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[19] W. Edwards, "The Theory of Decision Making," Psychological Bulletin 51 (April 1954): 381.

published in 1944.[20] Since, under conditions of risk, the outcome of actions is known to the decision maker only in a probabilistic way, the assumption of complete information is violated. The Theory of Risky Choices assumes:

1. The decision maker can completely order probability combinations of states of nature.
2. He will act so as to maximize the expected value (average value) of utility of outcomes.

This theory has generated much activity, mostly under the title of game theory or gambling. Luce and Raffia made a classical presentation of such theories.[21] Halter and Dean presented empirical examples from agriculture and natural resources of risky decision making.[22]

The other category of individual decision making is decision making under uncertainty. Under uncertain conditions, the decision maker does not know the state of nature at the time of choice, the probability of a given state of nature, or what states of nature are associated with what available actions; in an extreme case, he may not even be conscious of all possible states of nature or alternative actions. The extreme situation would be one of mathematically "unbounded" variables and psychologically "complete ignorance." No consistent theory exists to predict behavior under these conditions.

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[20]Ibid.

[21]R. D. Luce and H. Raffia, Games and Decisions (New York: John Wiley and Sons, 1965).

[22]A. Halter and G. Dean, Decisions Under Uncertainty (Chicago: Southwestern Publishing Co., 1971), p. 139.

Approaches to developing theory have been based on the assumption that the set of states of nature forms a mutually exclusive and exhaustive list of those aspects of nature that are relevant to the particular choice problem about which the decision maker is uncertain.

Earlier theorists attempted to modify the Theory of Decision Making Under Risk to predict decision making under uncertainty, by introducing the notion of subjective or personal probability.[23] The notion attempts to use the decision maker's personal a priori probability over the states of nature in place of an objectively arrived at probability distribution function.

The logical validity of the notion of subjective probability has drawn serious criticism. Bayesian decision theorists have accepted the use of subjective probability a priori and applied Bayes' theorem to calculate conditional probabilities to aid in a posteriori evaluation of the chance of events occurring. Empirical techniques for determining subjective probability functions have been slow to gain the approval of many decision theorists, and have failed to survive.

One might begin to wonder at this point if it is not impossible to predict the behavior of individual decision makers under uncertainty, because of the ignorance of the decision maker about the possible states of nature and the probabilities associated with those states. Cannon and Kmietowicz discussed this problem and alternatives for conducting research in spite of the lack of an objectively

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[23]S. V. Vail, "Alternative Calculi of Subjective Probability," in Decision Processes, ed. R. Thrall, C. H. Coombs and R. L. Davis (New York: John Wiley and Sons, 1955).

verified theory.[24] Researchers make the basic assumption that administrators, in an uncertain environment, do not operate in complete ignorance but bring some a priori knowledge to bear on the choice situation. Having made this assumption, one can draw on the work of theorists such as Luce and Raffia and Halter and Dean for a theoretical conceptual framework of decision making under partial ignorance and the use of a priori information.[25]

Halter and Dean used Bayes' formula in the decision-making framework, to provide a means of expressing conditional probability. Given two sets of not mutually exclusive events, A_1 and A_2, then

$$P(A_2/A_1) = \frac{P(A_1 \cap A_2)}{P(A_1)}$$

where $A_1 \cap A_2$ is the union of the two sets (Figure 10).

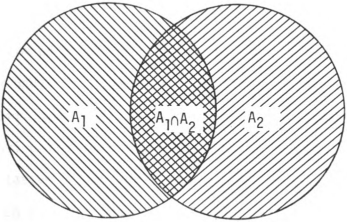

Figure 10.--Two sets of not mutually exclusive events.

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[24]C. M. Cannon and Z. W. Kmietowicz, "Decision Theory and Incomplete Knowledge," The Journal of Management Studies, October 1974, p. 224.

[25]Ibid.

Also $P(A_1/A_2) = \frac{P(A_1 \cap A_2)}{P(A_2)}$

Now if E is any subset of A made up of one or more of the subsets A_i, and the subsets $E \cap A_i$, (i=1,n), are mutually exclusive and exhaustive of E, then

$$P(E) = \sum_{i=1}^{n} P(E \cap A_i) = \sum_{i=1}^{n} P(A_i)\, P(E/A_i)$$

and in Bayes' formula

$$P(A_j/E) = \frac{P(E \cap A_j)}{P(E)}$$

and

$$P(A_j/E) = \frac{P(A_j)\, P(E/A_j)}{\sum_{i=1}^{n} P(A_i)\, P(E/A_i)}$$

This form of Bayes' formula can be used in the development of decision theory under uncertainty with partial ignorance. A body of theory has developed, which is based on different strategies using the Bayesian a priori probability approach. This mathematical theory is useful if quantitative values for the probabilities can be obtained. The Bayesian approach can also be used to develop a conceptual activity model of individual decision making under uncertainty.

An example of the application of Bayes' formula to which most readers can relate is deciding which card has been drawn from a standard poker deck. If a standard deck of poker cards is shuffled thoroughly, spread on a table face down, and one card drawn from the deck, a participant might be required to determine which card has been drawn. The participant knows the card drawn is one of a set of fifty-two cards. Let us call this set A. Based on this a priori information, the probability of the participant making the correct choice is 1/52. Set A can be further divided into subsets according to suit, color of suit, number on the card, face cards, or sex of face cards. A likely list of subsets might be:

A_1 = aces

A_2 = kings

A_3 = queens

A_4 = jacks

A_5 = tens

A_6 = nines

A_7 = eights

A_8 = sevens

A_9 = sixes

A_{10} = fives

A_{11} = fours

A_{12} = threes

A_{13} = twos

These subsets are mutually exclusive. Any card chosen can belong to only one of the subsets. If mapped in set space such as in Figure 10, there would be no overlapping. At this point the participant has no information with which to improve his chance of making the correct choice. Let us assume the participant decides that the card drawn was the queen of hearts. This is a preliminary decision; the participant is likely to seek more information before making a final choice.

Assuming that an unbiased observer peeks at the card and tells the participant the card drawn is a heart, the participant can now focus his attention on a subset, E, of the larger set, A, which contains only thirteen cards, namely hearts. A list of subsets, E, is

E_1 = hearts

E_2 = spades

E_3 = clubs

E_4 = diamonds

The union of E_1 with subsets A_1 to A_{13} is exhaustive of E_1, in that all of the elements of E_1 are accounted for.

Bayes' formula can be used to calculate the probability of the queen of hearts being the correct choice, given the new information. The probability is given by

$$P(A_3/E_1) = \frac{P(A_3)P(E_1/A_3)}{\sum_{i=1}^{13} P(A_i)P(E_1/A_i)}$$

where A_3 = queens

E_1 = hearts

and $P(A_i)$ = 1/13

$P(A_3)$ = 1/13

$P(E_1/A_3)$ = 1/4

$P(E_1/A_i)$ = 1/4

The probability of the queen of hearts being the correct choice is

$$\frac{(1/13)(1/4)}{13(1/13)(1/4)} = 1/13$$

At this point, the participant must choose between the queen of hearts as a final choice or seeking more information to increase the probability of his final choice being the correct one.

Related Studies in Individual Decision Making Under Uncertainty

A search of the literature revealed much discussion of the theoretical and axiomatic approaches to prediction of decision processes, but a relative dearth of experimental or quasi-experimental studies on the subject. Soelberg, in a study of members of the graduating class of the Sloan School of Management at MIT, investigated "how individuals make important, difficult, and highly judgemental decisions."[26] Soelberg used an expanded model of Simon's characterization of the decision process with the following structural phases:

1. Participation--the decision maker (Dm) is induced to work in a given task environment, in which he is motivated to attain one or more nontrivial objectives.
2. Recognition and definition--Dm surveys his task environment and then discovers, selects, or is provided with the particular problem he intends to devote his resources to solving.
3. Understanding--In a search for solution alternatives, Dm investigates his task environment to formulate and test

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[26] P. Soelberg, "Unprogrammed Decision Making," Studies in Managerial Process and Organization Behavior, ed. J. H. Turner, A. C. Filley and R. J. House (Glenview, Illinois: Scott, Foresman and Co., 1972).

hypotheses about the apparent cause-effect relationships in the environment.

4. Design--Dm develops or searches for alternative courses of action for solving his problem.
5. Evaluation--Dm assigns some sort of value measure to the estimated consequences of his perceived decision alternatives.
6. Reduction--Dm reduces his set of viable decision alternatives to a single one.
7. Implementation--Dm introduces and manages his decision solution in the task environment.
8. Feedback and control--Dm receives and evaluates information from the task environment.

Soelberg used the task of finding a job as the decision to be resolved. Results of the study indicated that

1. The search for new alternatives terminated before the time at which subjects reported having made a decision.
2. Two or more acceptable alternatives were selected before terminating the search.
3. Great uncertainty about the final choice existed at the termination of the search.
4. Most subjects made final choices that had been independently identified as their choices before reporting the decision.

5. No subject reported a reduction in dissonance in his liking for accepted versus rejected alternatives immediately following the decision.

Soelberg cited as implications of his research the multidimensionality of utility, personal probability, and the parallel and continuous form of the human decision process. His findings are consistent with the theoretical concepts on which the model of the present study is based. Soelberg's findings also imply that the decision maker tends to focus his activity on interacting with the real world to gain information from which to formulate alternatives at one time, and at other times he focuses on a simple decision strategy for the final choice.

Morlock studied the effect of outcome desirability on the amount of information required to make a decision.[27] In repeated decision tasks, subjects were allowed to acquire as much information as necessary to make a decision in which the subject knew in advance the outcome and payoff for a correct decision. The outcomes were known to be desirable or undesirable, with associated risks. Findings indicated that, under moderate levels of difficulty, less information was required to decide that a desirable event would occur. These findings imply that the confidence the decision maker associates with quantitative information is related to the utility of such information as perceived by the individual.

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[27] H. Morlock, "The Effect of Outcome Desirability on Information Required for Decisions," Behavior Science 12 (June 1967): 296.

Porat and Haas, in an experiment dealing with the effects of initial information and feedback on goal setting and performance, tested three hypotheses:

1. The more specific information a decision maker has, the more accurate will be his levels of aspiration and decision.
2. The setting of goals will be a function of previous goals and comparative experiences in similar organizations.
3. Decision makers with less specific information initially will exhibit a higher rate of learning.[28]

The information was quantitative data about the firm in which the subject was presumably operating. Hypothesis 1 was not rejected, although there was an indication that the marginal utility of additional information declined with an increase in quantity. Hypothesis 2 was not rejected, but difficulties with the data analysis made the outcome questionable. Hypothesis 3 was not rejected. Based on profit in the industrial firm, subjects with little initial information showed a greater improvement than did those with more initial information. This trend was most obvious when no information was compared with information, which led the researchers to point out the difficulty of assessing incremental information effects. The research cited tends to imply that quantitative management information has a measurable effect on the decision-making process of the individual under uncertainty.

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[28]A. Porat and J. Haas, "Information Effects on Decision Making," Behavioral Science 14 (December 1969): 98.

Preston and Baratta, in an experimental study at the University of Pennsylvania, examined the relationship between the price individuals were willing to pay for prizes and expected payoff of the prizes in an uncertain environment.[29] A deck of forty-two cards was marked with six prize values and seven corresponding probabilities for each prize. Subjects were given a fixed sum of money at the beginning of the experiment. The cards were randomly auctioned to the highest bidder and the actual payoff determined by the roll of dice. Results of the data analysis indicated that subjects were willing to pay more than the mathematically calculated payoff for low-probability prizes and less than the mathematically calculated payoff for high-probability prizes. This behavior was independent of the cash value of the prizes, and was consistently demonstrated by college students, mathematicians, psychologists, and statisticians. The indifference point fell at approximately 0.20 on the probability scale. The researchers concluded that subjects conceived the probabilities associated with prize payoffs differently than the mathematically expected payoff. The difference was attributed to psychological probability, which the researchers defined as that probability which must be used to bring the price paid into rational relationship with the prize.

Cummings and Harnett conducted experimental studies at the University of Indiana, aimed at determining the effects of information

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[29] M. G. Preston and P. Baratta, "An Experimental Study of the Auction-Value of an Uncertain Outcome," American Journal of Psychology 61 (February 1948): 183.

on bargaining behavior in decision making.[30] The researchers attempted to simulate the effects of real-world variables in a bargaining paradigm. The subjects were placed in a three-channel bargaining relationship such as manufacturer, wholesaler, and retailer, and were provided with different amounts of information under controlled communication conditions. Results indicated that:

1. For bargaining in a channel relationship, a bargainer had no profit advantage in being completely informed if his bargaining opponents were completely uninformed.
2. The less information available in the channel, the greater the impact of risk-taking propensity on bargaining behavior.
3. In the superior-subordinate relationship, a bargainer who was provided with complete information regarding the other party's possible monetary rewards had a more realistic bargaining attitude.
4. Allowing the bargainers to communicate with one another influenced bargaining in a manner similar to the effect of information.

In a study at the University of Minnesota, Chervany and Dickson investigated the problem of information overload.[31] Graduate students in the School of Business were provided with quantitative management information about the operation of an industrial manufacturing firm in

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[30]L. L. Cummings and D. L. Harnett, "Managerial Problems and the Experimental Method," Business Horizons, April 1968.

[31]N. L. Chervany and G. W. Dickson, "An Experimental Evaluation of Information Overload in a Production Environment," Management Science 20 (June 1974): 1335.

the typical raw data format and in the form of statistical summaries. During a weekend of intensive training and decision making, experimental gaming was used to evaluate the decision outcomes of groups receiving the two types of information. Minimization of operating costs, time required to make decisions, and subject confidence in the decisions made were the experimental measures. Results indicated that subjects who used the statistically summarized information had significantly lower operating costs than did the subjects who used raw data, showed less variance in operating costs than did subjects who used raw data, but had less confidence in their decisions than did subjects who used raw data. Subjects using the statistically summarized management information took more time to make decisions than did their counterparts using the raw data.

Most studies reported in the literature used the same type of management information with variation in the amount of information, exchange of information, or the search for information. The present study is the first known to examine the effect of different kinds of information--quantitative versus nonquantitative. The study of Chervany and Dickson is similar, but both information treatments were quantitative, according to the definition given in Chapter I.

The studies reported here show a definite bias toward the use of the experimental method in research on the behavior of individuals in decision making under uncertainty.

Cummings and Harnett urged more use of experimentation in research on management-type problems.[32] The experimental design

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[31]Ibid.

presented in Chapter III is aimed at investigating the effect of quantitative management information on the generation and selection of alternatives in an uncertain decision environment.

CHAPTER III

THE EXPERIMENTAL DESIGN

At the founding conference of the Society for Management Information Systems held at the University of Minnesota, management information systems professionals were asked to rank twenty-six potential research projects. The two projects receiving the highest ranking, according to Chervany and Dickson, were:

1. development of methods for determining what the content of an information system should be, and
2. investigation of the characteristics of decision makers that affect MIS design.[1]

The content of an information system is measurable on several dimensions. One of the dimensions is the quantitative or nonquantitative form in which operational data are presented to the user. The experiment of this dissertation was designed to evaluate the effect of information treatments on the generation and selection of alternatives in individual decision making in an uncertain environment. A theoretical activity model is developed, research questions posed, procedures described, data analysis techniques explained, and the data collection instrument presented in this chapter.

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[1]N. L. Chervany and G. W. Dickson, "An Experimental Evaluation of Information Overload in a Production Environment," Management Science 20 (June 1974): 1335.

Theoretical Model of Individual Decision-Making Activity

The research of this dissertation was grounded in the theory of decision making. Most of the theoretical developments in decision making have been reported in the journals of psychology, economics, statistics, management science, and business administration. A review of the history, theories, and experimental studies from the literature was presented in Chapter II.

The field of decision making can be classified on two dimensions:

1. decision making--individual or group
2. conditions--certainty, risk, or uncertainty

The three conditions are:

a. Certainty--if each action is known to lead invariably to a specific outcome.

b. Risk--if each action leads to one of a set of possible specific outcomes, each outcome occurring with a known probability.

c. Uncertainty--if either action or both has as its consequences a set of possible specific outcomes whose probabilities are completely unknown or are not even meaningful.

Figure 11 shows the resulting matrix of decision activities that could be studied.

The present study is concerned with Type-C decisions, individual and uncertain. The rationale for this choice was twofold:

1. a belief that implementation of MIS requires an understanding of the possible impact on administrative behavior, and
2. a belief that the condition of uncertainty is more descriptive of the environment in which educational administrators live and work.

	Certainty	Risk	Uncertainty
Individual	Type-A	Type-B	Type-C
Group	Type-D	Type-E	Type-F

Figure 11.--Decision activity matrix.

In summary, this study concerns <u>individual decision making under conditions in which any action has as its consequences a set of possible specific outcomes, but where the probabilities of these outcomes are completely unknown or are not even meaningful and the decision maker might not even be conscious of all possible outcomes</u>.

The example of the application of Bayes' formula to decision making in Chapter II was a Type-B decision--individual decision making under risk. The application of Bayes' formula in the decision-making process under uncertainty is not so easily or clearly demonstrated. A model developed by this researcher to relate the formula to the decision-making process under uncertainty is shown in Figure 12. The model depicts the closed loop decision-making process an individual uses in an uncertain environment. The model allows for an unspecified number of possible states of nature in the real world, represented by s_1, s_2, s_3 ... s_n. Through interaction with the real world, events occur whose outcomes o_1, o_2, o_3, ... o_n provide information for the decision maker. The information may be acquired directly or provided by analysts, subordinates, administrators, or other sources. It may be quantitative or nonquantitative information. This information affects the decision maker's perceived probability of the possible states of nature, $P(s_j)$; his perceived probability of the outcome given the particular state of nature, $P(o_i/s_j)$; the alternative actions available, a_1, a_2, a_3, ... a_n; and the utility (value) associated with the given actions for a particular state of nature. The individual combines the a priori probability, $P(s_j)$, and the conditional probability of the outcome of the event, $P(o_i/s_j)$, according to Bayes' formula, to arrive at the new probability of the particular state of nature, $P(s_j/o_i)$, based on the new information. The decision maker replaces the original a priori probability, $P(s_j)$, with the new probability, $P(s_j/o_i)$. This probability is used in combination with alternative courses of action and the decision maker's utility of outcomes to form decision rules, or strategies, for the action to be taken or recommended. The choice may be tentative, with the decision maker returning to the real world to seek new information before making

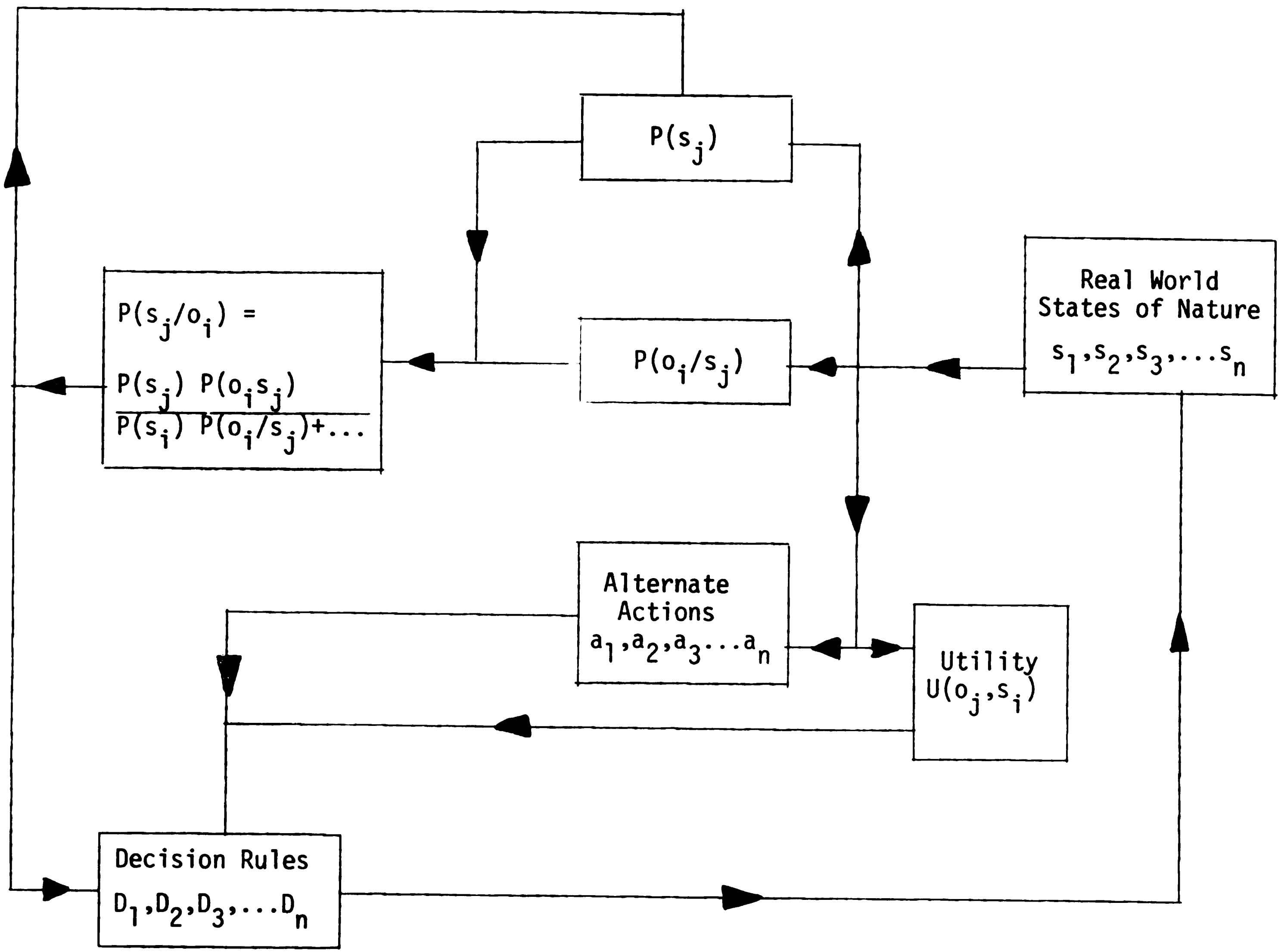

Figure 12.--Bayesian model for decision making.

a final choice, as was demonstrated in the card-choosing example of the previous section.

The model is a closed loop, so there is not necessarily any starting point or sequential path to follow. The decision maker may be at any point in the process at any time, and indeed may move in either direction in the process of finalizing a decision.

The primary function of Bayes' formula is to identify the modification of the decision maker's perceived probability of the states of nature in the real world to account for information obtained from the outcomes of events occurring or having occurred before the time of the decision. The probabilities need not be objective. The model is also descriptive of subjective, or personal, probabilities. Dean and Halter showed evidence from empirical examples of individual decision making under uncertainty in oil well drilling, agricultural crop selection, turkey farming, and livestock management that a combination of objective and subjective probability is often used in real life.[2]

Since this study concerns quantitative management information and its effects on the decision process, a partial list of points in the model where such information enters the process will demonstrate the usefulness of the model in the experiment.

1. The outcome of events occurring in the real world can be partially described in terms of quantitative parameters. In the

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[2]A. Halter and G. Dean, <u>Decisions Under Uncertainty</u> (Chicago: Southwestern Publishing Co., 1971).

university setting, such parameters might be course demand, student flow, attrition rates, economic forecasts, and employment profiles.

2. The utility associated with particular states of nature can be quantified on some dimensions. In universities, parameters such as tuition income based on enrollment patterns, athletic profits based on sports activities, and legislative income based on FTE student enrollment are readily quantifiable.

3. Alternative actions are, for the most part, quantitatively presented. In the college environment, parameters such as admissions criteria, program changes, publicity budgets, recruiting, and staffing changes are very quantifiable.

Areas in which quantitative information exerts influence in establishing parameters and their magnitudes but where the primary functions are more likely to be subjective are:

4. Formulating probability functions for possible states of nature. Although quantitative data on the outcome of events occurring in the real world are taken into consideration by the decision maker, intuition, judgment, experience, political perceptions, hunches, and "gut-level" feelings are likely to be heavily weighed in shaping personal probabilities.

5. Formulating conditional probabilities of states of nature is likely to involve considerable judgment on the part of the decision maker. This same problem is faced by researchers in the use of hypothesis testing based on experimentation. The decision maker, like the researcher, subjectively assigns confidence criteria to the empirical information about the states of nature.

6. The application of Bayes' formula seems to be a highly objective process, but this is a deceptive viewpoint. Even if the decision maker had assigned quantitative values to each of the a priori and posterior probabilities in the formula, there is still the problem of which terms will be included in the summation of conditional probabilities in the denominator. In other words, how many states of nature are relevant to the matter about which the individual is uncertain? Also, how many states of nature can a human be cognitively aware of at one time? March and Simon proposed the concept of "limits of cognitive rationality," which implies that an individual can only attend to a limited number of things at any given time.[3] This places limits on how many conditional probabilities are included in the weighting factor to determine posterior probability.

7. Decision rules (or strategies) can seldom be quantitatively stated and are likely not to be pure strategies but some form of mixed strategy. This is especially true in higher education, where goals and subgoals are seldom explicitly stated (or even known) by the decision maker.

Some strengths and limitations of the model should be recognized. Limitations are:

1. The model does not show the parallel or multidimensioned activity that the human mind is capable of engaging.

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[3] J. G. March and H. A. Simon, Organizations (New York: John Wiley and Sons, 1958).

2. The model implies discrete paths for moving from one activity to another, when in actual practice the individual may skip haphazardly from point to point at will.
3. The model does not rank activities in terms of time spent or relative contribution to the decision process.

Strengths are:

1. The model is simple. It reduces a complex process to a relatively simple and manageable framework.
2. The model is explicit. Relationships among different activities in the decision process are functionally demonstrated. Discussion of the decision process is facilitated without the limitations of verbal communication.

Grayson, in discussing the procedures on which the model is based, observed:

> . . . But even if such procedures are not adopted in total now, the mere discussion of them may help operators (1) to realize the problems that they are now handling implicitly in their minds, and (2) to think about them in a more formal manner.[4]

3. The model is continuous, so that no starting or ending point is implied. This is consistent with intuitive feelings about human behavior. Complex decisions seldom are discrete and independent of the past or future. Action is often stimulated by exogenous demands such as time deadlines, resource depletion, or demands from superiors.

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[4] C. J. Grayson, Decisions Under Uncertainty: Drilling Decisions by Oil and Gas Operators (New York: Plimpton Press, 1960).

This model presents the theoretical-conceptual framework for the experiment.

Research Questions

So little research has been published on the subject of individual decision making under uncertainty that this study is considered exploratory. For this reason, the research hypotheses are stated in the form of questions rather than as null hypotheses. The question framework of stating research hypotheses allows more flexibility to explore whatever results the data might reveal.

The problem being investigated in the study is the effect of quantitative management information about the state of an uncertain environment on the generation and selection of alternative actions in the individual decision-making process in that environment. Previous research has indicated that early activity in the decision-making process under uncertainty focuses on the search for alternative actions and the reduction to two or more acceptable alternatives before terminating the search. This activity involves examination of the environment by the decision maker to obtain information about possible states of nature and the testing of hypotheses about the probability of states of nature in the environment as a result of the decision to be made.

This study seeks answers to the questions:

1. Is there any difference in the number of alternative actions generated by the individual decision maker in an uncertain environment because of the effect of quantitative management information

as compared to nonquantitative management information or no management information?

2. Is there any difference in the number of alternative actions selected by the individual decision maker in an uncertain environment because of the effect of quantitative management information as compared to nonquantitative management information or no management information?

3. Is there any difference in the number of alternative actions generated by an individual decision maker under uncertain conditions because of the combination of quantitative and nonquantitative management information when compared to the use of either type separately?

4. Is there any difference in the number of alternative actions selected by an individual decision maker in an uncertain environment because of the combination of quantitative and nonquantitative management information as compared to either type separately?

5. Is there any difference in the distribution of alternative actions selected by individual decision makers in an uncertain environment because of the effect of quantitative management information when compared to nonquantitative management information or no management information where the distribution variate is a randomly ordered nominal set of alternatives representative of a reference distribution?

The methodology and data analysis are aimed at extracting answers to these questions from the experimental data.

Experimental Procedure

The methodology of this study was experimentation, as compared to the field study or case study. So many variables are involved in complex human behavior such as individual decision making, that causal inference is nearly impossible in the real-world environment. Experimentation allows the researcher to limit the influence of some variables not related to the one being tested. The effect of related variables can be minimized by randomization or accounted for in the analysis of data. This study is not pure enough to attempt causal inference, so some theorists, such as Stanley, would call it quasi-experimental.[5]

The subjects used in the experiment were college students in business curricula. Subjects were randomly assigned to four treatment groups; an equal number of subjects was assigned to each group to maintain a balanced design.

Each subject was instructed to read a narrative description of the decision situation and the general environment in which the decision must be made. Subjects in individual treatment groups were instructed as follows:

Treatment Group #1

Subjects were given quantitative management information about the decision situation and instructed to read the information first, then list as many alternative actions to resolve the decision problem as they could think of at the time.

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[5]D. T. Campbell and J. C. Stanley, Experimental and Quasi-Experimental Designs for Research (Chicago: Rand-McNally and Co., 1966).

Treatment Group #2

Subjects were given nonquantitative management information about the decision situation and instructed to read the information first, then list as many alternative actions to resolve the decision problem as they could think of at the time.

Treatment Group #3

Subjects were given the same management information as treatment groups 1 and 2; they were instructed to read the information first and then list as many alternative actions to resolve the decision problem as they could think of at the time.

Treatment Group #4

Subjects were instructed to list as many alternative actions as possible to resolve the decision problem, based on the initial narrative description, without the aid of any management information.

While retaining the list of alternative actions, each treatment group was asked to select from the list of alternative actions only those considered acceptable for resolution of the decision problem. The subjects were not aware of the categorization of the management information before or during the conduct of the experiment.

Techniques for Analysis of the Data

The matrix of raw data collected is shown on the following page.

Treatment Groups

Subjects	#1 Quantitative	#2 Nonquantitative	#3 Both	#4 No Management Information
X_1	a_{111} a_{112} . . .	a_{121} a_{122} . . .	a_{131} a_{132} . . .	a_{141} a_{142} . . .
X_2	a_{211} a_{212} . . .			
. . .	. . .	. . .	. . .	. . .
X_n	a_{n11} a_{n12} . . .			

where a_{ijk} = the kth alternative of the ith subject in treatment group j

n = number of subjects in each treatment group

$N = 4n$ = total number of subjects

Let Y_{ij} = number of alternatives generated by subject i in treatment group j.

Then $M = \sum_{i=1}^{n} \sum_{j=1}^{4} Y_{ij}$ = total number of alternatives generated by all subjects.

$Q_j = \sum_{i=1}^{n} Y_{ij}$ = the number of alternatives generated by subjects in treatment group j.

$M_j = \frac{Q_j}{n}$ = average number of alternatives generated by subjects in treatment group j.

A similar raw data matrix was obtained for the selection of alternative actions.

Because of the open-ended responses of subjects in the experiment, it was expected the raw data would reveal that the same alternative would be stated differently by individual subjects. This duplication was removed by mapping the raw data set onto a smaller set of alternatives by grouping apparently equivalent alternatives into a single alternative statement. Figure 13 shows how such a reduction can be made. The precision of this reduction challenges the skill of the experimenter in much the same way that the use of measuring instruments challenges the skill of the physical scientist. Subjectivity is minimized by favoring a large set of alternatives with fewer original alternatives grouped together, rather than attempting to make minute distinctions among responses. The form of the data matrix remains the same; the number of alternatives in each cell might be reduced.

The method of planned comparisons was used to analyze the number of alternatives generated and selected by individuals in the different treatment groups. This method, as described by Hays, allows the

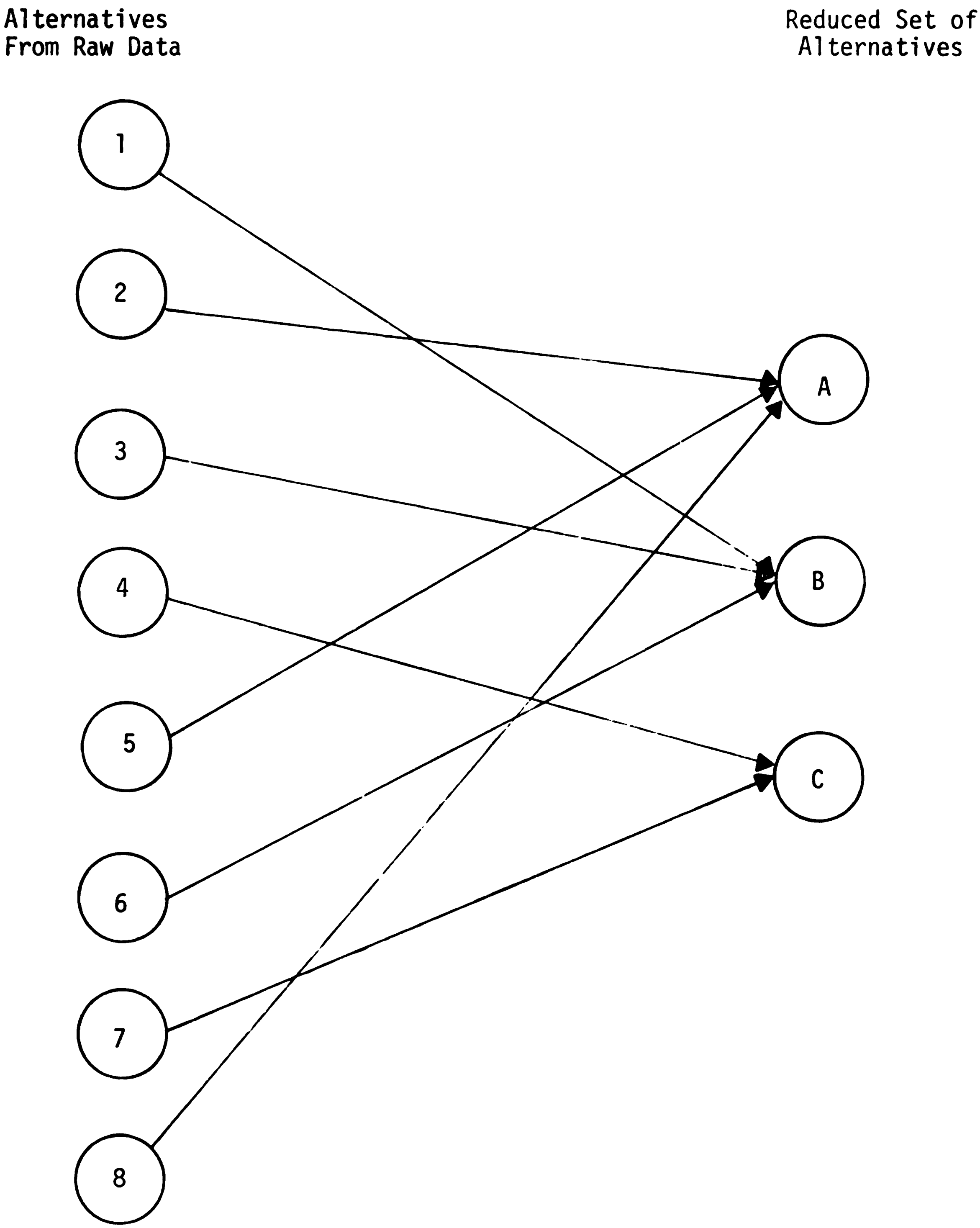

Figure 13.--Example of the reduction of original alternatives.

researcher closer examination of the data than does the traditional analysis of variance.[6] Instead of analyzing the data to see if any overall effects exist, the use of planned comparisons allows the researcher to examine a number of specific effects separately.

The basic theory underlying the planned comparisons technique is that, given normally distributed variables sampled independently and at random, values from any linear combination of those random variables will also be normally distributed. Furthermore, if the mean and variance for each variable are known, then the mean and variance of the sampling distribution of the linear combination are also known. Weighted, linear combinations of the treatment means were compared to determine if there were any significant differences. The comparison equation

$$\psi = c_1\mu_1 + c_2\mu_2 + \ldots = \sum_j c_j\mu_j = 0$$

was used so that each comparison value would be independent of the grand mean of the population.

One comparison equation was associated with each linear combination of means contrasted. Each sample mean was multiplied by a weighting coefficient and summed with other means of interest to the researcher. Table 5 shows the weighting coefficients applied for each of the comparisons. The matrix of weighting coefficients is orthogonal; that is

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[6] W. L. Hays, Statistics (New York: Holt, Rinehart and Winston, 1965), p. 459.

$$\sum_{j=1}^{6} c_{1j}\, c_{2j} = 0$$

for any two rows of the matrix.

Table 5.--Orthogonal weighting coefficients for comparison of means.

Comparison	Generation of Alternatives by Treatment Groups				Selection of Alternatives by Treatment Groups			
	#1	#2	#3	#4	#1	#2	#3	#4
1	1	-1	0	0	0	0	0	0
2	0	0	0	0	1	-1	0	0
3	-1/2	-1/2	1	0	0	0	0	0
4	0	0	0	0	-1/2	-1/2	1	0
5	-1/3	-1/3	-1/3	1	0	0	0	0
6	0	0	0	0	-1/3	-1/3	-1/3	1

The selection of an orthogonal set of weighting coefficients enhances statistical independence of the comparisons. There is no redundancy in the comparisons.

Comparison 1 asks if there is any difference between the average number of alternative actions generated by subjects in treatment groups 1 and 2.

Comparison 2 asks if there is any difference between the average number of acceptable alternatives selected by subjects in treatment group 1 when compared with subjects in treatment group 2.

Comparison 3 asks if there is any difference between the average number of alternatives generated by subjects in treatment groups 1 and 2 when compared with subjects in treatment group 3.

Comparison 4 asks if there is any difference between the average number of acceptable alternatives selected by subjects in treatment groups 1 and 2 when compared with subjects in treatment group 3.

Comparison 5 asks if there is any difference between the average number of alternative actions generated by subjects in treatment groups 1, 2, and 3 when compared to subjects in treatment group 4.

Comparison 6 asks if there is any difference between the average number of acceptable alternative actions selected by subjects in treatment groups 1, 2, and 3 when compared with subjects in treatment group 4.

Statistical Computations

The expected value of ψ was calculated from the sample means and the weighting coefficients according to the equation

$$E\ (\hat{\psi}) = \sum_j c_j\ E\ (m_j)$$

where m_j is the mean of the sample population in the comparison.

The variance of $\hat{\psi}$ as calculated from the sample data is

$$VAR\ (\hat{\psi}) = \sigma_e^{\ 2} \sum_j \frac{c_j}{n_j}^{2}$$

where σ_e^2 is the variance of each sample population and is estimated from MS_{error}, or mean square error within, calculated from analysis of variance. So

$$VAR\ (\hat{\psi}) = MS_{error} \sum_j \frac{c_j}{n_j}^2$$

where c_j is the weighting coefficient and n_j is the number of samples included in the mean.

Statistical inference was based on the t-test with a confidence interval determined by

$$\hat{\psi} - t_{(\alpha/2,\ \nu)} \sqrt{VAR\ (\hat{\psi})} \le \psi \le \hat{\psi} + t_{(\alpha/2,\ \nu)} \sqrt{VAR\ (\hat{\psi})}$$

where the value of $t_{(\alpha/2,\ \nu)}$ represents the value cutting off the upper $\alpha/2$ portion of sample values in a distribution of t with ν degrees of freedom. The number of degrees of freedom is the same as the degrees of freedom of the MS_{error} calculation.

The nondirectional t-test was used, or

$$H_o : \psi = 0$$

is the usual test hypothesis for planned comparisons. The test statistic is

$$t = \frac{\hat{\psi}}{\sqrt{VAR\ (\hat{\psi})}}$$

with N-4 degrees of freedom, where N = total number of subjects in the experiment.

A problem inherent in multiple planned comparisons is that if an experimenter makes C independent comparisons among means, the probability of obtaining at least one significant comparison by chance alone is given by $1 - (1 - \alpha)^c$, which is approximately equal to αc for small values of α. If α = 0, 05 is used and three comparisons are made as planned in this study for alternatives generated, then the probability of a spurious significant result is 0.15 or fifteen times in 100 attempts. Kirk discussed this problem and presented techniques to offset the inherent deficiencies.[7] Multiple planned comparisons result in a Type I error larger than the confidence interval associated with each comparison. Techniques developed to offset the increased Type I error result in an increase in Type II error, because of the increase in width of the confidence interval beyond that of the t-test. For the experiment of this proposal, Dunn's table was used to determine the confidence interval, so that the confidence level of $\alpha = 0.05$ would be evenly distributed over all comparisons. The conceptual unit for experimental error was the experiment and not the individual comparison. This established the Type I error at 0.05 for generation of alternative actions and 0.05 for the selection of acceptable alternative actions.

The earlier analysis of the data focused on the number of alternative actions generated and the number of alternative actions selected by comparisons of the means of each treatment group. The planned comparisons technique used in this analysis was based on the assumption of a normal distribution of the sample means. This assumption was based on the "Central Limit Theorem," independent of the

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[7] R. E. Kirk, Experimental Design: Procedures for the Behavioral Sciences (Belmont, Calif.: Brooks/Cole Publishing Co., 1968), p. 78.

distribution of the number of alternatives within each treatment group. The Central Limit Theorem states that

> If a population has a finite variance, σ^2, and a finite mean, μ, then the distribution of sample means from samples of N independent observations approaches a normal distribution with variance σ^2/N and mean μ as sample size, N, increases. When N is very large, the sampling distribution of M is approximately normal.

Nothing is said in this theorem about the form of the population distribution. The theorem is quite applicable for sample sizes as small as ten.

A comparison of the distribution of selected alternatives by treatment groups violates the assumptions of the usual statistical analysis techniques. The response variable (alternative selected) is not measurable on an interval scale. Only weak nominal measurement can be claimed. Any deterministic ordinal measurement would require subjective assignment by the experimenter. The assumption of normality would be weak, at best. A nonparametric, distribution-free technique is required to achieve comparison of the distribution of alternatives across the different treatment groups. An analytical technique that can be used is "RIDIT" analysis. The first three letters stand for "relative to an identified distribution." The technique is based on the probability integral transformation theorem. Its development grew out of efforts at Cornell University in 1958 to apply the rank t-test to a study of automotive crash injuries, where the severity of injuries could not be measured on an interval scale but could be grouped and subjectively rank ordered.[8] The technique employs average quantile ranking and is closely related to the Wilcoxon Rank Test.

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[8] I. D. Bross, "How to Use RIDIT Analysis," Biometrics, March 1958, p. 18.

The first step in the use of RIDIT is choosing an identified distribution to act as a reference. The mechanics of the calculations involved in obtaining RIDIT values from the reference distribution is demonstrated in Table 6.

Table 6.--Calculation of RIDIT values.

	COLUMNS[a]					
	(1)	(2)	(3)	(4)	(5)	(6)
ALTERNATIVES	A	1	0.5	0	0.5	0.0096
	B	12	6	1	7	0.1346
	C	8	4	13	17	0.3269
	D	4	2	21	23	0.4423
	E	11	5.5	25	30.5	0.5865
	F	0	0	36	36	0.6923
	G	4	2	36	38	0.7308
	H	9	4.5	40	44.5	0.8557
	J	3	1.5	49	50.5	0.9711

[a]Column 1 = the alternative selected.
Column 2 = the frequency distribution of the identified group.
Column 3 = one-half of the frequency of column 2.
Column 4 = the cumulate of column 2 displaced one line downward.
Column 5 = sum of columns 3 and 4.
Column 6 = the RIDIT value of each alternative derived by dividing column 5 entries by the total number of observations in the group.

The hypothetical reference distribution shown in Table 6 might be from treatment group 1. Each alternative action selected in the other treatment groups would be assigned the numerical RIDIT value from column 6 of Table 6. Standard statistical tests can now be used for the comparison of the distributions of the other treatment groups with the distribution of treatment group 1.

The theoretical basis for ridit analysis is quantile ranking. The quantile is the proportion of observations lying below the corresponding integer rank (adjusted upward one-half unit). For data measured on a nominal scale, such as in the proposed study, objective rank ordering is often impossible, but for purposes of calculation, an artificial integer rank can be assigned to each category on the nominal scale. The ridit value is the average quantile rank of all observations in a given category.

Kantor et al. published an analytical interpretation of the ridit as a quantile rank.[9] Kantor's equation for calculating the ridit value is

$$Q_R = \frac{M_j - 0.5}{n}$$

where M_j is the median integer rank of observations in a category if each observation was individually ranked, and n is the total number of observations in the sample distribution.

Interpretation of ridit analysis was described by Bross as a statement about the "probability of a probability."[10] For this study, imagine that treatment group 1 is chosen as the reference group for

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[9] S. Kantor, W. Winkelstein, and M. Ibrahim, "A Note on the Interpretation of the RIDIT as a Quantile Rank," American Journal of Epideminology 87 (June 1968): 609.

[10] Ibid.

calculating ridit values to be assigned each alternative action selected. The average ridit of the reference group is always 0.5. The average ridit for the distribution of alternatives selected in treatment group 2 could be determined by assigning ridit values calculated from treatment group 1 to each alternative selected in treatment group 2 and finding the statistical average in treatment group 2. The difference between the two average ridits would be calculated. Probability odds can then be derived from the equation

$$P = \frac{0.5 + d}{1 - (0.5 + d)}$$

where d is the numerical difference between the average ridit for the reference distribution and the test distribution.

Imagine that, for the example just cited, the average ridit for treatment group 2 was determined to be 0.38. Then d = 0.5 - 0.38 = 0.12 and p = (0.5 + 0.12) / (1 - (0.5 + 0.12)) = 1.63. Thus the odds are 1.63 to 1 that an individual chosen at random from treatment group 2 would select a lower ranked alternative than would an individual chosen at random from treatment group 1. Bross verified, from empirical studies, that 95 percent confidence intervals can be placed on the mean ridits from a distribution by adding (subtracting) $1/\sqrt{3N}$ where N is the total number of observations.

Multiple comparisons of all treatment groups with the reference group can be determined and plotted very conveniently on the same graph for interpretation at the 0.05 confidence level. Figure 14 shows an example of a hypothetical graph from the proposed study. From this hypothetical graph, one would tend to conclude that the distribution of treatment group 4 was not different from the distribution of the reference group, but that treatment groups 2 and 3 had significantly different distributions. It must be remembered that ridit analysis was used in this study to compare the distributions of alternatives selected across treatment groups, where alternatives were measured on a nominal scale. In summary, the analysis of distributions of alternatives was performed by using treatment group 1 as the reference distribution from which ridit values were determined. The distribution of selection of alternative actions in the other treatment groups was compared to the reference distribution. Upon examination of the graph of the average ridits, other treatment groups were chosen as the reference distribution and multiple comparisons performed.

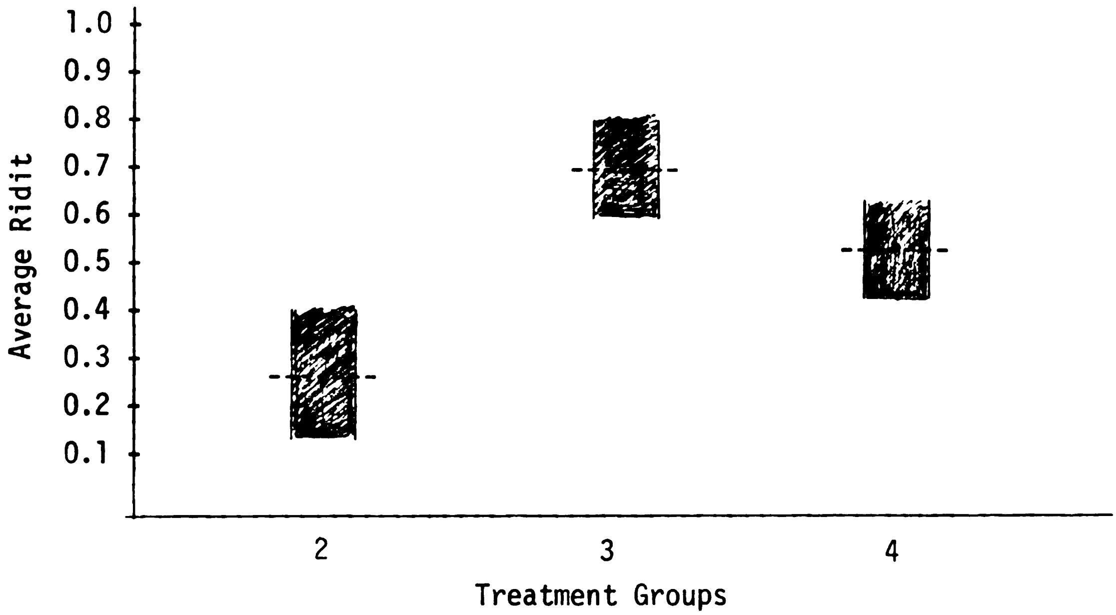

Figure 14.--Graph of average ridits using treatment group 1 as a reference.

For this study, integer rank was randomly assigned to the alternative actions selected. This did not affect the outcome of comparisons of the distribution of alternatives but eliminated the subjective influence of the experimenter in rank ordering and focused on the comparisons for which the experiment was designed.

Possible Outcomes of the Experiment

This study was previously identified as exploratory, because of the lack of a body of research to draw upon. It is appropriate, however, to anticipate some of the possible outcomes and their implications for further study. The results of the planned comparisons between the average number of alternatives generated across treatment groups and the average number of alternatives selected across treatment groups can be diagrammed in matrix form (see Figure 15). Eight possible outcomes must be considered.

If the test on ψ_3 was significant, the experimenter would conclude that the use of management information does make a difference in terms of the number of alternative actions generated (selected), and the examination of outcomes A, B, C, and D would take on added importance. If the test on ψ_3 was not significant, the experimenter would have no reason to believe that the use of management information made any difference, at least when equally weighted, and further examination of outcomes E, F, G, and H might offer some insight about why no significant difference was observed. This might suggest that a study of unequal weighting of information types would be a logical next step. If the test on ψ_3 was significant and the test on ψ_1 was significant,

		ψ_3			
		Significant		Not Significant	
		ψ_2		ψ_2	
		Significant	Not Significant	Significant	Not Significant
ψ_1	Significant	A	B	E	F
	Not Significant	C	D	G	H

ψ_1 = comparison of quantitative and nonquantitative information

ψ_2 = comparison of both quantitative and nonquantitative information used together with the use of each one separately

ψ_3 = comparison of no management information with the weighted use of other combinations of quantitative and nonquantitative management information.

Figure 15.--Possible outcomes of the experiment.

the experimenter would conclude that it does make a difference whether quantitative or nonquantitative management information is used in the generation (selection) of alternatives in a complex, uncertain environment. If the tests on ψ_3 and ψ_1 were both significant, the experimenter would then examine whether the test on ψ_2 was significant. If the latter was significant, the experimenter could conclude that the difference between the use of quantitative and nonquantitative management information in the generation (selection) of alternatives is a result not only of the type of information used but also of the interaction between the types of information. If the test on ψ_3 was significant but the test on ψ_1 was not significant, then the experimenter would question whether some interaction between the use of quantitative and nonquantitative information had contributed to the significance of the test on ψ_3. Significance of the test on ψ_2 would tend to indicate that there was some interaction. Further study would be suggested to determine the nature of the interaction. If the test on ψ_2 was not significant, then the experimenter might conclude that interaction did not contribute to the significance of the test on ψ_3 and that further study should concentrate on the difference between the two types of information.

The results of analysis would allow the experimenter to examine the nature of any differences or lack of differences in the distribution of alternatives selected by subjects under different information treatments. The combination of number of alternatives and the distribution of alternatives allows the experimenter to extract more information from the data. One possible outcome would be if the experimenter concluded there was a significant difference in the number of alternatives selected by subjects in treatment group 1 compared to treatment group 2, but also found that the distribution of alternatives selected was the same in both treatment groups. This might suggest that time spent in the selection of alternatives was a confounding factor, or that some other confounding factor contributed to the rate of selection of alternative actions.

Upon examining differences in the distribution of alternative actions selected, some observable objective or subjective characteristics might provide insight about where further study might be most useful.

Instrument for Collection of the Data

Each subject in the experiment was instructed to read the general description of a higher education environment in which a decision must be made. The decision problem was the reduction of academic programs to decrease the operating budget of a college to compensate for a reduction in money available for the next academic year. Three different groups of subjects were given additional instructions on the use of chosen management information and asked to respond with alternative actions from which final choices might be made. A fourth control group was provided no additional management information and was also asked to respond with alternative actions. Written, open-ended responses were sought concerning the subject's generation and selection of alternative actions.

The instrument consisted of five parts:

Part I --Introduction

Part II --General Instructions

Part III--Alternative Actions to Be Taken

Part IV --Selected Alternatives

Part V --Personal Data

Appendix A contains a complete copy of the instrument. A brief description of each part is presented here.

Part I--Introduction

This part of the instrument explains the general nature of the experiment to the subject.

Part II--General Instructions

This part of the instrument provides general instructions, presents a general description of the decision environment, and provides the subjects with the appropriate management information.

Part III--Alternative Actions to Be Taken

This part of the instrument instructs the subject to list all of the alternative actions he can think of to be considered in reaching a final decision, based on the information provided.

Part IV--Selected Alternatives

This part of the instrument instructs the subject to select from the list of alternatives generated in Part III those that he finds most acceptable, based on the information provided.

Part V--Personal Data

This part of the instrument requests a limited amount of personal data to allow the researcher to establish a profile of the subject population. Subjects are also asked to indicate which items of information influenced their responses in the experiment. Space is provided for any additional comments.

The information given to the treatment groups consisted of combinations of quantitative and nonquantitative information about the decision problem. The control group was given no additional information.

Figure 16 shows the combination of information given to each treatment group. Appendix A contains the complete instrument given to subjects in treatment group 3. Items 1 through 6 contain quantitative information. Items 11 through 15 contain nonquantitative information. There were no items numbered 7 through 10. The instruments were identified by coded letters. Subjects were not provided the code and did not know the information treatment of any given instrument.

	Treatment Group			
	1	2	3	4
Quantitative Information	X		X	
Nonquantitative Information		X	X	
No Additional Information				X

Figure 16.--Combinations of information given to treatment groups.

The raw data collected in the experiment and the results of the analysis of the raw data are presented in the following chapter.

CHAPTER IV

ANALYSIS OF THE RESULTS

Objective of the Research

The present research was intended to contribute to the understanding of the decision-making activity of individuals in an uncertain environment. An experiment was designed to investigate the effects of quantitative management information on the generation and selection of alternatives by individual decision makers in an uncertain environment. Analysis of the results of the experiment is intended to answer five basic questions:

1. Is there any difference in the number of alternative actions generated by the individual decision maker in an uncertain environment as a result of quantitative management information as compared to nonquantitative management information or no management information?

2. Is there any difference in the number of alternative actions selected by the individual decision maker in an uncertain environment as a result of quantitative management information as compared to nonquantitative management information or no management information?

3. Is there any difference in the number of alternative actions generated by an individual decision maker under uncertain conditions as a result of the combination of quantitative and

nonquantitative management information when compared to the use of either type separately?

4. Is there any difference in the number of alternative actions selected by an individual decision maker in an uncertain environment as a result of the combination of quantitative and nonquantitative management information when compared to the use of either type separately?

5. Is there any difference in the distribution of alternatives selected by individual decision makers in an uncertain environment as a result of quantitative management information when compared to nonquantitative management information when the distribution variate is a randomly ordered nominal set of alternatives representative of a reference distribution?

The method of planned comparisons was used to analyze the results of the experiment for questions 1, 2, 3, and 4. RIDIT analysis of the distribution data was used for question 5.

Raw Data

Subjects in the experimental study were randomly assigned to four treatment groups. Each subject was given a general description of the decision situation (see Appendix A) and a specific type of management information. The four information treatments were:

1. Quantitative management information
2. Nonquantitative management information
3. Quantitative and nonquantitative management information
4. No management information

Management information was categorized as quantitative if it met the following criteria:

1. The variables on which data measurements were made were, in principle, naturally quantifiable.
2. The format in which the data were presented did not alter the information content.

Any management information not meeting these two criteria was categorized as nonquantitative.

The instrument used to collect the data consisted of the general description of the decision situations, the appropriate management information, and the response sheets (see Appendix A). The subjects were asked to provide open-ended responses to the decision problem in two parts. First responses were the alternative actions generated by the subjects based on the general description of the decision situation and the management information provided by the researcher. Second responses were the alternative actions selected from the list of alternative actions generated by the same subject.

Subjects were instructed to work individually so that no group interactive effects contaminated the data.

The sample population chosen for the experiment was a group of senior and graduate students enrolled in a large course in General Business. The class met on Monday, Wednesday, and Friday for one and one-half hours at each meeting. In-class conduct of the experiment, preferable to the researcher, would have consumed a large portion of the class meeting time. As an alternative method, students were given the data collection instruments and asked to return them at the next class meeting if they wished to participate in the research effort. Distribution of the instruments was handled by the regular classroom instructors. Approximately 115 instruments were distributed at the first class meeting of the semester. Twenty-three instruments were returned within one week. A notice was placed on the class bulletin board and a verbal announcement was made by the instructor requesting return of the instruments. Approximately forty instruments were returned by the end of the third week. A telephone campaign was implemented and personal requests aided in securing the return of additional instruments. Soliciting the eighty instruments required to complete the experiment took approximately eight weeks.

Because of the open-ended responses, subjects stated the alternative actions differently. Apparently equivalent alternative actions were grouped into a single alternative statement constructed by the researcher. Subjectivity was minimized by favoring a large set of alternative actions rather than attempting to make minute distinctions among subject responses. An example of how a group of alternative actions was reduced to a single statement of an alternative action by the researcher is shown below:

<u>Original alternative actions</u>

- reduce the number of faculty
- use more part-time faculty
- eliminate graduate assistants
- reduce the number of part-time faculty

<u>Alternative action structured by the researcher</u>

- reduce the number of faculty

All of the responses of subjects were grouped into eleven alternative actions, as shown in Table 7. For identification purposes, numbers were associated with each alternative action. Only categorical grouping of alternative actions was intended. No criterion for ordinal or interval measurement was available. The alternative actions generated by each subject in each treatment group are shown in Table 8. The alternative actions selected by each subject in each treatment group are shown in Table 9. These two tables contain the raw data collected during the conduct of the experiment.

Table 7.--Set of alternative actions generated by subjects.

Alternative Number	Alternative
2	Control faculty research and travel expenses
3	Reduce expenses proportionately across the board
4	Control costs of library and computer services
5	Reduce number of faculty
6	Reduce number of administrators
7	Reduce courses and programs
8	Control all salaries
9	Control equipment costs and operating expenses
10	Reduce student financial aid
11	Increase student/teacher ratio
12	Increase institutional income

Table 8.--Raw data for alternatives generated.[a]

Subject	Treatment Group 1	Treatment Group 2	Treatment Group 3	Treatment Group 4
1	7,11,5,2	5,9,7,3	3,9,7,6,11,5	3,5,7,8
2	8,9,7,3	3,7	5,8,11,4,9,6	3,7,5,4,8
3	6,10,7,5,11	11,5,9,8,3, 10,7,2,4	5,9	9,2,5,4,10
4	3,11,5,7,10	2,9,11,8,4	10,2,9,8,5	5,11,7,3,9
5	3,5,6,7,4,9	9,5,3,2,12,10	9,8,7	3,7,10,4,9
6	11,7	11,9,7	5,6,8,7,11,9 2,10,4	8,10,7
7	3,5,9,8,7, 10,4,6	11,10,12,5, 3,7,8,9	7	3,8,6,5,9,11
8	8,5,9,11,2	3,5,8,2	3,5,2,10	5,11,2,9,4
9	3,5,8,12	3,7,9	3,5,11,4,2, 8,9,10	11,9,10,2,7
10	12,4,9,2,10, 5,6	7,8	9,5,7	3,8,5,6,7,9,11
11	7,4,8,9,10	10,11,5,2,9, 7,6,4	5,8,2	3,6,9
12	2,3,8,5,10	5,2,9,6,11, 4,7	6,8,7,11,2, 10,3,5	5,2,9,4
13	3,5,6,9,7,8 4,10,2	2,9,4,6	8,4,9,10,2,3	2,8,9,3
14	5,11,6,9,8, 3,10,2,4	7	3,5,11,2	8,2,9,10,4,5,6
15	8,4,9,7,11	11,10,2,8, 9,7	5,8,6,3,11, 12,4,9	3,5,8,10,2,9,11
16	11	7,5,8,4,9,10	3,11,5,6,9	2,9,11,5,6,7,4,8
17	2,10,4,5	9,8,3,7,6,2,4	5,7,8,2	8,5,10,9,6
18	5,3,11	11,9,4,10,8,2	8,5,6,2,4, 10,7	3,9,12,7
19	3,8,7,5,10, 11,9,2	11,5,9,10,6,8	5,6,4,9,10, 12	2,10,9,4,11,7,5
20	11,5,10,4	7,12	8,4,5,9,12	5,6,11

[a]Numbers in each cell indicate the alternative actions as identified in Table 7.

Table 9.--Raw data for alternatives selected.[a]

Subject	Treatment Group 1	2	3	4
1	5	5,9,7	9,8,5,6	7
2	8,9,7,3	8,5,11,10,2,3	5,11,8,4,6	7,5
3	12,11,6,10, 7,5	8,2,9,11,5, 10,4	5,9	2,10,5,6,3
4	7,11,5,2	11,2,4,9	10,2,9,8,5	9,3
5	5,6	3	9,8,4	3
6	7	11,9	9,2,5,12	10,7
7	8,5,4	10,5,3	7	8,5,9,3
8	12,11	3	2,5	11,5,2
9	3,8	9	8,11,9,2,10,5	11
10	12,2,10	7,8	9,5,7	8,2,9,4,10,7
11	7,4,9,8,10	7,9,6,11,4, 10,2,5	8,5	3
12	10,2,5	5,2,9,6	6,8,7,11	5,4,9,2
13	5,6,9	2,9,4,6	3,5,6,4,9,2	3
14	5,7,8	11	8,11,3	2,8,5,10
15	8,4,9,7	11,7,10,8,2	3,5,6	9,2,5,11
16	7,11	9,4,7,5	3,5,9,2	7,6
17	10,4,5	9,7	5	5,9,6
18	5,11	11,9,4,10, 8,2	5,6,8,2,7	9,7,12
19	8,3	11,5,10,6,8	4,9	2,10,9,4,8
20	5,7,11	7,12	8,2	11

[a]Numbers in each cell indicate the alternative actions as identified in Table 7.

Planned Comparisons Analysis

Planned comparisons analysis of the mean number of alternatives generated and selected by each treatment group required a numerical count of the number of alternatives generated and selected by each subject. Table 10 shows the number of alternatives generated and selected by each subject. The data of Table 10 are taken from the raw data of Tables 8 and 9.

Three comparisons of the mean number of alternatives generated by subjects in the four treatment groups and three comparisons of the mean number of alternatives selected by subjects in the four treatment groups were required to answer the research questions. The mean number of alternatives generated and selected by subjects in each treatment group was determined by totaling the columns in Table 10 and dividing the total number of alternatives by twenty.

The sample comparisons were determined by the weighted sum of the sample means according to the equation

$$\psi = E\,(\hat{\psi}) = \sum_j c_j\, m_j$$

where ψ is the population comparison

$E(\hat{\psi})$ is the expected value of weighted sample comparisons

c_j is the weighting coefficient associated with sample j

m_j is the mean number of alternatives in treatment group j

The matrix of weighting coefficients for the three comparisons is shown in Table 11.

Table 10.--Number of alternatives generated and selected by subjects.

Subject	Alternatives Generated by Treatment Group				Alternatives Selected by Treatment Group			
	1	2	3	4	1	2	3	4
1	4	2	6	4	1	2	4	1
2	4	4	6	5	4	3	5	2
3	5	5	2	5	6	6	2	5
4	5	9	5	5	4	7	5	2
5	6	5	3	5	2	4	3	1
6	2	6	9	3	1	1	4	2
7	8	3	1	6	3	2	1	4
8	5	8	4	5	2	3	2	4
9	4	4	8	5	2	1	6	1
10	7	3	3	7	3	1	3	6
11	5	2	3	3	5	2	2	1
12	5	8	8	4	3	8	4	4
13	9	7	6	4	3	4	6	1
14	9	4	4	7	3	4	3	4
15	5	1	8	7	4	1	3	4
16	5	6	5	8	2	5	4	2
17	4	6	4	5	3	4	1	3
18	3	7	7	4	2	2	5	3
19	8	6	6	7	2	6	2	5
20	4	6	5	3	3	5	2	1

Table 11.--Weighting coefficients for planned comparisons.

Comparison	Weighting Coefficient			
	c_1	c_2	c_3	c_4
1	1	-1	0	0
2	-1/2	-1/2	1	0
3	-1/3	-1/3	-1/3	1

The sample comparisons for alternatives generated were:

comparison 1: $\hat{\psi} = 0.40$

comparison 2: $\hat{\psi} = 0.0$

comparison 3: $\hat{\psi} = -.050$

The sample comparisons for alternatives selected were:

comparison 1: $\hat{\psi} = -.650$

comparison 2: $\hat{\psi} = 0.125$

comparison 3: $\hat{\psi} = -.467$

Sample calculations are in Appendix B.

Statistical inference was based on student's t-test, modified by Dunn for multiple comparisons.[1] The confidence interval was determined by

$$\hat{\psi} - t' \left(\frac{\alpha}{2}, \nu, c\right)\sqrt{VAR(\hat{\psi})} \leq \psi \leq \hat{\psi} + t' \left(\frac{\alpha}{2}, \nu, c\right)\sqrt{VAR(\hat{\psi})}$$

where $t' (\frac{\alpha}{2}, \nu, c)$ was taken from Dunn's table with $\alpha = .05$, $\nu = 76$, and $c = 3$. The critical value of t' was 2.47.

[1]O. J. Dunn, "Multiple Comparisons Among Means," Journal of American Statistical Association 56 (December 1961): 52-64.

$VAR(\hat{\psi})$ was calculated from the equation

$$VAR\ (\hat{\psi}) = \sigma_e^2 \sum_j c_j^2/n_j$$

where σ_e^2 was estimated from MS_{error} calculation of one-way analysis of variance. Sample calculations and the ANOVA data are in Appendix B.

The calculated values of $VAR(\hat{\psi})$ are shown in Table 12. $VAR(\hat{\psi})$ represents the variance in the weighted sample comparison due to random variation in the number of alternatives generated or selected by all subjects in the experiment. The calculation of $VAR(\hat{\psi})$ is analogous to the calculation of pooled variance for the sum of normal random variates. Smaller values of $VAR(\hat{\psi})$ represent less variation in sample comparisons. From Table 12, there is less scattering of sample comparisons for alternatives selected than for those generated.

Table 12.--Calculated values of $VAR(\hat{\psi})$.

Comparison	Alternatives Generated	Alternatives Selected
1	0.3998	0.2743
2	0.2998	0.2057
3	0.2665	0.1829

The test statistic was

$$t = \frac{\hat{\psi}}{\sqrt{VAR(\hat{\psi})}}$$

for comparison 1, alternatives generated,

$$t = \frac{0.40}{\sqrt{0.3998}} = 0.633$$

Table 13 shows the value of the test statistic for all comparisons.

Table 13.--Test statistic for planned comparisons.

Comparison	Alternatives Generated	Alternatives Selected
1	0.633	-1.24
2	0.0	0.276
3	-0.097	-1.09

Larger values of the magnitude of the test statistic indicate a greater chance to reject the hypothesis that there is no difference between the means being compared. A test statistic value of 0.0, as for comparison 2, indicates that the weighted means are not different.

Significance was determined by comparing the calculated value of the test statistic with the two-tailed t-distribution with 76 degrees of freedom. If the absolute value of the test statistic was greater than the critical value of the t-distribution, 2.47, then the researcher inferred that there was a significant difference between the means being compared. Ninety-five percent of the time, the confidence interval for the sample comparison would include zero if the null hypothesis was true. Table 14 shows the confidence interval for each comparison.

Table 14.--Confidence intervals for planned comparisons.

	Generation of Alternatives
Comparison 1	$-1.162 \leq \psi \leq 1.962$
Comparison 2	$-1.352 \leq \psi \leq 1.352$
Comparison 3	$-1.325 \leq \psi \leq 1.225$
	Selection of Alternatives
Comparison 1	$-1.944 \leq \psi \leq 0.644$
Comparison 2	$-.995 \leq \psi \leq 1.245$
Comparison 3	$-1.523 \leq \psi \leq 0.590$

From Table 13, the absolute value of the test statistic is less than the critical value of 2.47 for all comparisons of means. Using the null hypothesis, $\psi = 0$, for all comparisons at the 95 percent confidence level, the null hypothesis cannot be rejected for any of the planned comparisons. Failure to reject the null hypothesis supports the conclusion that there is no difference between any of the comparisons of means under test. From Table 14, zero is well within the confidence interval for all comparisons. Again, using the null hypothesis $\psi = 0$ for all comparisons, there is not enough difference between any of the weighted means for rejection of the null hypothesis.

RIDIT Analysis of the Distributions of Alternatives

A comparison of the frequency distribution of alternatives generated by treatment groups using ordinary parametric techniques would have violated the assumptions of such techniques. The response variable was measurable only weakly on a nominal scale. At best, alternatives could be grouped subjectively into categories. Nonparametric ridit analysis has been developed for comparison of the distributions of categorically grouped variates and was used in the analysis of the current research.

Ridit analysis of the distribution of alternatives requires a tally of the number of times each alternative was generated or selected in each treatment group. Table 15 shows a bar chart of the number of times each alternative was generated and selected by subjects in treatment group 1. The length of the bars indicates the relative frequency of each alternative. Longer bars represent more frequent generation or selection of a given alternative. Tables 16, 17, and 18 show the same relative frequencies for treatment groups 2, 3, and 4, respectively. Visual inspection of the frequency distributions shows similarity between the distribution of alternatives generated and alternatives selected within each treatment group.

The frequency distribution of alternatives generated and those selected by treatment group 1 was used as the reference, or standard, against which other distributions were compared. Table 19 shows the ridit calculations for alternatives generated by subjects in treatment group 1. The ridit values of column 6, Table 19, were used to calculate the average ridit values for the distributions of treatment groups 2, 3, and 4. A comparison of their average ridit values with the average ridit value for treatment group 1 was used to determine if the distributions were significantly different.

Table 15.--Frequency distribution of alternatives generated and selected by treatment group 1.

	Alternatives Generated	Alternatives Selected
2	xxxxxxxx	xxx
3	xxxxxxxxxx	xxx
4	xxxxxxxxx	xxxx
5	xxxxxxxxxxxxxxx	xxxxxxxxxxx
6	xxxxxx	xxx
7	xxxxxxxxxxx	xxxxxxxxx
8	xxxxxxxxxx	xxxxxxx
9	xxxxxxxxxx	xxxx
10	xxxxxxxxxxx	xxxxx
11	xxxxxxxxxxx	xxxxxx
12	xx	xxx

Table 16.--Frequency distribution of alternatives generated and selected by treatment group 2.

	Alternatives Generated	Alternatives Selected
2	xxxxxxxxxx	xxxxxxxx
3	xxxxxxxx	xxxx
4	xxxxxxxx	xxxxxx
5	xxxxxxxxx	xxxxxxx
6	xxxxx	xxx
7	xxxxxxxxxxxxxx	xxxxxxx
8	xxxxxxxxxx	xxxxx
9	xxxxxxxxxxxxxxx	xxxxxxxxxxx
10	xxxxxxxx	xxxxxx
11	xxxxxxxxx	xxxxxxxx
12	xxx	x

Table 17.--Frequency distribution of alternatives generated and selected by treatment group 3.

	Alternatives Generated	Alternatives Selected
2	xxxxxxxxxxx	xxxxxxxx
3	xxxxxxxxx	xxxx
4	xxxxxxxxx	xxxx
5	xxxxxxxxxxxxxxxxxx	xxxxxxxxxxxxxx
6	xxxxxxxx	xxxxxx
7	xxxxxxxx	xxxx
8	xxxxxxxxxxxxx	xxxxxxxxxx
9	xxxxxxxxxxxxxx	xxxxxxxxxx
10	xxxxxxxxx	xx
11	xxxxxxxxx	xxxx
12	xxxxxxxx	x

Table 18.--Frequency distribution of alternatives generated and selected by treatment group 4.

	Alternatives Generated	Alternatives Selected
2	xxxxxxxxx	xxxxxxx
3	xxxxxxxxxx	xxxxxx
4	xxxxxxxx	xxx
5	xxxxxxxxxxxxxx	xxxxxxxxx
6	xxxxxxx	xxx
7	xxxxxxxxxx	xxxxxx
8	xxxxxxxxxx	xxxx
9	xxxxxxxxxxxxxxxx	xxxxxxxx
10	xxxxxxxx	xxxxx
11	xxxxxxxxx	xxxx
12	x	x

Table 19.--RIDIT calculations for alternatives generated by treatment group 1.[a]

Alternative	Frequency	Frequency/2	Cumulative Frequency	Mean Cumulative Frequency	RIDIT Value
2	8	4.0	0	4.0	0.0388
3	10	5.0	9	13.0	0.1262
4	9	4.5	18	22.5	0.2185
5	15	7.5	27	34.5	0.3350
6	6	3.0	42	45.0	0.4369
7	11	5.5	48	53.5	0.5194
8	10	5.0	59	64.0	0.6214
9	10	5.0	69	74.0	0.7185
10	11	5.5	79	84.5	0.8204
11	11	5.5	90	95.9	0.9272
12	2	1.0	101	102.0	0.9903

[a]See Table 6 for an explanation of column headings.

Average ridit values and 95 percent confidence intervals for the treatment groups were:

Treatment Group	R_{ave}	Confidence Interval
2	0.510	± 0.058
3	0.509	± 0.054
4	0.489	± 0.057

Sample calculations are in Appendix B.

A graphical plot of the average ridit values and their confidence intervals is shown in Figure 17. Interpretation of the data is similar to significance testing using the t-test. If the 95 percent confidence interval includes 0.5, then the researcher concludes that there is no significant difference between the reference distribution and the distribution being tested. If the confidence interval does not include 0.5, then the researcher concludes that the test distribution is significantly different than the reference distribution.

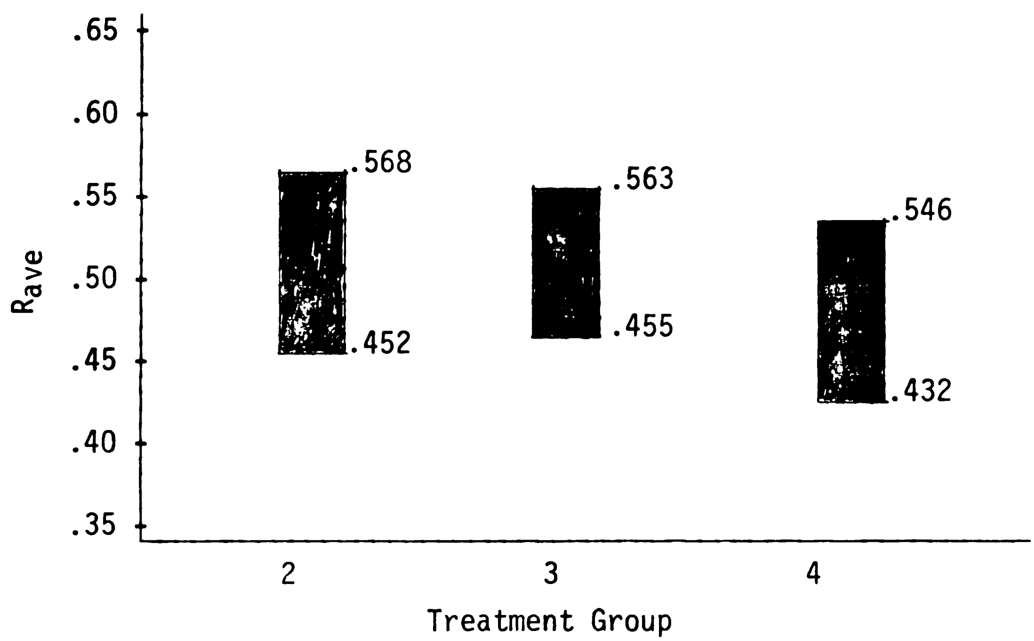

Figure 17.--R_{ave} vs. treatment groups for alternatives generated.

From Figure 17, the confidence interval includes 0.5 for all three test distributions. At the 95 percent confidence level, there was no difference between the distribution of alternatives generated by subjects in treatment group 1 and subjects in treatment groups 2, 3, and 4.

Average ridit values and their 95 percent confidence intervals for alternatives selected by subjects in treatment groups 2, 3, and 4 were:

Treatment Group	R_{ave}	Confidence Interval
2	0.483	± 0.076
3	0.430	± 0.070
4	0.437	± 0.077

A graphical plot of the average ridit values and their 95 percent confidence intervals is shown in Figure 18. The interpretation of the data was the same as for Figure 17.

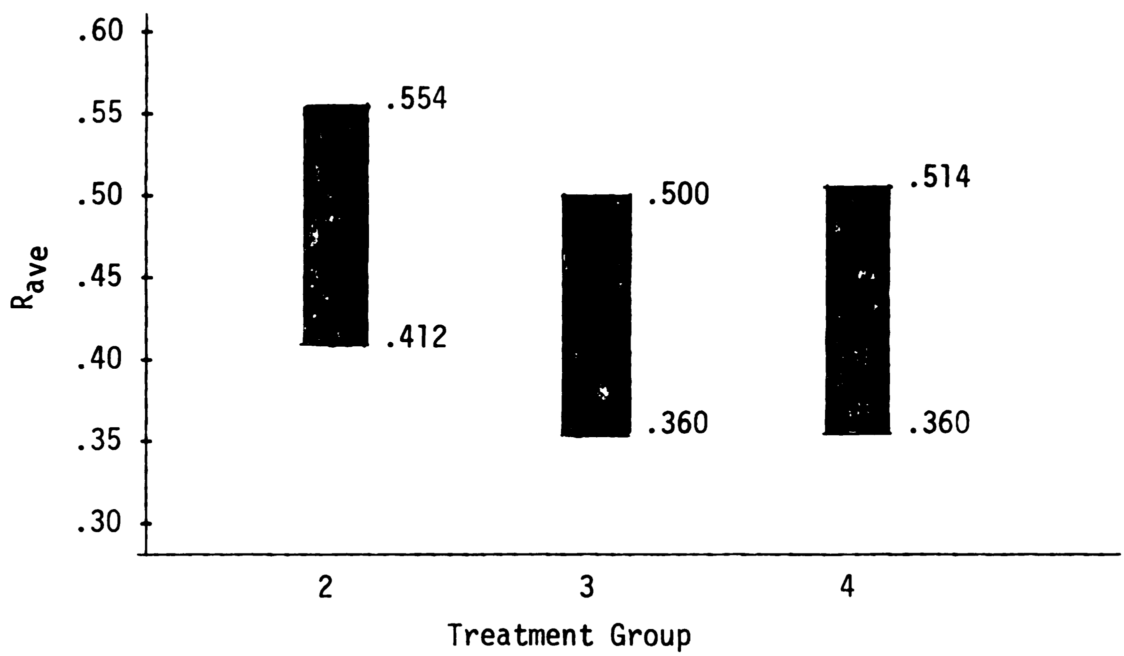

Figure 18.--R_{ave} vs. treatment groups for alternatives selected.

The distribution of alternatives selected by subjects in treatment group 3 was significantly different than the reference distribution of alternatives selected by subjects in treatment group 1 at the 95 percent confidence level. The distribution of alternatives selected by subjects in treatment group 4 bordered on significance but was not quite different than that of subjects in the reference group at the 95 percent confidence level. The distribution of alternatives selected by subjects in treatment group 2 was not significantly different than that of the reference group at the 95 percent confidence level.

Characteristics of the Sampled Population

Subjects used in the experiment were chosen from seniors and graduate students in the College of Business at Western Michigan University in the spring of 1975. Eighty students were randomly assigned to the four treatment groups; twenty subjects were assigned to each group. The number of subjects was determined to maintain a balance between the power of the statistical tests to detect any significant differences between the responses of the subjects in each treatment group and the researcher's desire to avoid detecting trivial differences not associated with the information treatment. Since the study was exploratory, the researcher was concerned with statistical association between alternatives generated and selected and the type of management information provided the subjects. This association is contained in but is not the same as a statistically significant difference between the means of treatment group parameters. The controlling factor between the two effects is the size of the sample. Large samples increase the power of statistical tests and increase the chance of detecting small differences at high confidence levels, but offer no assurance that the differences detected reflect an association among the variables of interest to the researcher. "Virtually any study," said Hays, "can be made to show significant results if one uses enough subjects, regardless of how nonsensical the content may be."[2] Hays developed an equation for relating sample size, statistical association, confidence level, power of the test, and normalized difference between means in a comparison situation such as t-tests:

$$n = \frac{[Z_{(1 - \alpha/2)} - Z_{\beta}]^2}{2 \left(\frac{\omega^2}{1 - \omega^2}\right)}$$

where Z is the cumulative normal probability

β is the desired power of the tests

ω^2 is the percentage of variation in the dependent variable accounted for by the independent variable

n is the size of the sample

For the present research, $\alpha = 0.05$; a reasonable value of $\beta = 0.5$ was used and $\omega^2 = 0.1$ was established as the minimum association in any significant difference detected by comparison of means of parameters of the treatment group responses. This level of association assured that at least 10 percent of any differences between means

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[2] W. L. Hays, Statistics (New York: Holt, Rinehart and Winston, 1963), p. 236.

would be a result of the effect of management information treatment and not entirely the result of variances in the treatment groups. Using these values, the minimum number of subjects per treatment group was calculated.

$$n = \frac{[1.96 - 0]^2}{2\left(\frac{0.1}{1 - 0.1}\right)} = 17.3$$

Each subject was asked to provide his age, sex, supervisory job experience, and class standing in the university. Table 20 shows a summary of those characteristics of the sampled population. Subjects were generally male, twenty-seven years old, equally divided between seniors and graduate students, and equally divided between having supervisory experience and not having such experience.

Table 20.--Summary of characteristics of the sampled population.

Treatment Group	Age		Class		Sex		Supervisory Experience	
	Ave.	Std. Dev.	Sr.	Grad.	Male	Female	Yes	No
1	27.6	6.3	11	9	18	2	11	9
2	26.0	5.1	8	12	16	4	11	9
3	29.3	6.1	9	11	5	5	8	12
4	26.9	5.3	7	13	18	2	9	11
Total	27.6	5.7	35	45	67	13	39	41

Correlation Matrix

Pearson correlation coefficients were calculated for the following variables: age, number of supervision courses, class standing, number of alternatives generated, and number of alternatives selected. The coefficients were calculated from the equation:

$$R = \frac{\sum_{i=1}^{N} (X_i - \overline{X})(Y_i - \overline{Y})}{\left\{\left[\sum_{i=1}^{N} (X_i - \overline{X})^2\right]\left[\sum_{i=1}^{N} (Y_i - \overline{Y})^2\right]\right\}^{\frac{1}{2}}}$$

where X_i is the ith observation of variable X

Y_i is the ith observation of variable Y

N is the total number of observations

$\overline{X}$ is the mean value of variable X

$\overline{Y}$ is the mean value of variable Y

The value of the correlation coefficient can vary between +1 and -1. Perfect positive correlation, r = +1, means that one variable is directly related to the other--as one increases the other also increases. Perfect negative correlation, r = -1, means that one variable is directly related to the other, but as one increases the other decreases at the same rate.

Guilford provided a guide for interpreting the degree of association represented by the correlation coefficient.[3]

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[3] J. P. Guilford, Fundamental Statistics in Psychology and Education (New York: McGraw-Hill, 1956), p. 145.

r less than 0.20	--	almost negligible relationship
r less than 0.4 but greater than 0.20	--	low correlation but definite relationship
r less than 0.7 but greater than 0.40	--	moderate correlation
r less than 0.90 but greater than 0.70	--	high correlation
r less than 1.00 but greater than 0.90	--	very high relationship, very dependable relationship

Table 21 shows the matrix of correlation coefficients by treatment groups. The complete matrix would be 5x5, with twenty entries. The matrix is symmetrical about the diagonal with all 1's on the diagonal. Only the lower left half of the correlation matrix is shown in Table 21. Entries in the matrix must be between +1.00000 and -1.00000. The Pearson correlation coefficient for two given variables is found at the intersection of the row and column in which the two variables are located. An example of the use of Table 21 is as follows:

> To find the correlation coefficient for alternatives generated and alternatives selected for subjects in treatment group 3, select column 1 and row 2. The entry at the intersection is 0.62900, the desired coefficient.

Consistently, the highest degree of correlation was between the number of alternatives generated and the number of alternatives selected except for subjects in treatment group 1, for whom less than 2 percent of the variance in one was attributable to the other. As could be expected, age of the subjects was positively related to class standing and the number of supervision courses the subjects had taken.

Table 21.--Pearson correlation coefficients by treatment groups.

		Alternatives Generated	Alternatives Selected	Age	# of Courses	Class
Tr. Group 4	Alt. generated	1.00000				
	Alt. selected	0.14612	1.00000			
	Age	-0.07117	-0.11049	1.00000		
	No. of courses	-0.11228	-0.24782	0.59403	1.00000	
	Class	0.09900	0.23877	0.50569	0.49489	1.00000
Tr. Group 3	Alt. generated	1.00000				
	Alt. selected	0.53507	1.00000			
	Age	0.30338	-0.04104	1.00000		
	No. of courses	0.01764	-0.24227	0.26813	1.00000	
	Class	0.39068	0.46551	-.36560	0.12942	1.00000
Tr. Group 2	Alt. generated	1.00000				
	Alt. selected	0.62900	1.00000			
	Age	0.15088	0.24785	1.00000		
	No. of courses	-0.07389	0.07525	0.25992	1.00000	
	Class	0.52877	0.17431	0.06036	-0.07083	1.00000
Tr. Group 1	Alt. generated	1.00000				
	Alt. selected	0.56010	1.00000			
	Age	-0.24057	-0.03964	1.00000		
	No. of courses	-0.10890	-0.08390	0.23148	1.00000	
	Class	-0.30843	-0.14215	0.60311	0.23374	1.00000

Other correlation coefficients could be considered negligible, using Guilford's guidelines.

Summary

Presented in Chapter IV were the raw data collected during the conduct of the experiment and the analysis of those data. Planned comparison analysis of the mean number of alternatives generated and selected by subjects in each treatment group was presented. Nonparametric ridit analysis of the frequency distributions of the alternatives was also completed. A summary of the characteristics of the sampled population was presented and rationalization of the chosen sample size was also provided. Analysis of the Pearson correlation coefficients of several variables concluded the chapter.

Chapter V contains a summary of the results of the study, conclusions and recommendations for future research, and the researcher's reflections on the present research.

CHAPTER V

THE PROBLEM, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS FOR FUTURE RESEARCH

The Problem

Increased demands for more efficient operation of higher education institutions have led to attempts to adapt management information systems to the control and planning function of these complex organizations. The integration of new management technology into the established management structure of colleges and universities has led to a variety of strategies for effective implementation. A search of the literature, however, revealed little evidence of basic research aimed at understanding the effects of new management systems and technology on the individual manager or how individual managers use such systems and technology. The present research focused on that area of the management function in which management information systems can aid the individual manager in meeting his responsibility to the complex organization--the decision-making process.

The problem investigated was the effect of quantitative management information about the state of an uncertain environment on the generation and selection of alternative actions in the individual decision-making process in that environment. The theoretical framework for the study was embodied in the Bayesian model derived from decision-making theory and supported by Soelberg's research.[1] The model characterizes the decision maker's search for alternative actions and the reduction to two or more acceptable alternatives when a decision must be made in an uncertain environment.

Findings

The present research sought the answers to five basic questions:

1. Is there any difference in the number of alternative actions generated by the individual decision maker in an uncertain environment as a result of quantitative management information as compared to nonquantitative management information or no management information?

2. Is there any difference in the number of alternative actions selected by the individual decision maker in an uncertain environment as a result of quantitative management information as compared to nonquantitative management information or no management information?

3. Is there any difference in the number of alternative actions generated by an individual decision maker in an uncertain environment as a result of the combination of quantitative and nonquantitative management information when compared to the use of either type separately?

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[1]P. Soelberg, "Unprogrammed Decision Making," in _Studies in Managerial Process and Organization Behavior_, ed. J. H. Turner (Glenview, Ill.: Scott, Foresman & Co., 1972), p. 135.

4. Is there any difference in the number of alternative actions selected by an individual decision maker in an uncertain environment as a result of the combination of quantitative and nonquantitative management information when compared to the use of either type separately?

5. Is there any difference in the distribution of alternative actions selected by individual decision makers in an uncertain environment as a result of quantitative management information when compared to nonquantitative management information or no management information where the distribution variate is a randomly ordered nominal set of alternatives representative of a reference distribution?

Planned comparison of the mean number of alternatives generated and selected by individual decision makers in an uncertain environment was used to investigate questions 1, 2, 3, and 4. Orthogonal planned comparisons of the mean number of alternatives generated by treatment groups given quantitative management information, nonquantitative management information, both types of management information, and no management information resulted in values of the test statistic less than the critical values. Examination of the confidence intervals showed that for the null hypothesis, $\psi = 0$, there was no question about failure to reject this hypothesis for all comparisons. The researcher concluded that:

1. There was no evidence of a difference in the number of alternative actions generated by individual decision makers in an uncertain environment as a result of the effect of quantitative

management information as compared to nonquantitative management information or no management information.

2. There was no evidence of a difference in the number of alternatives generated by individual decision makers in an uncertain environment as a result of the combination of quantitative and nonquantitative management information as compared to the use of either type separately.

Orthogonal planned comparisons of the mean number of alternatives selected by individual decision makers in the four treatment groups resulted in values of the test statistic less than the critical values, resulting in failure to reject the null hypothesis that the means were equal. Examination of the confidence intervals showed that the failure to reject was not so decisive as in the case of alternatives generated. The researcher concluded, based on present research, that:

1. There was no difference in the number of alternative actions selected by individual decision makers in an uncertain environment as a result of quantitative management information as compared to nonquantitative management information or no management information.

2. There was no difference in the number of alternative actions selected by individual decision makers in an uncertain environment as a result of the combination of quantitative and nonquantitative management information as compared to the use of either type separately.

The nonparametric ridit analysis technique was used to compare the distribution of alternatives selected by individuals provided quantitative management information with the distributions of alternatives selected by individuals in the other treatment groups. From a graphical plot of the 95 percent confidence intervals for all treatment groups, the researcher concluded that the distribution of alternatives selected by individual decision makers provided with both quantitative and nonquantitative management information was different than the distribution of alternative actions selected by individual decision makers provided with only quantitative management information. The distribution of alternative actions selected by individual decision makers provided no management information bordered on statistical significance, so the researcher suspended judgment about comparison with the distribution of alternatives by individuals provided only quantitative management information. The distribution of alternatives selected by individual decision makers provided only nonquantitative management information was not significantly different than the distribution of alternatives selected by decision makers given quantitative management information.

The Pearson correlation coefficient was calculated for the number of alternatives generated, the number of alternatives selected, and characteristics of the subjects in the sampled population. The population characteristics were age, class standing, and number of supervision courses taken before participation in the present research. Positive correlation was observed between the number of alternatives generated and the number of alternatives selected, except for the treatment group provided only quantitative management information.

Conclusions

The theoretical model of decision-making activity on which the present research was based characterized the decision maker's early search for alternative actions in an uncertain decision environment. The decision maker attempts to select from among the alternatives available those considered most acceptable, based on evaluation of the environment. The present research indicated that quantitative management information had no effect on the number of alternatives generated by the decision maker in the early search. There was no evidence that quantitative management information had any effect on the number of acceptable alternatives selected by individual decision makers in an uncertain environment. An average of five alternatives was generated and three alternatives selected regardless of the information treatment. The use of quantitative management information seemed to be coincidental with a scattering of the number of alternatives selected when compared to the number of alternatives generated by the same decision maker. Subjects who generated more alternatives tended to select more acceptable alternatives, except when quantitative management information was provided.

The results of the present research agreed with Soelberg's experience that individuals in an uncertain decision environment tend to reduce the alternatives available to two or more alternatives considered acceptable, based on evaluation of the environment. Written comments of the subjects in the experiment were consistent with Soelberg's observation that the decision maker was still quite uncertain about the acceptable alternatives selected.

One of the limitations of the present research was that subjects were given the information treatment before the generation or selection of alternative actions. There is some question about whether the subjects considered the information immediately before the selection of acceptable alternative actions. This could have accounted for considerable variance in the number of alternatives selected, thus making the effect of information treatment more difficult to detect.

The present research indicated that the number of alternatives generated was a predictor of the number of alternatives that would be selected except when quantitative management information was provided. This implies that the decision-making activity was affected by quantitative management information, but the experiment was not designed to investigate this apparent effect.

The distribution of alternatives selected by individual decision makers was different when quantitative and nonquantitative management information was combined, compared to the use of quantitative management information alone. This has implications for designers and practitioners of management information systems for higher education institutions. The present research was not designed to evaluate qualitatively which distribution was more desirable, but the presence of a difference suggests that further investigation is needed.

The present research indicated three significant relationships between quantitative management information and decision making that have not been published in current literature:

1. Quantitative management information had no effect on the number of alternatives generated or selected by individual decision makers in an uncertain environment when compared with nonquantitative management information or no management information.

2. Quantitative information appeared to be related to a scattering of the number of alternatives selected, compared to the number of alternatives available.

3. The distribution of alternatives selected by individual decision makers in an uncertain environment was affected by the combination of quantitative and nonquantitative management information when compared with the use of quantitative management information alone.

These relationships should be considered for further investigation.

Recommendations for Future Research

The present research suggested several areas for future research. The research failed to establish that quantitative management information had any effect on the generation of alternatives by individual decision makers in an uncertain environment. Further understanding of the effect of quantitative management information on the selection of acceptable alternatives requires that the experiment be duplicated with the information treatment introduced after the generation of alternatives. This design would tend to reduce the variance in responses of subjects because of the choice to consider or not consider the information treatment just before selection of alternatives. The researcher would also have additional analysis techniques available, such as analysis of covariance and pair-wise correlation, to aid in analysis of the data.

The present research was exploratory, so that subjects' responses were open ended. It is recommended that a finite set of alternatives be constructed and that some quantitative measure be associated with each alternative action so that more powerful parametric analysis techniques can be applied to the comparison of responses of the four treatment groups.

The evidence of the effects of combining quantitative and nonquantitative management information on the distribution of alternatives selected by subjects needs further investigation. A qualitative or quantitative evaluation of alternatives must be accomplished to allow for rank ordering of alternatives in some nonrandom manner. Techniques for the comparison of frequency distributions more powerful than ridit analysis can then be applied to determine the nature of the apparent difference in the distributions.

Reflections of the Researcher

The present research was undertaken as an exploratory study of the effects of quantitative management information on the individual decision maker in an uncertain environment. The researcher held no initial bias about the outcome. The results were quite conclusively in favor of the null hypotheses as far as the effect of quantitative management information on the number of alternatives generated and selected by the subjects in this uncertain environment. The researcher is willing to accept these findings with confidence. Those conditioned to equating successful research with rejection of null hypotheses will be concerned with the repeated failure to reject the hypotheses of this study.

Throughout the dissertation, emphasis has been on the role of management technology in the administration of higher education institutions. The primary interest of this researcher is in continuing education in higher education institutions. It is critically important that managers of continuing education programs in higher education institutions demonstrate efficient management of their resources and justify their decisions on allocation of those resources. Management information systems have the potential to be of valuable assistance to continuing education administrators if successful implementation can be achieved.

The instrument used for collection of the data required more of the subjects than any researcher should expect. The researcher apologizes for this imposition on his subjects. Future designers of experimental research in decision making in an uncertain environment must be more considerate of the subjects.

If the discussion of the present research, whether in agreement or disagreement, contributes to the further understanding of the effects of quantitative management information on decision making under uncertainty, and enhances the possibility of successful implementation of management information systems in higher education institutions, then the effort will be rewarded.

APPENDICES

APPENDIX A

INSTRUMENT FOR THE COLLECTION OF THE DATA

APPENDIX A

INSTRUMENT FOR THE COLLECTION OF THE DATA

Part I: Introduction

This is an experiment designed to gather data on the generation and selection of alternatives in decision making. It is based on a real situation that occurred on a college campus two years ago. Your responses will be analyzed statistically to determine the effects of information on the behavior of decision makers. Do not put your name on any of the documents used in the experiment.

The validity of the results of this project depends on the sincerity of your responses. Please concentrate.

Part II: General Instructions

Given a decision situation in a college environment, you are asked to assume the role of a college administrator and list alternative actions that could be taken to resolve a problem. As you read the description of the decision situation try to see it through the eyes of the administrator.

This project is aimed at determining the effect of different information on administrative actions. Attached is information to aid you in generating alternative actions that might be used in the decision situation. You are first asked to list all alternatives that come to mind, whether they seem good or bad, practical or impractical, or whether you would personally recommend such actions. You are then asked to select from the list, those alternative actions that you, as a college administrator, would recommend to the college president.

General Description of the Decision Situation

Imagine that you are the Vice-President for Academic Affairs at a small midwestern college and that you are responsible for making final recommendations to the president on all matters affecting courses offered on campus, faculty matters, student affairs, graduate assistants, laboratory equipment and supplies, course scheduling, travel expenses, departmental administration, curriculum changes, degrees offered and budget preparation.

The total budget for all of your operations in 1973 was $3,200,000. The allocation of budget dollars was:

faculty salaries	$1,800,000
administrative staff salaries	400,000
library and computer services	480,000
laboratory equipment and supplies	320,000
student financial aid	80,000
travel costs	7,000
faculty research fund	40,000
audio-visual equipment	73,000

In anticipation of poor economic conditions in 1974, the college budget committee has held hearings on campus during the past two months to get inputs from all segments of the community on where money is needed most. The committee has recommended that the budget for 1974 remain the same as in 1973 with no changes in any area.

Imagine that now you have been called to the president's office and told that due to the reduced income, you must reduce your

1974 operating budget by 8%, or approximately $250,000. You must seek alternative ways of reducing your programs to achieve the budget cut.

Your college enrolls 2700 students in 29 curricula majors within 11 departments. The staff includes 109 full-time faculty, 18 part-time faculty and 23 administrative staff persons. There are 466 courses offered, 40 classrooms in 5 buildings with 87 laboratories housing $4,000,000 worth of equipment.

The college is a state-supported institution and has been prohibited from increasing tuition or soliciting private funding so the budget reduction must be made by internal cost cutting. The president of the college has publicly stated that "the quality of education will be maintained" and that "the hardship will be spread across all segments of the campus."

This is the situation in which you must decide what actions to recommend to the president to achieve the desired budget reduction.

The following pages contain additional information to assist you in determining alternative actions.

Actual department names are not used in this experiment, instead, the college departments are labled alphabetically from A thru L.

Item #1

Total Cost Per Graduate[a]

Department	1973	1974 (projected)
A	$ 8,400	$ 9,300
B	7,800	9,100
C	9,200	10,400
D	10,700	11,500
E	14,600	16,000
F	6,040	6,500
G	11,128	13,500
H	10,000	11,000
J	9,800	10,400
K	2,300	3,500
L	11,400	12,150
College Average	9,215	10,305

[a]Academic costs for four academic years of instruction averaged over all curricula in the department.

Item #2

Average Salaries in 1973, 1974

Category	1973	1974 (projected)
Full-time faculty	$15,000	$16,200
Part-time faculty	$12,000	$12,700
Graduate assistants	$ 3,300	$ 3,300
Administrative staff	$18,000	$19,200

Item #3

Incoming Revenue for Academic Operations

Source	1973	1974 (projected)
Student tuition	$ 800,000	$ 760,000
State funding	$2,200,000	$1,974,000
Private donations	$ 167,400	$ 180,000
Total revenue	$3,167,400	$2,914,000

Item #4

Budget Allocations for 1973

Area	1973 Budget	% of Total
Instructional faculty	$1,800,000	56.2
Administrative staff	400,000	12.6
Educational services[a]	480,000	15.0
Lab equipment & supplies	320,000	10.0
Student fellowships, scholarships & grants	80,000	2.5
Instructional communications[b]	73,000	2.3
Research	40,000	1.2
Travel	7,400	0.2
Total college budget	$3,200,000	100.0%

[a]Libraries, computer center, testing services, etc.

[b]Audio-visual equipment and self-tutorial equipment.

Item #5

Departmental Information

Department	Courses Offered	Student Enrollment	Credit Hours Produced[a]	Student-Teacher Ratio[b]
A	67	287	7923	15.0
B	44	174	5934	12.3
C	33	107	1334	10.7
D	27	265	4464	16.7
E	40	201	5991	15.2
F	23	162	1885	13.6
G	105	366	8509	13.7
H	70	424	9666	18.6
J	14	27	1292	21.3
K	11	58	253	no data
L	32	290	6153	16.0
College Total	466	2746	27,758	15.3

[a]Fifteen students in a 3-credit-hour course = 45 student credit hours.

[b]Includes classrooms only, not laboratories.

Item #6

Departmental Faculty--1973

Department	Full-Time Faculty	Part-Time Faculty	Graduate Assistants
A	18	0	0
B	15	1	3
C	4	1	1
D	9	1	4
E	12	1	3
F	4	0	0
G	20	0	6
H	15	2	0
J	2	0	0
K	not applicable		
L	10	0	0
College total	109	6	17

Item #11

December 14, 1973

MEMORANDUM

TO: Vice-President for Academic Affairs

FROM: Chairpersons of Departments E and L

SUBJECT: Maintainance of Laboratory Facilities

Upon learning of the president's request to reduce program costs for the 1974 academic year, we are concerned that laboratory equipment and supplies monies might suffer drastic and disproportionate cuts. We must bring to your attention the following statement from the college handbook on educational goals:

> "to educate students who are technically oriented to be capable of on-the-job performance upon graduation. . . ."

It is this strong emphasis on performance that was responsible for 100% placement of our graduates in 1973. The hands-on character of laboratory work in our programs is an essential element in maintaining the high rate of employment of our graduates in the future and provides a direct relationship between the student and the professor similar to that in a project type situation in industry.

We strongly support the budget committee's recommendation of $320,000 for laboratory equipment and supplies in 1974.

Item #12

MEMORANDUM

TO: Vice-President for Academic Affairs

FROM: Faculty Senate Committee on Faculty Concerns

SUBJECT: Faculty Salaries for 1974

We are concerned about reports that there will be no increase in faculty salaries in 1974 despite the 7% increase in the cost of living during the past year. This action is unrepresentative of the contributions of the faculty to the progress of this college. The accomplishments of the college are a direct result of the accomplishments of it's faculty. The faculty's expertise, concerns, visions and professional compotence are the bulwark of the programs of the college. This faculty has maintained it's proficiency in teaching and it's vision of the future by continued involvement in professional societies, self development activities, research, publishing and other scholarly pursuits.

A recent survey of alumni, conducted by this committee, revealed that 85% of recent graduates rated this faculty above average in both teaching ability and professional compotence. We think this is an indication of the quality of people on our faculty.

It is the strong feeling of this committee that faculty salaries must be increased in 1974 and that no less than 4.5% would be adequate.

Item #13

Departmental Costs per Graduate, 1973, Ranked
From Highest Cost to Lowest Cost

Department	Rank
E	1
L	2
G	3
D	4
H	5
J	6
C	7
A	8
B	9
F	10
K	11

Item #14

December 14, 1973

Excerpt of a Speech Given by the President of the College to a General Meeting of the Faculty Senate

"It has been brought to my attention that due to difficult economic conditions, it might be necessary to reduce the size of our college faculty in order to reduce our operating budget. I want to assure you that we are going about collecting hard data as rapidly as possible in case we are forced to take this drastic action. No decision has been made at this time. We are examining the data to get some idea of the dimension of the particular problems with which we must deal. No one is in a position to look at this data and reach any clear reaction as to what might be done. For example, there is one area where the data indicates that there should be an increase in faculty, yet, this is an area where a decrease in enrollment is expected in the next few years. There are many factors that must be taken into account.

There are many options to consider. We are refining the hard data and will release it to the general public in the near future. We will do everything possible to honor our contractural agreements and guidelines for the protection of faculty rights but this thing must be dealt with realistically if this college is to survive."

Item #15

MEMORANDUM

TO: Vice-President for Academic Affairs

FROM: Director of Institutional Research

SUBJECT: Teacher/Student Ratios in the College

Our office has just completed a study of the student/teacher ratios for colleges comparable to ours in this geographical region. The results show that our student/teacher ratio of 15.3 is less than the regional average of 18.2 by 2.9 students per faculty member. As you no doubt recall, this issue has been raised by several legislators in the state capital and is likely to be a factor in state funding next year. We will be hard pressed to justify such small class sizes during a period when educational funding is so limited.

You might consider whether an increase in our budget for audio-visual equipment would allow us to more fully utilize our faculty by increasing the student/teacher ratio in the future.

Part III: Alternative Actions to Be Taken

Based on what you now know about the situation, you can probably think of several ways to make budget cuts. Please list below all of the alternative actions that you can think of for reducing the college operating cost. Do not limit your thinking to actions that you like or that you feel are practical. List all the actions that you can think of based on the description of this college situation.

Please proceed to Part IV.

Part IV--Selected Alternatives

Please go back to the previous page and select the actions that you find most acceptable, based on what you know about the college situation, and that you as Vice-President would recommend to your President. List those alternative actions that you recommend below. Feel free to go back and review the description of the situation or the additional information.

Please proceed to Part V.

Part V--Personal Data Form

Please circle the correct response.

1. Your age is between 16 & 20 21 & 25 26 & 30 31 & 35 36 & 40 above 41

2. Your sex is female male

3. How many formal courses in management or supervision have you completed?

   0 1 2 3 4 5 6 or more

4. Have you ever held a job as a supervisor, manager or director?

   yes no

5. Your student classification is

   freshman sophomore junior senior graduate

Please circle the item number of those items of additional information that influenced your responses in Part III or in Part IV.

Item Numbers	1	2	3	4	5	6	7	8
	9	10	11	12	13	14	15	

Space is provided below for any comments you would like to make about your participation in this experiment.

Thanks for your cooperation.

APPENDIX B

CALCULATIONS

APPENDIX B

CALCULATIONS

Planned Comparisons Calculations

$$M_i = \sum_{j=1}^{20} y_{ij}/n_i$$

where m_i is the mean number of alternatives generated in treatment group i

y_{ij} is the number of alternatives generated by subject j in treatment group i

n_i is the number of subjects in treatment group i

$m_1 = (4+4+5+5+6+2+8+5+4+7+5+5+9+9+5+5+4+3+8+4) \div 20 = 5.35$

$m_2 = 4.95$

$m_3 = 5.15$

$m_4 = 5.10$

The mean number of alternatives selected was calculated in the same manner. The results were:

$m_1 = 2.90$

$m_2 = 3.55$

$m_3 = 3.35$

$m_4 = 2.80$

$\psi = \sum_j c_j m_j$ for each comparison.

For alternatives generated, comparison 1, $\psi = 1 \times 5.35 - 1 \times 4.95 = 0.40$.

Analysis of variance data for alternatives generated and alternatives selected are shown below:

Alternatives Generated

Treatment	Size	Mean	Std. Dev.
1	20	5.350	1.926956
2	20	4.950	2.305029
3	20	5.150	2.183069
4	20	5.100	1.483240

Source	Sum of Sq.	D.F.	Mean Sq.
Between	1.637482	3	.5459
Within	303.8500	76	3.998
Total	305.4875	79	

Alternatives Selected

Treatment	Size	Mean	Std. Dev.
1	20	2.900	1.252366
2	20	3.550	2.114486
3	20	3.350	1.531253
4	20	2.800	1.609184

Source	Sum of Sq.	D.F.	Mean Sq.
Between	7.700005	3	2.567
Within	208.5000	76	2.743
Total	216.2000	79	

$$VAR\ (\hat{\psi}) = MS_{error} \sum_j c_j^2/n_j$$

For alternatives generated, comparison 1,

$c_1 = 1,\ c_2 = -1,\ c_3 = 0,\ c_4 = 0$

$MS_{error} = 3.998$

$\sum_j c_j^2/n_j = 1/20 + 1/20 = 1/10$

$VAR(\hat{\psi}) = 3.998 \times 1/10 = 0.3998$

ν = Degrees of freedom for t-test

= N - J

where N is the total number of subjects in all treatment groups

J is the number of treatment groups

$\nu = 80 - 4 = 76$ degrees of freedom for t-test

The confidence interval was determined by

$$0.40 - 2.47\sqrt{.3998} \leq \psi \leq 0.40 + 2.47\sqrt{.3998}$$

$$-1.62 \leq \psi \leq 1.962$$

RIDIT Analysis Calculations

The average ridit value for the reference distribution of treatment group 1 is 0.05 because of the nature of the ridit technique. The ridit value for distributions to be compared to the reference is determined by the equation

$$R_{ave} = \sum_j \frac{f_j\, r_j}{n}$$

where f_j is the frequency of alternative j

r_j is the ridit value for alternative j

n is the total number of alternatives in the distribution

Table 22 shows the calculation of R_{ave} for treatment group 2. The confidence interval for $\alpha = 0.05$ is determined by the equation

$1/\sqrt{3N}$

where N is the total number of alternatives in the treatment group. For treatment group 1, $1/\sqrt{3N} = 1/\sqrt{3(103)} = 0.057$

Table 22.--Calculation of R_{ave} for treatment group 2.

Alternative	Frequency	Frequency x ridit value
2	10	0.3883
3	8	1.0097
4	8	1.7476
5	9	3.0146
6	5	2.1845
7	14	7.2718
8	10	6.2136
9	15	10.7767
10	8	6.5631
11	9	8.3447
12	3	2.9709
Totals	99	50.4855

$R_{ave} = 50.4855/99 = 0.5100$

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