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Conceptualization and formulization of an optimizing-resource allocation model of a public service delivery function - - higher education

by

John M. Whitmer Jr.

A Dissertation Submitted to the
Graduate Faculty in Partial Fulfillment of
The Requirements for the Degree of
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Department: Professional Studies
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For the Graduate College

Iowa State University
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CHAPTER 1. INTRODUCTION

Objectives of the introduction

After reading the introduction, you should:

* Be aware that "rational" is not universally accepted as the axiom for individual or group decision-making.

* Be aware that the concept of rationality has been used very ambiguously in the literature, resulting in confusion and disagreement over its definition and application.

* Be aware that the lack of technology to filter and compress information has also contributed to the reluctance to pursue the rational axiom in socio-political policy analysis.

* Be aware that the innovative techniques of the Delphi Method and Multiple Objective Linear Programming (MOLP) may be used to identify, filter and compress information for decision makers.

* Be acquainted with the specific definitions of decision making, rationality and model that are critical to this study.

Nature of the research problem

For many years social scientists have recognized a need to improve decision making in the socio-political environment and acknowledged the merit of the concept of rational decision making (Buchanan & Tollison 1972; Downs 1967; Dye 1975; Friedland 1974; Simon 1976 & 1977; Wade 1972 and Wildavsky 1974; Lindblom 1968; Sharkansky 1972; Smithies 1967). But generally, the political scientists appear to hold rational decision making as idealistic, utopian and not realistically functional (Buchanan and Tollison 1972 p. 325). On the concept of rationality in political science Edward Friedland has observed that "Theories of rationality are logically consistent presentations built upon a set of necessarily unprovable beliefs about the way in which choices should be made" (Friedland 1974 p. 22). Miewald concludes that "human behavior is rational, but the body of knowledge from which rational premises are derived is necessarily limited; the human mind is too puny a vessel for complete rationality" (Miewald 1978 p. 27).

Economists do not have as much trouble with the concept of rationality. "The economic definition refers solely to a man who moves toward his goals in a way which, to the best of his knowledge, uses the least possible input of scarce resources per unit of valued output" (Downs 1957 p. 5). Economic rationality is more elaborately defined by Kenneth Arrow. He believes that a rational man is one who behaves as follows: (1) he can always make a decision when confronted with a range of alternatives; (2) he ranks all the alternatives facing him in order of his preference in such a way that each is either preferred to, indifferent to or inferior to each other; (3) his preference ranking is transitive; (4) he always chooses from among the possible alternatives that which ranks highest in his preference ordering; and (5) he always makes the same decision each time he is confronted with the same alternatives (Arrow as cited in Downs 1957 p. 6). I would add a sixth(6); he always chooses the highest ranked alternative he can afford.

Economic analysis thus consists of two major steps: (1) discovery of the ends a decision maker is pursuing, and (2) analysis of which means of attaining them are most reasonable (Downs 1957 p. 4). In the long run, economists expect a rational man to outperform an irrational man, because randomly selected effective and ineffective strategies cancel each other, but learned and tested procedures have a higher likelihood to lead to desired results.

In addition to the apparent conflicting attitudes between political scientists and economists, the level of computer technology sophistication and the author's acceptance of the capability of existing computer technology to handle massive amounts of data appear to have considerable explanatory value on each writer's attitude toward the legitimacy of rational problem solving in socio-political environments. The greater the acceptance of systems analysis and computer technology, the broader the acceptance and acknowledgement of the legitimate role of rational problem solving in socio-political environments.

The difference between acceptance or rejection of the applicability and practicality of rational problem solving in socio-political environments may be closely associated with what Simon terms "the whole concept of what it means to 'know'." Simon observes that "in the pre-computer era, a person knew something when he had it stored in his memory in such a form that he could retrieve it on appropriate cues." "Nowadays, there are many additional ways of 'knowing'." "Today the critical path is not to generate, store or distribute information, but to filter it so that the processing demands on the components of the system, human and mechanical, will not far exceed their capacities" (Simon 1977 p.180). Simon and his several collaborators are saying that we no longer need to rely so heavily upon the bounded rationality with all its obvious deficiencies because modern methods of handling data, plus the techniques for using them in decision making, enable managers to push back the frontiers of rationality (Miewald 1978 p. 169).

The magnitude and stature of the political science literature has cast a dark shadow on the legitimacy of rational decision making as a viable process in determining the effectiveness of public service organizations in meeting clientele needs. Generally, political scientists have opted for a descriptive (incremental) concept that was formulated from empirical research. The principal supporting argument for the preference of the incremental descriptive model is its feasibility.

The attitude toward the validity and practicality of the concept of rational problem solving in a political-social-economic environment is expressed in Peter G. W. Keen's description of "The Evolving Concept of Optimality" and can be summarized as an ideological continuum. At one extreme is Lindblom's concept of "Pluralism" and "Science of Muddling Through" and at the other is "Economic Man" with the "natural linkage from the concept of scarcity to that of economizing to that of optimizing." In between lie Hirschman's "Imbalance and Corrective Reactions," March's "Technology of Foolishness" and Simon's "Bounded Rationality" and "Satisficing." Keen concludes "there is no reason to reject either the rational or the pluralist axioms." However, he cautions that "optimization science, in economics and in OR/MS (Operations

Research / Management Science) has tended to take its axioms for granted and to assume that they are self-evident. They are not" (Keen 1977 p. 52-4).

Briefly and succinctly stated, the objections to the application of rational decision making in public service delivery are that it is utopian and the process is too costly in terms of the resources consumed (time and human intellect) in the elaborate process of arriving at a final choice. It is important to understand that it is not the cost of the possible consequences of the choice arrived at in a rational framework that is questioned. Riker, a political scientist, puts it this way. "It must not be asserted that all behavior is rational but rather merely that some behavior is and that this possibly small amount is critical for the construction and operation of economic and political institutions" (Riker 1962 p. 20). Friedland, another political scientist, concludes that "the ideal of rationality as a standard towards which we should aspire is simply too valuable an ideal to relinquish because of the presently unsatisfactory state of theories about rationality." "Despite our dissatisfaction and no matter how limited we conceive the idea (rationality) to be, we must still face up to the fact that it is virtually the only game in town." "The most important feature of the concept of rationality is its capacity to serve as an independent perspective for the criticism of existing institutions." "...the best summary statement that can be made about reason as a guide to political choice is that it is probably the least untrustworthy of the instruments on which men rely" (Friedland 1974 p. 24-5). Finally, Thompson concludes that "the rules of rational choice apply to situations where middle-range values are involved in a long series of similar choices. This situation typically confronts organizations continually producing goods or services of a reasonably well-understood kind. Such organizations become highly rationalized, and we call them bureaucracies" (Thompson 1971 p. 6).

Purpose and objectives of the study

The purpose of this study is to demonstrate that recent innovations in technology, namely the Delphi Technique and Multiple Objective Linear Programming, (MOLP) now make it possible to utilize a rational decision-making model to process the critical information in public service delivery decisions without overtaxing the financial limits and mental ability of the institutions and individuals involved in the process. The marked shift in the role of information processing is a basis for the general hypothesis of this study. Innovative techniques of the Delphi Method and Multiple Objective Linear Programming (MOLP) now make it possible to identify, filter and compress much of the information in socio-political problems so that it is now possible to develop and illustrate a model of rational decision making that will have heuristic, investigative and clinical value in adult and extension education, program budgeting (PPBS), and management by objectives (MBO).

Specifically, this research is to demonstrate that Multiple Objective Linear Programming (MOLP) and the Delphi Method can be combined with existing organizational/administrative theory and institutional resource allocation models to estimate the impact and relative importance of competing organizational objectives on resource allocation within a public university. It is a model of a process that asks and attempts to answer the following organizational questions:

* Given a set of objectives, all considered "very important," what is the level of each alternative activity that contributes to the achievement of the objectives such that the combined attainment of all objectives produces the maximum satisfaction in relation to the decision makers' values?
* What resources or commitments are necessary with each alternative activity?
* What is the relative value of each resource when it is utilized in different activities to maximize the combined

attainment of all the objectives?

* What criteria should be used to evaluate effectiveness?

Specific objectives of the study include:

A. Illustrate how to identify the attributes of a college that is vigorously pursuing specific objectives.

B. Illustrate how to establish the technical relationships between objectives, attributes and activities in higher education.

C. Illustrate how behavior revealed preferences can differ from professed preferences.

D. Illustrate how to formulate a multiple objective linear programming model that simulates the objective attainment and resource allocation of an institution of higher education.

E. Illustrate how the total model can enable the participants to experience the consequences of :

1. Changes in the rank order of organizational objectives.
2. Changes in the level of resource-constraints.

Rational (comprehensive) decision making

Decision making and rationality are fundamental concepts to this study but are not the principal subjects. Therefore, the following brief discussion of these concepts is necessary to establish the context of the study by defining the various concepts and by delineating the specific relevant application of each concept.

Individual behavior can be the result of many stimuli including drives, such as wishes, habit and impulse; feeling, such as emotion; random action; and intelligent acts of thought. In somewhat the same manner, organizational activities may be affected by many influences including past practice, activities of similar organizations, and deliberate decisions. A decision is a choice. The decision-making (choice) process is fundamental to the conscious behavior of individuals and groups of individuals. It is a very complex process and it has been the focal point of considerable research and publications (Thompson 1971; Friedland 1974; Lee 1972). Dye concludes that organizational decisions, each with its own unique focus and assumptions, can be classified as institutional, incremental, systematic, gaming, elitist and rational (Dye 1975 p. 18-39).

This is a study of rational, organizational decision making. The "formal organization" is "a group of individuals who have been brought together for the attainment of more or less explicit goals" (Miewald 1978 p. 6).

The traditional image of a decision maker "is a person at the moment of choice...." This image "falsifies decision making by focusing on its final moment." Decision making is a "full, lengthy, complex process of altering, exploring and analyzing that precedes the final moment, (of choice) and the process of evaluating that succeeds it" (Simon 1977 p. 40). "The decision maker is then, in reality, one who attempts to attain a set of goals to the fullest possible extent in an environment of conflicting interests, incomplete information, limited resources, and limited ability to analyze the complex environment" (Lee 1972 p. xii). "The soundness or rationality of decision making is measured by the degree of organizational goals achieved by the decision" (Lee 1972 p. 7).

Simon further identifies the four phases of the process. The first phase, searching the environment for conditions calling for decision, he calls "intelligence activities" (borrowing the military meaning of intelligence). The second phase, inventing, developing and analyzing possible courses of action - he terms "design activity." The third phase, selecting a particular course of action from those available, is "choice activity." The fourth phase, assessing past choices, is "review activity" (Simon 1977 p. 41).

Simon's definition of decision making fits in very nicely with most definitions of problem solving. When a person wants something and does not know immediately what series of actions he can perform to get it, he is confronted with a problem (Newell 1972 p. 72) (see also Jackson 1975;

Kepner and Tregoe 1965; and Kaufman 1976). Figure I reproduces Roger Kaufman's six step general problem solving process.

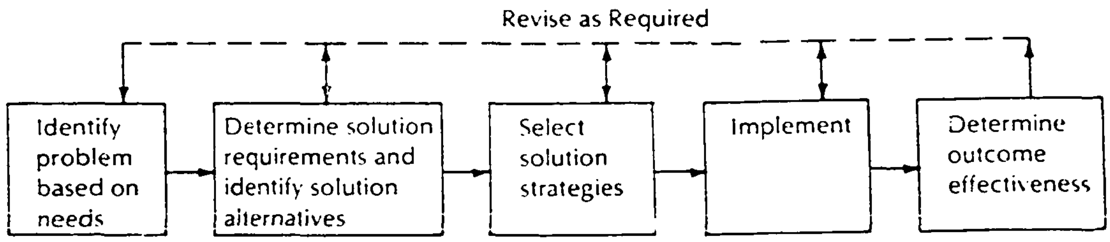

Figure 01. General problem solving process

From either the decision-making or problem-solving perspective, the process is a hierarchy of specific choices involved in learning, understanding, information processing, assessment and definition of the decision situation. Depending on whether the underlying logic of the process is calculation or evaluation, the level of certainty has varying effects on the final decision. In calculating routine situations, in which the effects of each option is viewed as certain and only one choice will meet "the criteria of rationality," a machine could make the choice. This is defined as "situational determinism" by Thompson (Thompson 1971 p.3). However, Thompson claims that "certainty resides only in tautologies. In the empirical world of consequences of action, we have either probabilities or no knowledge at all" (Thompson 1971 p. 5).

This study is concerned primarily with the aspects of the decision-making process that Simon identifies as "design" and "choice" activities and the problem-solving steps that Kaufman identifies as determination of solution requirements, identification of solution alternatives and selection of solution strategies. The other aspects of decision making and problem solving are stipulated as given.

It is not enough to identify the logic of the process as rationality. The behaviors commonly elicited when people are placed in problem-solving situations and are motivated toward a goal are called rational (Newell 1972 p. 53). A cursory review of the literature on rational decision making reveals that there are at least thirteen (13) concepts of rationality as it relates to decision making.

Mannheim's dichotomy of rationality into "functional" and "substantial" appears to be basic to the discussion of rationality in general.

Substantial rationality applies to individual decisions and involves <u>thoughts</u> (my emphasis) "which reveal intelligent insight into the interrelations of events in a given situation" (Mannheim 1940 p. 53). Diesing's expanded definition states that "a decision or action is substantially rational when it takes into account the possibilities and limitations of a given situation and <u>reorganizes</u> (my emphasis) it so as to produce, or increase or preserve some good." This definition has two features: (A) The decision or action "must be an effective (my emphasis) response, produces some possible good, and (B) effectiveness must be based on intelligent insight rather than luck" (Diesing 1976 p. 3).

Functional rationality applies to organizations and involves the scheduling and implementation of predetermined techniques to attain specific goals. Karl Mannheim provided that "a series of actions is functionally rational if": (A) the structure "is organized with reference to a definite goal" and (B)"an individual can be integrated into it because its future behavior is predictable" (Mannheim 1940 p. 54). Diesing expands this definition to provide that "an organization is functionally rational when its structure is conducive "to produce, or increase or preserve some good in a consistent dependable fashion." "It is the structure which enables the organization to continue effective operation through variations of personnel and through changes in the enviroment" (Diesing 1976 p. 3).

Diesing develops five specific dimensions of rationality that are refinements of Mannheim's "substantial and functional rationality." They differ in that Diesing rejects Mannheim's notion that rationality is identical with efficiency. He supports his rejection on the basis of the identity that: (1) the efficient achievement of a single goal is technical rationality and (2) the maximum achievement of a plurality of goals is economic rationality, and no other types of rationality are admitted. He reasons that "such a conception of rationality limits its scope rather severely." He argues that "the criterion of efficiency used in this context is applicable only to means and not to ends, unless these are in turn means to further ends" (Diesing 1976 p. 1). Therefore Diesing replaces efficiency with effectiveness which is a wider concept that "refers to the successful production of any kind of value, leaving open and problematic the question of what kinds of value there may be" (Diesing 1976 p. 3).

Diesing's effectiveness is similar to Dye's "efficiency" used in describing rational policy making. Dye defines a rational policy as "one that is correctly designed to maximize 'net value achievement'." He goes on to say that "this definition of rationality is interchangeable with the concept of efficiency - efficiency is the relation betweeen valued inputs and valued outputs." He concludes that "a policy is rational when it is most efficient -- that is, if the relation between the values it achieves and the values it sacrifices is positive and higher than any other policy alternative" (Dye 1975 p. 27). Dye further elaborates on "rationalism" by explaining that "to select a rational policy, policymakers must:

1) know all the society's value preferences and their relative weights;

(2) know all the policy alternatives available;

(3) know all the consequences of each policy alternative;

(4) calculate the ratio of achieved to sacrificed societal values for each alternative;

(5) select the most efficient policy alternative" (Dye 1975 p. 27).

Diesing develops an elaborate framework to define reason in society so that it is defensible in five different contexts. He concludes that there are two phases of reason; (1) rationality of organizations and, (2) rationality of decisions. By discussing rationality in terms of scope, trends and values in a technical, economic, social, legal and political setting, he defines five distinguishable types of rationality.

Technical rationality is concerned with the effectiveness of the process of physically mixing various factors together to achieve a single end that is likely determined outside the decision structure. It is a calculating process designed to avoid waste, and its principal element is efficiency of production and physical distribution.

Economic Rationality is concerned with the allocation of scarce resources among competing or alternative ends. It is an evaluation process designed to provide maximum satisfaction which, in addition to including the technical elements of production and physical distribution, involves internal allocation and external exchange based on the value of the resources and the commodities.

Social Rationality is concerned with the elimination of the causes of conflict, frustration and anxiety by progressive assimilation, resolution or exclusion so that the participants can exhibit as much agreement as possible. It is an integrating process in which its principal components such as feeling, mutual support and action are combined to increase the expression of self and self-realization.

Legal Rationality is concerned with the existence and maintenance of a public framework of common values and some mutual trust for preventing and solving disputes between parties of conflicting interests when other methods fail. It is a public system of clear, relevant and neutral rules prescribing rights and duties together with some neutral person qualified to apply them in an environment in which the distribution of power is stabilized by mutual checks and balances such that the result is legal justice.

Political Rationality is concerned with the preservation and correction of the decision-making structure's ability to yield adequate decisions from complex situations with some regularity. It is a process of discussion and decision in which the processes of problem-solving, persuasion, bargaining and politics are blended in to its principal components of compromise and mediation to bring about a balance between the forces of differentiation and unification such that there is a delicate balance of interests that can be tolerated by all parties who continue to maintain their differences.

Each definition equates reason with order, such that order is the opposite of randomness. Rationality is a special kind of order which has a guiding logic that makes it intelligible. In this context, technical rationality is an order of production that makes action productive and is designed to avoid waste. Economic rationality is an order of measurement and value comparison designed to facilitate allocation of resources and exchanges of commodities. Social rationality is an order of interdependence and solidarity which works to eliminate conflict and disjunction and promotes trust and self-assurance. Legal rationality is an order identifying that availability of clear and exact assignment of individual rights and duties designed to resolve conflict when all other approaches fail. Political rationality is an order of discussion and decision designed to result in tolerable relationships with a delicate balance of interests. Finally, functional rationality is order and substantial rationality is the making of order.

Simon says "rationality is concerned with the selection of preferred behavior alternatives in terms of some system of values whereby the consequences of behavior can be evaluated" (Simon 1976 p. 75). He illustrates that this definition has many complexities and concludes that the term "rational" must be preceded by appropriate adverbs to clarify its meanings.

(A) A decision "may be called 'objectively' rational if, in fact, it is the correct behavior for maximizing given values in a given situation."

(B) A decision "is 'subjectively' rational if it maximizes attainment relative to the actual knowledge of the subject."

(C) A decision "is 'consciously' rational to the degree that the adjustment of means to ends is a conscious process."

(D) A decision "is 'deliberately' rational to the degree that the adjustment of means to ends has been deliberately brought about" by the individual or by the organization.

(E) A decision "is 'organizationally' rational if it is oriented to the organization's goals."

(F) A decision "is 'personally' rational if it is oriented to the individual's goals" (Simon 1976 p. 76-77).

Figure 02 graphically presents Diesing's and Mannheim's concepts of rationality together with six adverbs offered by Simon. The five (5) concepts listed down the middle of Figure 02 come from Paul Diesing's book Reason in Society (Five Types of Decisions and their Social Conditions) The six (6) concepts listed across the top come from Herbert A. Simon's book, Administrative Behavior (A Study of Decision-Making Processes in Administration). The two (2) concepts listed down the right side come from Karl Mannheim's book, Man and Society in an Age of Reconstruction.

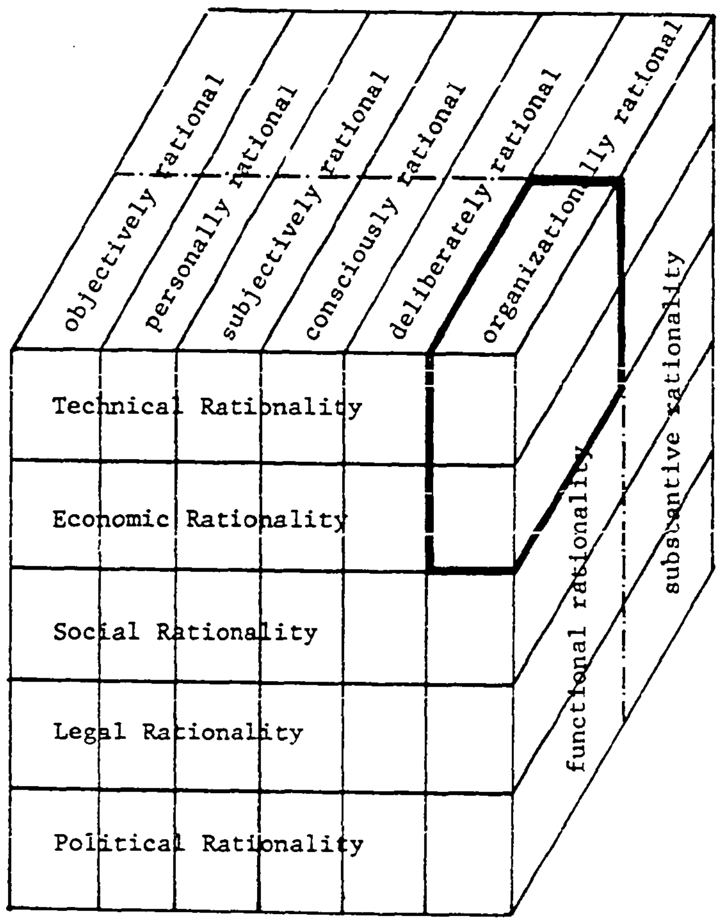

Figure 02. Multiple dimensions of rationality

The purpose of Figure 02 is to identify the principal concepts of rationality that are critical to this study. These are indicated by the dark outline. The rationality of the model includes the concepts of Mannheim's functional rationality and Diesing's technical and economic rationality all set in an environment that Simon describes as organizationally rational.

Prior to multiple criteria decision making, Diesing's economic rationality is infeasible in the public sector because the dollar is not an acceptable numeraire to measurer the allocation or resource and evaluate the exchange value of the outcomes. Downs states "if multiple goals are allowed, means appropriate to one may block attainment of another; hence, no unique course can be charted for a rational decision maker to follow" (Downs 1957 p. 5). "Both the believers, critics and modifiers of the rational ideal accept that optimization is impossible if multiple criteria are not resolved" (Keen 1977 p. 33). Keen states that "Optimization science is based on a normative model of rational choice" (Keen 1977 p. 31). "Any conception of optimality rests on a theory of rational decision making. OR/MS (Operations Research/Management Science) is dominated by a normative, specialized model of rational choice that is rarely debated because it is 'obvious'" (Keen 1977 p. 31).

Rational decision making and systematic problem solving together with a set of supporting values are implicit in the purposes (i.e. professed missions of organizations that identify goals and objectives to be achieved) of adult education, program budgeting-PPBS and management by objective. Because "almost no society can survive for long if no one in it is efficiently pursuing his goals..." (Downs

1957 p. 10). For example, in the area of education, educators believe it is more desirable for people to be civilized than primitive. Civilized people supposedly understand much of what is happening to them and primitive people attribute the "origins of events and situations that they do not understand to supernatural powers" (Jackson 1975 p. 5).

The educational philosopher John Dewey, was one of the first people to integrate explicit aspects of rational behavior into problem solving. His book, How We Think, (1910), identified explicit stages of problem solving. Dewey's "functionalism," often cited as an underlying principle of adult education, is supported by a rational problem-solving process. Gross maintains that "a rational society is one in which people and organizations are capable of sustained learning and, in fact, are explicitly oriented toward recreating themselves through sustained learning" (Friedland 1974 p.19). "Life is adaption in the interest of survival" (Thompson 1971 p. 1).

Management science and public management

This study collates administrative science, management science and public management. The question raised by administrative science is "the degree to which the decisions in and about organizations are rational ones" (Miewald 1978 p. 167). Simon says, "the terms 'operation research' and 'management science' are nowadays used almost interchangeably to refer to the application of orderly analytic methods often involving sophisticated mathematical tools, to management decision making, and particularly to program decision making" (Simon 1977 p. 55). "The body of information and techniques that management science borrows from other disciplines is of course important, but it is incidental to the scientific methodology." "Management science uses what it needs and what is available to solve executive problems" (Clough 1963 p. 27). "Management science has grown out of efforts to develop decision making criteria and operating strategies which are effective in the face of the increasing complexities and higher stakes of modern military and industrial operations" (Clough 1963 p. 27-8).

"At a more philosophical level, operations research may be viewed as the application of scientific method to management problems..." (Simon 1977 p. 55). "The primary difficulty in modern decision analysis is the treatment of multiple conflicting objectives." "The question becomes one of value trades in the social structure of conflicting interests. A formal decision analysis that is capable of handling multiple conflicting goals through the use of priorities may be a new frontier of management science" (Lee 1972 p. xii). "...operations research brought into management decision making a point of view called the systems approach."

"The systems approach is a set of attitudes and a frame of mind rather than a definite and explicit theory" (Simon 1977 p. 56). "At its vaguest, it means looking at the whole problem - - somewhat more concretely, it means designing the components of a system and making individual decisions within it in the light of the implications of these decisions for the system as a whole." "This may involve rational behavior and complex systems from economic analysis, mathematical techniques..." (Simon 1977 p. 56).

The systems analysis approach describes many means by which problems are analyzed to find the most effective and efficient solution within certain constraints. Although there are many variations, the analysis is composed of nine basic steps:

- Define the problem
- Define the objectives
- Define the alternatives
- Make assumptions concerning the system
- Define the constraints
- Define the criteria
- Collect the data

- Build the model

- Evaluate the alternatives.

(Shell & Stelzer 1971 p. 67-8).

Rapp and Patitucci define "public management" as an important discipline, separate and distinct from political science or public administration. Public management recognizes the inconsistency and obsolescence of the traditional belief that politicians establish public policy and administrators carry it out. It recognizes that politics and administration overlap in government because deciding what to do and getting it done are inseparable. Public management involves the total process (Rapp & Patitucci 1977 p. xvi).

Public management is, in essence, one of the most complex, diffused and variable phenomena in modern society. There is not one local government institution, but many; not one state government institution, but many; not one federal government institution, but many; each with specific problems to solve, its own (implicit or explicit) goals, and objectives with activities and resources to utilize to pursue its purposes. These public institutions are not 'united' into a single coordinated organization, but instead are many autonomous units with similar, overlapping and even conflicting purposes and a conglomerate of activities performed with little or no evaluation of their impact on the public need that is the justification for their existence. According to Michel Crozier "the public organization has resisted rational control because of an irrationality protected by the incalculability of performance" (Miewald 1978 p. 163). Yet all of these institutions are justified on the pretense of serving the public, i.e. meeting specific needs. Because it is obvious that there are more public institutions than public needs, it seems a reasonable deduction that some public institutions are supposedly responding to similar needs. This is particularly true between and among state and local government institutions.

In many situations at the state and local level, what works for one unit may also work, after very little modification, for another unit serving a similar clientele in a different jurisdiction. Conclusions, judgments rendered, generalizations drawn after painstaking examination of facts and values, are very likely to be transferable and may benefit many similar public units. The decisions involved in these situations are what Simon refers to as "program decision making," and could be included in Thompson's classification "situational determinism" (Thompson 1971 p. 6).

"A program is a detailed prescription or strategy that governs the sequence of responses of a system to a complex task environment" (Simon 1977 p. 46). "The intent of a program is to permit an adaptive response to the system to the situation" (Simon 1977 p. 47). "Making program decisions depends on relatively simple psychological processes that are somewhat understood, at least at the practical level. They include habit, memory, simple manipulations of things and symbols. Structure and standard operating procedure are also factors" (Simon 1977 p. 52).

The research framework

In an age of explosive growth in all levels of government, rapidly declining public confidence in the government's ability to respond to socio-political issues, and research model proliferation, it seems natural to attempt to develop a rational decision-making model, that has both normative and optimizing characteristics. With the advent of the high-speed computer, model building as a research tool in the social sciences has led to enormously powerful, intangible and conceptual insights. In social sciences, models are often constructed as deliberate oversimplifications of complex situations to reduce the complexity to a level which the mind can grasp, or to make an approximation to the actual state of affairs.

There is no claim that a model is a perfect detailed reflection of reality. However, even though the reality of human behavior is too complex and complicated to be perceived and studied directly, a mathematical programming model can simulate much of the real world data and manipulate a vastly greater number of variables than can be studied directly. In the very simplest sense, a model is a unique mode of human expression. Much like prose, poetry, mathematical formulas and various art forms, a model is a communications medium that faciliates organizing, understanding and transferring knowledge about complex situations. As such, it is a research tool that "is useful for scrutinizing a complex reality in a systematic manner" and "separating the significant from the milieu" (Graham 1971 p. 114). Just as writers use different sentence structures and word choices and painters use different colors and materials for different effects, model builders use many items in constructing a model. Concepts, abstractions, relationships, assumptions, hypotheses and anticipated consequences integrated with factual premises and value premises are common ingredients in many models (Thompson 1971 p. 2). This information "includes the 'facts' a decision maker 'knows' about reality that is, his perceptions of the way things were, are, and could be, and his values or feelings about the way things should have been and should be" (Friedland 1974 p.7).

Any flow chart or schematic-symbolic diagram, such as a roadmap, can be called a model if it illustrates how two or more characteristics of a situation are related. "A mathematical model is merely a symbolic representation of relationships of undefined terms" (Graham 1971 p. 114). "It must be internally consistent and mathematically valid" (Graham 1971 p. 114). "Such a model merely sets forth relationships that are logical consequences of the assumptions or axioms of the logical system" (Graham 1971 p. 114). A mathematical model is "a system of internally consistent relationships that are derived from an explicit set of assumptions" (Graham 1971 p. 114). "The model's test is a test of validity of conclusions and derivations - it is a test of internal consistency" (Graham 1971 p. 124).

The purpose in constructing a model of a given situation is to single out certain elements as relevant to the problem under consideration, to make explicit certain functional relationships among these elements, and to formulate hypotheses regarding the nature of these relationships (Kuhn 1963 p.36-8). Helmer states that "constructing a computer model puts explicitness to the most severe test" (Helmer 1966 p. 21).

Hopefully, this model will provide a flexible vehicle to facilitate the exchange of information between public institutions with similar purposes. This broad application justifies universities undertaking the development and continuous updating of the model so that all units can benefit from the past experiences of other units to better understand their challenges and activities as they attempt to achieve a maximum impact on the objectives they strive to attain.

The specific model

In terms of Tullock's science of choice and science of preferences, the identification of objectives falls in the latter and the analysis of the model including policy maker interaction, in the former category (Buchanan and Tollison 1972 p. 324). This study concentrates on the outcome of choice among preferences. It is now possible to obtain a cross section of preferences as a beginning point for choice. This study does not assume the content of the preferences but rather explicitly identifies them. We are assuming throughout this study that ends can be separated from means in the mind of the decision maker (Downs 1957 p. 5). This allows the study to compare revealed preferences with professed preferences. The comparison is not to judge goodness or badness but to probe apparent inconsistencies.

This model is a unique combination that has its foundations in both social technology and empirical science. Olaf Helmer explains the difference and concludes that social technology complements social science, not replaces it (Helmer 1966 p. 7). He distinguishes between "traditional exact scientific investigators" and "an operation analyst." "The exact scientist likely works with a well-confirmed body of scientific knowledge" and the operations analyst works with much more "tentative information" that has an ad-hoc quality, representing merely the best insight and information available." "This tentative procedure, dictated by pragmatic considerations, is thus essentially one of successive approximations" (Helmer 1966 p. 4-5). This process is complicated by "problems of craftsmanship in social technology" (Helmer 1966 p. 7). Researchers may "have to rely heavily on whatever systematicity of expert judgement may be available, rather than on a solid (nonexistent) theory" (Helmer 1966 p. 7). "Systematicity, in the sense of an orderly, planned, methodical procedure, in the elicitation and use of expert opinions" (Helmer 1966 p. 13).

This "expert opinion must be called upon whenever it becomes necessary to choose among several alternative courses of action in the absence of an accepted body of theoretical knowledge that would clearly single out one as the preferred alternative" (Helmer 1966 p. 11). Researchers may also have to conduct "pseudo-experimentation" (pseudo because the experiments are carried out in the model, not in reality). Pseudo-experimentation is nothing but the systematic use of the classical idea of a hypothetical experiment; it is applied when true experimentation is too costly or physically or morally impossible, when the real world situation is too complex to be analyzed directly (Helmer 1966 p. 9).

The specific design of this study is a problem-solving oriented strategy which; (1) given five objectives, defines attributes and their relationships to the objectives and activities, (Delphi Method) and (2) chooses the combinations of input resources expressed in terms of alternative, purposeful, organizational activities that best accomplish the identified objectives, (Multiple Objective Linear Programming - MOLP). "Tendency relationships" such as attributes tending to lead to objectives, are an important aspect of the model (Graham 1971 p. 131). "A tendency relationship is defined to be a relationship of two variables occurring together more often than warranted by chance" (Graham 1971 p. 132). While "necessary conditions are those which are always precedent to a particular consequence," ... "sufficient conditions are those conditions that together will lead to the consequece" (Graham 1971 p. 130). This model assumes a "functional relationship" between all the phenomena. i.e. "The phenomena are found to be associated whenever they occur" (Graham 1971 p. 129).

This model has the following explicit assumptions: (1) Expert judgment is objective and rational; (2) Collective judgment is a reasonable estimate of empirical data that exists but has not yet been compiled (i.e. there is a connection between consensus of expert judgement and plausibility.)

This study hypothesizes a causal chain: if resources are functionally related to activities, and activities are functionally related to attributes, and attributes are functionally related to objectives, then resources should also be functionally related to objectives. Once relationships are identified by expert judgment as "functional", they can be observed and possibly verified empirically so as to become "causal." Activities are common antecedents to the presence of a given attribute (Graham 1971 p. 132).

The normative findings of this study are limited by the fact that the data processed in the model only includes the perspectives of professional educators. Future studies will need to replicate the study using perspectives and perceptions of other groups such as students, university administrators, future employers, parents and legislators.

One of the benefits of this model is that it requires participants to make a quantum leap into a completely different frame of reference instead of the traditional approach to organizational analysis. Thus it requires a complete break and makes it difficult to carry over past habits or supported assumptions. One of these assumptions is the failure to recognize the difference between "schooling and learning" which leads to the conclusion that when the demand for learning increases, schooling must expand. Another is the failure to distinguish between what schools do to individuals and what schools do about individual differences (Weaver 1972 p. 20).

Figure 03 provides an overview of the model.

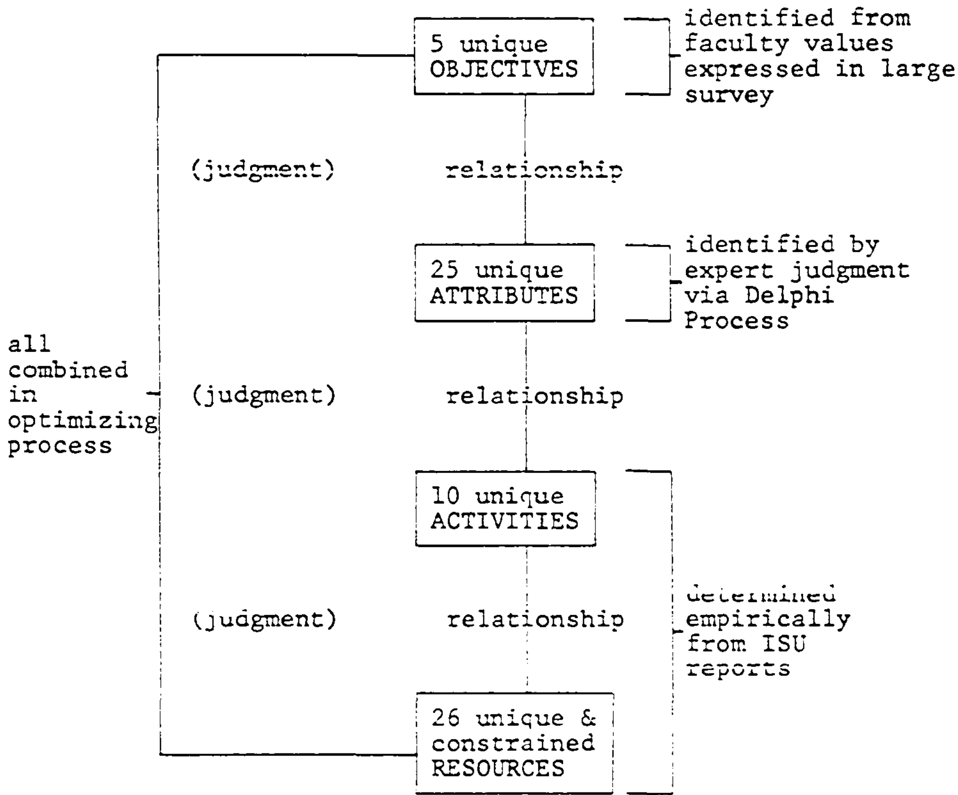

Figure 03. Diagram of Model

It illustrates the components and their relationships and the techniques used to establish their identity and degree of association. The model is a system. Everything in the model is related to every other thing in the model. As a result (1) the total level of achievement of the objectives can be varied by varying the constraints; or (2) the total amount of resources used, up to the constraining level can be varied by varying the total level of achievement of objectives. In addition, since the same resources can be utilized in different combinations to perform different activities which lead to the achievement of different objectives, a variation in the amount of any specific resource can affect the level of attainment of a specific objective.

It is significant that the model is designed so that decision makers can interact with it. The principal anticipated interaction will occur when decision makers, once they know the given trade-off ratios between objectives, will weigh or reorder the significance of specific objectives.

In this study, five (5) illustrative educational objectives are used as the "performance" objectives to be optimally achieved. These objectives were identified as 'Very Important' by a sample of the ISU College of Engineering faculty in "A Survey to Explore The Opinions and Attitudes of University Faculty and Administrators about University Goals, Governance and Working Conditions" conducted by the author in the fall of 1976. Each of these objectives is the subject of a Delphi process that:

(1) identifies twenty-five (25) attributes that are

likely to be present in students, faculty, administrators and campus life when a college is vigorously pursuing the achievement of a specific objective;

(2) judges the degree that a specific attribute will lead to the achievement of a specific objective at a college where it is present; (only the five attributes for each objective that are judged to lead most directly to its attainment will be used in the model.)

(3) judges how the ten (10) higher educational activities; undergraduate instruction, advising, research etc., contribute to the presence of the specific attributes.

The objectives from the former study, and the attributes from this research, the activities, and the technically related resource utilization data, empirically gathered from ISU records, will be incorporated into a Multiple Objective Linear Program (MOLP) to filter and compress information critical to organizational performance. It is assumed that higher education causes (or fails to cause) changes in characteristics of students and pushes (or fails to push) back the frontiers of knowledge.

<u>Summary</u>

Although some political scientists acknowledge the potential of rational decision making in a socio-political environment, present public administration literature labels it utopian. The thesis of this study is that recent innovations, namely the Delphi Technique and Multiple Objective Linear Programming (MOLP) make rational decision making a legitimate and viable approach when used in models of normative resource allocation in public service delivery functions. The resulting model has the potential to filter and compress information that is too complex and complicated to be perceived and studied directly.

CHAPTER II. REVIEW OF LITERATURE

Objectives of the review of literature

After reading the Review of Literature, you should:

* Be acquainted with the nature and magnitude of educational goals in higher education.

* Be aware of the present state of the art of institutional resource allocation models in higher education.

* Be aware that the Delphi Technique is capable of producing usable, expert judgment of the relationships between the variables of this model.

* Be aware of the concepts and relevant applications of multiple objective linear programming.

* Be acquainted with the developing discipline of multiple criteria decision making.

This study assumes a pragmatic dichotomization of the aspects of rational decision making, systems analysis and modeling: First, the objective content of the information and second, the information processing. Each section will be reviewed in terms of: (1) The general conditions (need situation - the motivation for the research) that lead to the development of the concept; (2) Definition and characteristics; (3) The theoretical foundation that underpins the concept;[1] (4) Methods and procedures of past utilizations and (5) Findings - verification of results of previous applications. The extant literature that supports the objectives of the study will be inventoried and classified in this general framework.

A significant value of the objective content of information is the identification of the subjective values that frame the situation that is the focus of concern. In this study, objective content are the organizational objectives. The objectives have their origin in the literature on goals for higher education. The next value of objective information is to describe the perceived conditions, factors, and relationships of the situation causing the concern which makes successful rational decision making, system analysis and modeling possible. This will be presented in terms of existing resource allocation models.

The significance of information processing is especially

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[1]A general theory identifies a structure for a complete explanation of the phenomenon and its relationships as they exist in reality. Utilizing precise definitions, axioms, and empirical concepts, it also provides the basic assumptions about the relationships of the factors. It also contains a calculus or logic that provides the rules for deducing theorems about the general relationships specified in the axioms. Empirical propositions are generated from the theorems and subjected to operationalization and potential verification (Graham 1971 pp. 127-8).

critical in this study. Information can be processed many different ways and with many different objectives in mind. The way information is structured in problem situations determines, to a great degree, the nature of the solution obtained. This fact is particularly significant in this study because of the multiple perceptions of rationality.

Objectives of higher education

Harold L. Hodgkinson believes that "goal setting and evaluation in higher education have been carried out pretty much 'in vacuo' for the last several hundred years, primarily because society did not give a hang what higher education's goals were." He further identifies three phases that colleges and universities have transcended. The first is the "aristocratic" period, (pre 1930) in which the objective was to turn out "a competent ruling class, of professionals and government officers, selected from the children of the existing aristocracy." Next was the "meritocratic" phase (about 1930 to 1960) in which the major objective was "to select the meritorious, whatever their background, and make of them a new elite, based not on birth ascription, but on talent." Since 1960 he believes that we have begun to pursue a course that could only be called "egalitarian", "based partially on a new interpretation of the Equal Protection Clause..." (Hodgkinson 1972 p. 33).

This "egalitarian" atmosphere combined with two additional factors produce a situation that generate an intensive interest in goals for higher education. The first additional factor is the realization that "colleges and universities are institutions which consume resources and which provide socially useful outputs of interest to the students, private contributors, and the general taxpaying public who provide those resources." The second factor is the awareness that colleges and universities "operate in a resource-constrained world so that costs of activities and programs must be reviewed not only in terms of the dollars spent on them, but also in terms of the benefits foregone in the other alternative uses of those fund" (Keller 1972 p.47).

Mission, goal, or objective are synonymous for "outcome" in the content of decision making and are often used interchangeably in the literature. If there is a distinction made, it relates to the time frame and magnitude, i.e. short-time horizon and fairly specific scope for objective, long-time horizon and more general scope for goal, and infinite-time horizon and extremely vague scope for mission.

Because the time dimension is immediate and the scope is fairly specific in this study, the term objective will be used. "An objective is a specific description of a desired result to be achieved" (McConkey 1975 p. 6). Stephen J. Knezevich further defines a "performance objective" as a desired "outcome that is specific in nature and measurable by degrees of achievement when conditions are known and given products, processes, or other achievements can be defined" (Knezevich 1973 p. 45). Radford's distinction between 'overt' objectives - those that are published-and 'covert' objectives-those that are confidential-will also have significance in this study. He points out that "in some cases, the overt and covert objectives may be mildly contradictory, or even in direct conflict" (Radford 1975 p. 7). Finally, he concludes that "in some cases, one objective of a multiple set may act as a constraint on the others" (Radford 1975 p. 8).

Outcome statements have their roots in the concept of motivation. Greek philosophers, English rational utilitarians, psychologists, social-psycologists and economists have attempted to use and explain motivation with the psychologists having the most success. Motivation has its beginnings in the principle of "hedonism" which is based on the assumption "that behavior is directed toward pleasure and away from pain" (Vroom 1964 p. 9). This principle is apparent in "Thorndike's law of effect" and "its modern counterpart, Hull's principle of re-enforcement." It is also in Tolman's and Lewin's "cognitive theories of behavior" and Vroom's "concept of valence" which is defined as "affective orientations toward particular outcomes" (Vroom 1964 p.

11-15). The same basic concept is found in "social exchange theory" which describes and explains the process governing the exchange of rewards and costs between human beings.

This concept includes many different terms used to refer to preferences such as, incentive, attitude, expected utility, need, motive, value and interest. The initial application of this "outcome theory" was in individual behavior in the work place. In 1960, it emerged as a critical aspect of the approach taken by the President's Commission on National Goals.

The President's Commission on National Goals introduced their report Goals for Americans, by concluding that the "paramount goal of the United States was ... set forth in the Declaration of Independence drafted by Thomas Jefferson and adopted by the Continental Congress July 4, 1776" (President's Commission 1960 p. 1). Using those stated convictions as a focal point, the commission proceeded to identify and explain specific goals for "at home" and "abroad." Since 1960, there have been two restatements of national goals; "Toward a Social Report" (1969) and "Toward Balanced Growth: Quantity with Quality" (1970).

Universities and cities were the state and local government institutions that copied the practice of outcome identification and adoption with the most enthusiasm. Goal statements for universities (a segment of post secondary education) have been predominantely the products of state education planning efforts and independent research.

The efforts at goal identification and statement in higher education appear to have two characteristics; the goal statements are general and there is no evidence of any rigorous attempt to explicitly integrate the goal information into higher education decision making or use the criteria for evaluation of organizational performance.

These characteristics are illustrated in the goal statements on higher education of ten (10) states. The states of Alabama, California, Connecticut, Iowa, Missouri, Montana, New Jersey, New York, Oklahoma, and South Carolina were arbitrarily chosen as representative of the existing state of the art of goal adoption in higher education.

The specific goal statements are too numerous to attempt to inventory and classify. They range from general statements to some fairly specific directives. One of the most general statements is in the Alabama report. Higher education is expected "to preserve the heritage of the past and to inculcate a critical appreciation of the values, aspirations, achievements, and failures of preceding generations in order to equip the rising generation with the knowledge and perspective to meet the recurrent problems of human society" (Alabama 1975 p. 25-6). California is almost as general. They conclude that "Learning is the primary purpose of California, public higher education." "Educational institutions exist to respond to the learning needs of our citizens and society." "The discovery of knowledge" and "public service" is a function of higher education" (California 1973 Chapter I).

Oklahoma groups their goals under the following headings: (1) higher education access, (2) institutional role and scope, (3) budgeting and finance, (4) accountability, (5) governance and administration, (6) quality and excellence, (7) creativity and change, and (8) private higher education. Montana alludes to more specific targets when it states that "Our goals must be challenging in order to invoke the best response -the highest degree of excellence - at the same time they should be realistic in order to serve as yardsticks of our achievements and deficiencies and as criteria for present and future policies" (Montana 1974). Connecticut offers an example of the more specific statements. Their first goal is "to insure that no student in Connecticut who is qualified or qualifiable and who seeks higher education be denied the opportunity for such education because of his social, ethnic or economic situation" (Connecticut 1974 p. 93).

The Alabama planning report expressed concern that the "state's system of higher education"... will... "through coordination and cooperation, most effectively achieve the purposes outlined above" (Alabama 1975 p. 3). The California report, on the other hand, "does not include means of accomplishing these goals, nor does it include specific planning objectives" (California 1972). An appendix in the Missouri report provides a definition of "productivity as the relationship between selected inputs and selected outputs" that can be used in analysis of an "educational enterprise" (Missouri 1966 p. 115).

In Iowa, the missions of Iowa's three universities are published in the Procedural Guide of the Iowa State Board of Regents. The specific university mission statements are preceeded by a role and scope statement for the Board of Regents that also relates to outcomes of higher education in Iowa. "Universities... strive to offer, (1) diversified and high quality programs... at reasonable cost to a major segment of those seeking post-secondary education in the state." (2) "... a wide range of subject selection and the greatest freedom to fulfill potentialities in pursuit of knowledge and in preparation for a role in society," are example of quasi-objectives included in the Board's role and scope statement (Iowa State Board of Regents 1978 p.VI-5).

Iowa State University's missions include (1) "to be a distinguished land-grant university,"... (2) "to maintain the overall strength and desirable balance of the university as a whole,"... and... (3) "the maintenance of strong programs... with graduate instruction, research, extension and public service functions... (that are) ... clearly recognized and generously supported" (Iowa State Board of Regents 1978 p.VI-7). The present mission statement is much more descriptive of institutional activities than the student centered objectives included in The 1973-75 Chart. At that time, "the purpose of the university center(ed) around achieving at least four ultimate objectives for the its students: (1) to give the student vocational competence in his chosen subject-matter area; (2) to provide an atmosphere which encourages further personal development; (3) to bring about a better awareness of social and civic responsibilities; and (4) to develop human relationships" (The Chart 1973 p. 7).

Some of the objective content of goal statements and their verification is the result of comprehensive studies. For example, California developed an elaborate "Institutional Goals Inventory" instrument in 1972 which gathered information on 90 goal statements and provided a framework whereby the participants could write their own. This survey form is published and distributed by Educational Testing Service, located at Princeton, New Jersey (Peterson 1973). Rand used a Delphi procedure that identified 45 characteristics of effectiveness of higher education (Dalkey/Rourke 1971 p. 13). The National Center for Higher Education Management Systems at the Western Interstate Commission for Higher Education published an "Outcome

Measures and Procedures Manual" in 1975 that offers an elaborate classification of objectives of higher education (Micek, Service and Lee 1975 p. 248). Finally, Edward Gross and Paul Grambsch replicated a 1964 survey in 1971 that included a large segment on university goals (Gross 1974).

An interesting sidelight that supports the utilization of outcome statements in Iowa education is the nature of Chapter 280.12 of the Code of Iowa. This Iowa law, passed by the Sixty-fifth General Assembly in 1974, provides that: "The board of directors of each public school district (there are 455 public school K-12 districts in Iowa) and the authories in charge of each nonpublic school shall: (1) Determine major educational needs and rank them in priority order. (2) Develop long-range plans to meet such needs. (3) Establish and implement continuously evaluated year by year short-range and intermediate-range plans to attain the desired levels of pupil achievement. (4) Maintain a record of programs under the plan. (5) Make such reports of progress as the superintendent of public instruction shall require (1975 Code of Iowa Vol. I Chapter 280.12).

Many school districts are using the Phi Delta Kappa Needs Assessment Project to meet the requirements of Chapter 280.12. Anton J. Netusil reported on Phase I, Needs Assessments and Ranking Goals at a meeting of The Canadian School Trustees Association on June 18,1976 . Elaine F.

McNally reported on the implementation of Phase II, "Identification of Needs in Iowa" in an article with Howard H. Bernie, who supervised a similar program in Canada. Their report describes a program evaluation strategy based on goal studies and needs assessment designed to "keep school offerings relevant" (McNally 1979 p.1). They report that over 150 goal exercises have been implemented in the last five years in Saskatchewan, Canada and in Iowa. Phase III, evaluation, is scheduled for implementation in Iowa in 1979.

The concept of goals is still the basis of current studies. The January 9, 1978, issue of The Chronicle of Higher Education had brief articles that are related to the concept. A Harvard study entitled "Harvard Study May Refute Claim That Colleges Have Only Modest Impact," (on students) is based on a three year study that concludes; "the college experience may cause marked, positive changes." Another article, "Britain to 'Rationalize' its System of Higher Education", implies there are goals and a rational decision-making structure to determine the direction of their higher education (The Chronicle Vol. XV No.17 Jan. 9, 1978 p.5&11).

Two current examples of the use of outcome statements in unrelated subject areas that are the focus of considerable interest, are the latest report of the U. S. Senate Select Committee on Nutrition and Human Needs, Dietary Goals for the United States, Second Edition, issued December 1977, and the

Iowa 2000 effort to develop goals for Iowa. Both efforts center around establishing goals relative to relevant public concerns with the aspiration of finding positive responses to alleviate the concerns.

This brief review is the foundation for a basic premise of this study: The concept of "outcome" statements are currently legitimate expressions in the management of higher education. But the study also supports Harold L. Hodgkinson's conclusion that "goal statements are next to meaningless without specific agreement on how the goals are to be implemented, by whom, what resources are to be used, and how the effort will be evaluated" (Hodgkinson 1972 p. 44).

Resource allocation models in higher education

"For many years higher education has presented the 'bill' for higher education to the public for support and it usually was paid" (Hussain 1976 p. 129). However, the "bill" is getting bigger. Hussain reports that 2.2 per cent of the Gross National Product (GNP), equaling $15.2 billion, was appropriated to higher education in 1965-67. By 1980, the appropriation will be $32.5 billion which is 2.5 per cent of GNP (1967 dollars).

In a period of continuous growth (1945-65), there was no apparent necessity for intensive scrutiny of financial management. Although the new resources were scarcely adequate, and usually lagged a year or two behind the rapidly expanding needs, the net revenue increased each year and also came with very few strings attached. Most institutions of higher education utilized the collegiate model that placed very little emphasis on attempting to achieve optimum results with the available resources. The management cliche, "any management strategy works when no management is needed" seems to be appropriate for this period.

Frederick deW. Bolman's reflections on that period of continuous growth are more critical. Proceeding from the premise that "ideally, colleges and universities serve society by preparing and helping people to live constructively in society" he portrays a university as a pyramid in which the apex is social need, the body consists of purposeful activities to meet the need, and the base is faculty resources in terms of teaching, research and service. He observes that the intuitive logic implies that the base through the body supports the apex. "But American ingenuity in higher education invented the inverted pyramid." The base has become the purpose of the university. "The academic department is a monopoly" which will destroy the university if the pyramid is not turned over (Bolman 1976 p. vii-viii).

The period of abundant budget increases in higher education, if it ever existed, appears to be over. The present period is being labeled the "new depression" (Miliard

1972 p. 5) or the "new environment" (Hussain 1976 p. 129). Dressel identifies the principal characteristics of the "new scenario", as (1) stable or declining enrollments, (2) stable or declining (because of inflation) budget allocations. (3) stronger, competing demands for state resources by health, welfare, environment, highways, etc., (4) increased resistance to higher taxes by taxpayers and legislators (5) diminishing number and magnitude of "soft money" grants and (6) public disillusion with higher education (Dressel and Simon 1976).

Prior student unrest, the prevailing, perceived need for reform of American society, and the desire that course work be relevant to contemporary life and problems, also contribute to the pressures on universities. All these pressures contribute to the impetus of questions like: How can we handle more students, or, how can we increase the quality of education with less resource expenditures? As university operations come under closer scrutiny, the need for more effective management and financial accountability becomes essential for the survival of the quality and a quanity of educational service commensurate with need.

Ernest L. Boyer contrasts "the old and new attitudes toward management in higher education." The concept of management has negative connotations to traditional academic leaders. They describe it in terms of "mechanization, control and output." The contemporary attitude views it as "merely the process by which universities seek to meet their obligations and achieve their goals with a minimum of waste of both human and material resources." It is "the exercise of more rational judgment based on more reliable data." It is "administration by perspective rather than by panic" (Boyer 1972 p. 16).

Like most organizations, institutions of higher education are prodded into purposeful management far more by necessity than by choice. The universities' concern for human values makes it vulnerable to cross pressures. The obligation to meet the needs of special groups, regardless of cost, is balanced by the need to balance one value against another because the university can never hope to satisfy everyone. The alternative for institutions that refuse to demonstrate accountability, rigorously scrutinize internal operations, and prudently manage resources, is the performance of these tasks by external agencies far less equipped to handle them.

Hussain concludes that in this "new environment" the academic community "has little choice except to explore PPBS and similar planning systems, or lose their credibility as legitimate managers of a vital social function" (Hussain 1976 p. 131). The pressure on higher education to consider simulation models stems from the use of such constructs by industry and government. Paul L. Dressel concludes that "efficient and effective methods of resource allocation compatible with institutional organization, goals and needs have not been put into effect" because they have not been developed. He points to the need for a model "predicated on the basic organizational unit of universities, the department, and build on a planning frame that facilitates redistribution of resources on the basis of the goals of the institution and the roles of the departments in fulfilling these goals" (Dressel and Simon 1976 p. 1).

Resource allocation models in higher education to date appear to refer to almost any scheme that has been recently devised and involves resources in any manner. Most of the existing models are enrollment-driven models and do little more than produce tentative resource requirements for alternative levels of enrollment. Hussain concludes that the existing resource allocation models "are not optimizing",... "do not consider ... the relevance of the program offered," ... or "enable the universities to calculate trade-offs directly" (Hussain 1976 p. 62-4, 122). However, the present models have developed a significant body of knowledge that is basic to any model of higher education. These include specific definitions for such concepts as "credit-hour," "program contact-hour," "student contact hour," "student credit hour", "full-time equivalent" student, and faculty person.

In this study, resource allocation is used in the economic sense of effectively allocating scarce organizational resources among competing or alternative ends to provide maximum satisfaction to the participants and clientele of the institution, an optimizing construct. In this framework, resource allocation is one of the principal functions of management. It is a function that attempts to answer three basic questions: (1) What are the appropriate objectives to pursue? (2) What are sensible levels of achievement of those objectives? (3) What are the most effective alternative activities for achieving those levels?

There are still significant, conceptual problems present in implementing resource allocation in the economic sense in higher education. First, it is difficult to identify the outcomes of higher education. Second, there is no identifiable unit of the university that produces a unique output. Third, production functions for higher education are not verified. Finally, the problems of benefit identification and measurement, as well as cost allocation rules, are not solved.

A full-scale theory of resources allocation, in the economic sense, has not been created in higher education to date. It may be generous to conclude that there exists a philosophy of optimizing management at the present time. Yet, at least some people believe that the time has come for universities and colleges to become "as searching in their self-inquiry and as data conscious in their self-analysis as they have long been about everything from economic behavior to the transplanting of human hearts" (Champion 1972 p. 55).

In 1970, there were only eight resource allocation models in higher education and only two of these were operational (Hussain 1976 p. 15). In May of 1975, the Center for Educational Management Studies (CEMS) at the University of Massachusetts at Amherst, conducted a survey that identified 394 institutions of higher education as using models. Two-hundred ninety-six (75%) of these were public institutions. Seventy-one percent (280) of these institutions were using the "Resource Requirements Prediction Model" (RRPM) which is an "Induced Course Load Matrix" (ICLM) enrollment driven model and is the model presently being considered at Iowa State University.

Hussain provides an extensive inventory of existing institutional resource allocation models in higher education based on his research for the Organization for Economic Cooperation and Development. He identifies three models that have fairly widespread adoption.

TUSS - Total University System Simulation;

RRPM - Resource Requirements Prediction Model;

CAMPUS - Comprehensive Analytical Methods of Planning in

University Systems.

Four other models are briefly referred to by Hussain but not discussed in detail. A limitation of all resource models, including CAMPUS, RRPM AND TUSS is that they are not optimizing models. Also, they do not consider benefits or performance; the quality of the student, teacher or course; nor the relevance of the programs offered nor their demand by society (Hussain 1976 p. 63-4). Hussain concludes that... "not enough work has been done on the economics and feasibility of using models to respond to 'what-if' questions. The models do not enable the user to calculate trade-offs directly" (Hussain 1976 p. 122). The resource implications of questions on staffing changes, curriculum changes, admissions policy and others may be answered only to a limited degree. "Clearly, there are other subjective implications which reflect upon the quality of operations such as effects on students' contributions to society, and impact on faculty values" (Hussain 1976 p. 37).

"The state of the art in modeling has not advanced sufficiently to deal in a quantitative manner with this aspect of planning and programming changes. However, the ability to compute rapidly the resource implications of alternatives will lead, hopefully, to a more ordered and structured consideration of the subjective aspects of higher education" (Hussain 1976 p.37).

The evaluation of the use of resource allocation models in higher education is not encouraging. Since it has not been proven that models will work, most of the comments elaborate on "why they won't work." Lyrell believes that most inadequacies that D. B. Lee attributed to urban planning models are applicable to models in higher education. These include "hypercomprehensiveness, grossness, hungriness, wrongheadness, complicatedness, mechanicalness, expensiveness and misimplementedness" (Lyrell 1976 p. 80). Kenneth Boulding feels that "computerized and numerical models, especially those with fancy diagrams and print-outs, are almost certain to produce illusion of certainty and may therefore easily lead to bad decisions" (Kirschling 1976 p. 2). Kirschling's appraisal is a little more encouraging. He points out that models may claim to do too much, create the appearance of certainty, use inappropriate techniques, be technique-oriented rather than problem oriented but concludes these are not critical errors. "Rather, the important blunders occur when either model sponsors or model builders or both (1) conclude that the other group is 'stupid' and not just ignorant and (2) fail to be reasonably open with the other group during the negotiations and discussions which precede actual model-building efforts" (Kirschling 1976 p.4).

Finally, there is the problem with the user. He may misuse the model, lacking appreciation for the model's capabilities and limitations.

The significant aspect of all the critic's adverse findings is the fact that none of them feel that modeling efforts should be abandoned. Kirschling conjectures three possible explanations for this: (1) Many "decision makers are highly critical of the bases on which they are forced to make decisions." They want better ways and hope that model builders may help them. (2) "Management Science is a young science" and needs time to mature and prove itself. (3) Model building is a "convenient way of representing the total experience which we possess, of then deducing from that experience whether we are in the presence of pattern or law, and if so, showing how such patterns and laws can be used to predict the future" (Kirschling 1976 p.12).

Modeling also has assumed greater importance as decision makers have realized that the next two or three decades will see postsecondary education undergo radical changes - new types and ages of students, a redefinition of higher education to include all postsecondary education, and changes in educational processes.

The Delphi technique

This study assumes that adequate information is a necessary condition for better institutional decisions. Information is data that adequately expresses all aspects of the situation, is provided in a timely manner and is presented in a format that facilitates decision making.

One of the most serious obstacles to acceptable conclusions within a rational decision-making structure is "voids" in information. In the real world, a human can substitute intuition, wisdom, insight, and judgment for information. Judgment and informed opinion have always played a crucial role in human enterprises. However, Dalkey states that the products of judgment, wisdom, insight and similar intellectual processes, are flattering names for kinds of opinion (Dalkey 1969 p. 2). He identifies three features of opinion: (1) Subjects do not know the answer. (2) Subjects have other relevant information that enables them to make estimates. (3) The route from "other relevant information" to an estimate is neither immediate nor direct (Dalkey 1969 p. 19).

It is man's ability to employ a logic with "fuzzy truths, fuzzy connectives and fuzzy rules of inference" that allows him "to summarize information - to extract from the collection of masses of data impinging upon the human brain those and only those subcollections which are relevant to the performance of the task at hand" (Kirschling 1976 p. 10).

Groups also use incomplete information to arrive at factual conclusions or judgments. The traditional modes of arriving at consensus involve group interaction that has three undesirable aspects. One is the influence of the dominant individual. Another is noise; i.e. irrevelant or redundant material that obscures the directly relevant material offered by participants. The third is the group pressure that puts a premium on compromise (Dalkey 1967 p. 2-3).

In the early 1960's, a group of researchers at the Rand Corporation set out to develop a procedure that did not have these drawbacks. The result was the Delphi Technique. Delphi is the name that has been assigned to a technique designed to elicit opinions from a group with the aim of generating a group response. The Delphi technique is a method for the systematic solicitation and collation of expert opinions and judgments. Delphi is a "methodological modification" of traditional methodology in social sciences (Helmer 1965 p. 1). "The Delphi method is nondata based and relies on collective judgement" (Linstone & Turoff 1975 p. 3). "The technique puts the emphasis on informed judgment. It attempts to improve the panel or committee approach by subjecting the views of individual experts to each other's criticism in ways that avoid face to face confrontation and provide anonymity of opinion and of arguments advanced in defense of those opinions" (Brown 1968 p. 3). "Delphi replaces direct confrontation and debate by a carefully planned, anonymous, orderly program of sequential individual interrogations usually conducted by questionnaires" (Brown, Cochran, Dalkey 1969 p. 1).

There are several unique properties of a Delphi exercise. (1) The procedure is a rapid and relatively efficient way to "cream the tops of the heads" of a group of knowledgeable people (2) A Delphi exercise, properly managed, can be a highly motivating environment for respondents. (3) The feedback, if the group of experts involved is mutually self-respecting, can be novel and interesting to all (Dalkey 1969 p. 16-7).

Delphi is a method for structuring group communication so that the process is effective in allowing the group of individuals, as a whole, to deal with a complex problem. To accomplish this "structured communication", it provides some feedback of individual contributions of information and knowledge; some assessment of the group judgment or view; some opportunity for individuals to revise views; and some degree of anonymity for the individual responses. The intention was to assure that changes in estimates reflect rational judgment, not the influence of certain opinion leaders (Weaver 1972 p. 1).

The Delphi Technique "eliminates the need for committee activity altogether, thus further reducing the influence of certain psychological factors, such as specious persuasion, the unwillingness to abandon publicly expressed opinions, and the bandwagon effect of majority opinion" (Helmer 1966 p. 17). The intent of Delphi is a controlled and rational exchange of opinion that will lead to the most defensible conclusion.

There are three distinct features of the Delphi procedure.

(1) Anonymous response is the title given to individual interrogration by questionnaire. "anonymity is a device to reduce the effect of the socially dominant individual. It is maintained by eliciting separate and private answers to prepared questions. Ordinarily, the procedure is carried out by written questionnaire; on-line computers have been used for some exercises. All other interactions between respondents is through formal communication channels controlled by experimentors."

(2) Iteration and controlled feedback between rounds. Controlled feedback "is a device to reduce noise (among other things)."

(3) Statistical group response - the group opinion is

defined as an appropriate aggregate of individual opinions on the final round. Some form of statistical index is reported as representative of the group opinion. The statistical group response is a device to assure that the opinion of every member of the group is represented in the final response (Dalkey 1969 p. 16).

Delphi gets its reasoning from the historical adage "two heads are better than one." This is not the unique characteristic of Delphi. The concept of "pooling many minds" is reflected in committees, councils, panels, commissions, juries, boards, legislatures and even in referrendums by the voting public (Dalkey 1969 p. 6). The unique feature is the use of systematic procedures which lends an air of objectivity to the conclusion that may or may not be spurious, but which is at least reassuring.

Most of the validate research on the Delphi technique has utilized "almanac material; i.e. little known factual information that is available only in obscure places," as a basis upon which to evaluate the validity of the technique. However, some research has been done with regard to "objective uncertainty," i.e., where the answers to questions do not already exist in some form (Dalkey/Brown 1971 p. 2). From the standpoint of the decision maker, opinions about values and objectives are just as relevant to decisions as factual opinions about consequences (Dalkey and Rourke 1971

p. 1).

The application of Delphi is based on the hypothesis that there is a "group opinion" and there is a "correct answer" that the group is trying to estimate. There are three testable consequences of the hypothesis that there is a correct judgment: (1) Individual judgments cannot be capricious in the sense that they "could be anything." This is a difficult consequence to test directly. It requires that individual judgments have a reasonable amount of stability. A simple retest for reliability runs into the problem of memory. If an individual expresses a given judgment at a particular time and is asked the same question some time later, he is very likely to remember his previous answer, thus introducing a "spurious reliability." However, the consequence can be tested indirectly by taking into account the group distribution of answers. If the distribution of answers is "reasonable", i.e., not completely flat, or U-shaped, the hypothesis that the responses are not capricious receives some confirmation. (2) The group should exhibit convergence, given iteration with feedback. In part, this requirement is set by analogy with factual judgments, and in part by the consideration that, if there is a judgment that the group is trying to approximate, individual judgments should be influenced in a reasonable way by the additional information furnished by feedback from the group. (3)

judgments should exhibit a reasonable amount of group reliability, i.e., two highly similar groups should, on the whole, arrive at similar judgments and, on iteration, should move in the same direction (Dalkey 1969 p. 74-5).

If there is the assumption that there is a correct answer that the group is trying to estimate; if the judgment can be expressed in numerical terms, as for example, the weights to be placed on objectives, then, in the absence of ways of distinguishing among a group of respondents with respect to their value-judgment-making ability, the group response is at least as likely to be "correct" as that of half of the respondents. This is a somewhat surprising conclusion, considering the usual feeling that value judgments are nebulous and unmanageable. The basic assumption, however, is not without foundation. In just this way, the question of correctness - and essentially factual correctness - can be raised with respect to the essentially contributory considerations at issue in evaluative-means-judgments.

There are three necessary (but not sufficient) conditions for assuming there is a group judgment: (1) Reasonable distributions of group responses can not be flat or bi-modal, (2) Group reliability - correlation for different groups should be high and (3) Change, and convergence on iteration with feedback, must consider feedback and have it affect the judgment. These three conditions could be interpreted as a partial definition of the term group judgment for objective, uncertain questions (Dalkey and Rourke 1971 p. 5).

There are also several tautologies which are directly relevant to the group judgment process: (1) The total amount of information available to a group is at least as great as that available to any member. (2) The median response to a numerical estimate is at least as good as that of one half of the respondents. (3) The amount of misinformation available to the group is at least as great as that available to any member. (4) The number of approaches for arriving at an estimate is at least as great for the group as for any member. These tautologies do not add up to anything like a theory of the group estimation process, but they are suggestive. At just this juncture, there certainly is a sphere in which "the concept of correctness is legitimately applicable in a straightforward and intelligible way" (Dalkey 1967 p. 5).

This application of Delphi utilizes evaluation judgments of experts. The use of expertise is not a retreat from objectivity. Expert judgment can be incorporated into the structure of an investigation and can be made subject to some of the safeguards that are commonly used to assure objectivity in any scientific inquiry (Brown 1968 p. 14). The advice received from experts is of two sorts: (1) Dealing with matters of fact and (2) Dealing with evaluations (criteria, priorities, goals, objectives, etc. (Dalkey and Rourke 1971 p. iii). Nicholas Rescher distinguishes between valuing and evaluation. "To value a thing is nothing more nor less than to assume a pro-attitude toward it." To evaluate something is to consider it "in terms of good/bad" or "to deem it to be meritorious or liabilist." "One can, without irrationality, value something 'for no good reason whatsoever,' but (rationally) to evaluate it positively is to take a 'principled' step that requires reference to criteria" (Rescher 1969 p. 3).

For cases in which the group task is to estimate a numerical quantity, the median of individual estimates has turned out to be the most useful index tried to date. "Aside from being independent of a particular metric, it has the intuitively appealing quality that it can be viewed as the outcome of a democratic voting procedure, in the sense that half the panel considers the correct answer to be less than or equal to the median, while the other half considers it to be greater than or equal to the median" (Dalkey 1967 p. 3). An obvious variant of the simple median is a weighted median, giving more than one vote to the opinions of experts whose judgment objectively deserves preferential treatment.

The use of confidence scores in a Delphi process serves two functions: (1) "To assign relative weights to responses for feedback purposes, and (2) To provide a kind of overall assessment of the quality of the group response after feedback" (Thompson 1973 p. 18). "The self-confidence rating appears to be measuring something about the questions fairly well and not just individual differences in self-assurances" (Dalkey 1969 p. 69). For example, even self-assigned competence scores may justify such differential weights.

If, in addition to a consensus, it is desirable to have an indication of the spread of opinions among the experts, that is, of the amount of their "dissensus," it may be expedient to state the interquartile range of their responses (Helmer 1966 p. 17).

Most experiments or applications of the Delphi technique involve from three to five sessions or questionnaires. In practice, the procedures are used with a group of experts or especially knowledgeable individuals (Dalkey 1967 p. 2). The standard operating procedure appears to devote the first two questionnaires to the generation of items to be scaled. The first questionnaire asks for information in an open-ended structure. This information is synthesized by the researcher and that synthesis is returned to the respondents to review, edit, and re-evaluate. The respondents are also asked to express their opinions on the relative importance, ranking, etc., of each edited category and to record the degree of confidence they had in their judgments. This information is processed and summarized by the researcher and returned to the respondents. This information informs each respondent of the present status of the group judgment. In a third questionnaire, each respondent is informed of the group median from the second round responses and of their interquartile range, as well as the frequency distribution of the self-ratings. The participants are instructed to reconsider each answer, make a revised estimate and, if the new answer lay outside the indicated interquartile range, briefly state a reason for this opinion (Helmer 1966 p. 100). Other rounds are necessary if the researcher wishes to introduce a new variable and relate it to the original information generated.

One study of a semi-professional group was asked to list five to ten skills they judged to be most important in the performance of their work. These were clustered to form composite skills and returned to the respondents for their editing and ranking for importance. The next questionnaire asked for five to ten of the most common problems they encountered in their work. The clustering process was repeated on this information by the researcher and returned to the respondents for editing and ranking. Finally, the respondents were asked to match skills clusters that help solve problems with the problems they will help solve. They were also asked to rank the effectiveness of each skill to solve each problem. Finally, the last questionnaire asked each respondent to estimate his/her level of competency of each skill. The results were used to plan a mid-career professional training program (International Institute of Municipal Clerks 1977).

The "reviews" of the Delphi method are no more glowing than those of resource allocation models in higher education. However, some researchers project hope, if not optimism, with the conclusions that the existing research leads us "to conclude that Delphi in combination with other tools, is a very potent device for teaching people to think about complex problems" (Weaver 1972 p. ii). A promising application of Delphi seems to be its use as a planning tool, which may aid in probing values and judgments held by members and constituencies of an organization.

The originators of Delphi claim that, used properly, it may be able to enhance policy makers capacity to think in complex ways about organizational productivity. "The evidence is mounting that systematic processing of expert opinion can produce significant improvements both in accuracy and reliability (using the notion of reliability to refer to the range of estimates)" (Dalkey 1967 p. 8). A "series of experiments... was conducted in order to increase the understanding of the process by which groups answer questions using the Delphi method" (Brown et al. 1969 p. 1). The study examined two aspects of Delphi. (1) it compared face-to-face discussion with the controlled feedback interaction and (2) It evaluated controlled feedback as a technique for improving group estimates. Some conclusions were: (1) Anonymous controlled feedback procedures produced more accurate group estimates than face-to-face discussion. (2) Delphi procedures create a well-defined process that can be described quantitatively. (3) A meaningful estimate of the accuracy of a group response to a given question can be obtained by combining individual self ratings of competence on that question into a group rating (Dalkey 1969 p. vi).

For material that can be confirmed, typical outcomes are that opinions tend to converge during the experiment, and, more often than not, the median response moves in the direction of the true answer (Dalkey 1967 p. 4).

There were a number of studies specifically aimed at determining the usefulness of the Delphi technique in formulating group judgments. These experiments produced the following generalizations: (1) The initial round produced widespread answers. (2) With interaction and feedback, the distribution of individual responses converged. (3) More often than not, the group responses (median of final response) became more accurate (Dalkey 1969 p. 20).

In a similar study Dalkey found that "overall 'group' judgments, concerned with factual knowledge, were 45% more accurate than individual judgments" (Dalkey and Brown 1971 p. 45-6). He concludes that "the results of the experiment are compatible with the assumption that 'group' judgments are, on the whole, as 'correct' for subjective judgments as they are for almanac material" (Dalkey and Brown 1971 p. iii).

It would appear that there is a certain amount of residual information remaining in the group after the first round estimates have been expressed. The interaction and feedback causes (or allows) this additional information to be brought into play, with consequent improvement in the group estimate (Dalkey 1969 p. 46). The results support the conclusion that Delphi procedures are appropriate (in a well-defined sense) for the formulation and assessment of criteria and objectives (Dalkey and Brown 1971 p. iii). The experiment furnished support for the conclusion that Delphi procedures are appropriate for processing value material, as well as factual material (Dalkey and Brown 1971 p. viii). The outcomes of these experiments appear to be that the Delphi procedure is appropriate for generating and assessing value material (Dalkey and Brown 1971 p. 6). The Delphi process can be used to assess the correctness of value judgments in the area of means-values (Rescher 1969 p. 17).

In another study conducted by Rand personnel in 1964, the experimental group obtained a sharper consensus than the control group (Brown 1968 p. 8). In still another study entitled, "Innovation in Education," which was carried out at the Institute of Government and Public Affairs at UCLA, the results indicated that "the Delphi technique may be potentially useful in educational planning" (Brown 1968 p. 11). "The experiment gives no basis for expecting that questions involving 'objective uncertainty' are inappropriate for Delphi treatment" (Dalkey and Brown 1971 p. 3).

Brown offers a scheme to improve the accuracy of experts judgment. His scheme is to have the experts express their judgments in probabilistic terms. The advantages of this requirement are: (1) It provides a concise expression of subjective uncertainty. (2) It provides an operational self-rating as to the degree of confidence to be placed in the judgment. (3) It is readily usable in decision-theoretic models. (4) It is easily combined with other forecasts couched in similar terms (Brown 1970 p. v).

Quade illustrates the potentialities of a specific application of Delphi in allocating a budget for crime prevention. His purpose was to determine what levels of each activity were the most effective. He hypothesized that there was a relationship between the degree of adoption and the value of the activity. That small amounts had almost no value and large amounts experienced rapidly diminishing returns. He used the Delphi to try to identify the lower threshold and upper limit that bounded the most effective range of operations (Quade 1970 p. 1). He concluded "imperfect as it is, the Delphi process or some further modification appears to promise a way to investigate many problems with high social and political content" (Quade 1970 p. 17).

Dror proposed a "trip-facet Delphi" method to predict "political feasibility" in terms of actions, policy-alternatives and policy areas where the variables are the main actors, the input into the policy areas, the actor-interactions and aggregated political leverages (required coalitions) and the critical leverage mass (rules of the process) (Dror 1969 p. 6).

In future studies it may be interesting to ask Delphi participants to comment why they believe an association or contribution exists more likely than by chance. The study could then report the basis for support/justification for the plausibility rather than probabilities and feedback. These could include (a) assumptions of the participant, (b) known or postulated causal factors, (c) specific evidence or (d) theoretical bases (Weaver 1972 p. 45).

Because critics cannot prove that the results of the Delphi technique are false, its results should be assessed as reasonable. The plausibility of the Delphi result, as now constructed, can be argued only on the basis of consensus or agreement. The singular weakness of Delphi is that its results have little substantive explanatory quality in their present form.

The purpose of the Delphi exercise in this study is to engage experts in conjecturing (asserting) about the plausibility (association or contribution) of specific higher education activities, attributes and objectives with each other. The established relationships will be the linkage between variables that will be manipulated by a multiple objective linear programming computer program.

Multiple criteria decision making

Martin K. Starr and Milan Zeleny's article "MCDM- State and Future of the Arts" traces the need for the understanding of multiple criteria decision making back to early philosophers' study of decisions (Starr and Zeleny 1977 p. 6). They conclude that it is the nature of, magnitude of, and values associated with the criteria that are key determinants in the decision-making process. They establish that the criteria concept must be combined with risk, uncertainty, randomness, rationality, and utility to adequately discuss either single or multiple criteria decision making. They conclude that single and multiple criteria decision making were developed on the assumption that "an understanding of a decision making process can be attained if one can predict its outcome with an acceptable accuracy" (Starr and Zeleny 1977 p. 15).

Another description of the environment that spawned MCDM is provided in the editors introduction to a book entitled Multiple Criteria Decision Making. This book, dated 1973, claims to be the first book published in the United States devoted entirely to MCDM. This description begins with the often-quoted section of Neumann and Morgenstern's book Theory of Games and Economic Behavior that identified a real problem but did little to answer it. Neumann and Morgenstern said:

> "This (optimization problem in the context of a social exchange economy) is certainly no maximum problem, but a peculiar and disconcerting mixture of several conflicting maximum problems... This kind of problem is nowhere dealt with in classical mathematics. We emphasize, at the risk of being pedantic, that this is no conditional maximum problem, no problem of the calculus of variation, of functional analysis, etc. It arises in full clarity even in most 'elementary' situations, e.g., when all variables can assume only a finite number of values (Cochrane and Zeleny 1973 p. xii).

The same introduction quotes Milton Friedman's position on the abuse of the single objective to simplify explanations rather than recognize that "'profit' is really a surrogate for a number of complex variables - such as earnings per share, stock price, debt-equity ratio, market share, goodwill, labor relations, product quality, ecological impact of operation and so forth" (Cochrane and Zeleny 1973 p. xiii).

The authors conclude that "the 'optimum optimorum' is gradually being replaced by fuzzy solution concepts such as compromise, arbitration, interaction, prominence, dominance, satisficing, negotiation, and bargaining" (Cochrane and Zeleny 1973 p. xiv). "Rejuvenation of the role of human judgment seems to be one of the main aspects of the literature on multiple criteria decision making but many participants seem to be skeptical about man's ability to choose among multiattributed alternatives, suggesting an interaction" (Cochrane and Zeleny 1973 p. xiv).

The concept of multiple criteria decision making involves decisions that have both multiple attributes and multiple objectives. Multiple attribute decision problem situations "deal with choosing among a set of alternatives which are described in terms of their attributes. The decision criteria in multiple attribute decisions are the strength of the decision maker's preference among the values of a given attribute and across attributes. Multiple objective decision situations recognize that attribute alternatives are often just means to higher ends - - the decision maker's objectives. The decision criteria in multiple objective decisions are the nature of the decision maker's preference in ordering objectives and the relationship between objectives and attributes. In general, "multiple objective decision models, because they explicitly treat the means-ends relationship, are more complex than multiple attribute models" (MacCrimmon 1973 p. 19). The main reasons for the distinction between attributes and objectives are summarized by Starr and Zeleny.

(1) Attributes are generally numerically measurable but objectives are very difficult to assess by numbers.

(2) Trade-offs between attribute levels can be more clearly defined for attributes, but in connection with objectives, the very concept of a trade-off is fuzzy.

(3) Attributes are more easily characterized through utilities while objectives may require fuzzy linguistic labels instead (Starr and Zeleny 1977 p. 14).

They identify another subtle distinction: "When mostly attributes are involved, we tend to refer to such situations as those of a 'theory of choice', while the cases dealing mostly with objectives may be referred to as a theory of 'decision making'." "In reality, both the attributes and the objectives are often involved in a mixed fashion. Criteria are both the attributes and the objectives judged to be salient in a given decision situation" (Starr and Zeleny 1977 p. 14).

The specific structure of the MCDM model dicates the source of the theory that supports it. Most of the support comes from mathematical, statistical, decision, game, and economic theory.

Martin K. Starr and Milan Zeleny, in an effort to establish some of the sources and roots of multiple criteria decision making (MCDM), refer to H. W. Kuhn and A. W. Tucker's introduction of a "vector-valued objective function in mathematical programming as an early contribution to MCDM. This was followed by the initial article by A. Charnes and W. W. Cooper on linear programming in 1957 and then their two volume works on the same subject in 1961. This publication Management Models and Industrial Applications of Linear Programming is still the basic theory on the general subject. Two years later (1963) Peter Bod laid the foundation of what is known today as multi criteria simplex method. It was not until 1968 that "the true foundation of serious and continuous study of MCDM were laid by Erik Johnsen in his monograph 'Studies in Multiobjective Decision Models'" (Starr and Zeleny 1977 p. 12). Seven years later, Tjalling C. Koopman's "efficient vector played a dominant role in bringing the Nobel Prize to him in 1975" (Starr and Zeleny 1977 p. 13).

Starr presents a unique description of the net attractiveness of different forms of MCDM, evaluated in terms of the information each makes available to a decision maker. Described in terms of a utility function, he identifies three basic levels of information availability. The first level is a set of "nondominated solutions." Here the decision maker is dominant and his decision-making role is unchanged throughout the procedure. Nondominated solutions, that are presented to the decision maker, provide minimal aid and can be obtained without his participation in the procedure. The second level is identified as "interactive programming." Here, the decision maker can actively participate in the assessment of his preferences and in the decision making process. The third level is en-titled "MultiAttribute Utility Theory (MAUT)." In this case the decision maker initially provides his preference function which is decomposed and used to select an appropriate solution. Although this technique has significant predictive value in models with up to five (5) attributes, it, in effect, replaces the decision maker with his initial preference function (Starr and Zeleny 1977 p. 15).

In addition to the applications of MOLP cited in the preceeding section, other forms of MCDM have been applied to the educational situation. Lee and Clayton illustrated how "goal programming" might be used to schedule an academic department (Lee and Clayton 1972 p. B-397). The resources were defined in terms of varying degrees of qualifications of faculty and non-faculty personnel. The goals were desired ratios and changes; i.e. faculty/student; faculty/staff; percentage increase in salaries etc. Geoffrion, Dyer, and Feinberg describe the use of interactive, multi-criterion programming in scheduling an academic department. Here, the variables were section size and research time available, with all resources held constant (Geoffrion et al. 1971). The other applications have been to a wide array of situations, many financially supported by grants from the federal, military branches.

Each application uses a different combination of techniques which Kenneth R. MacCrimmon presents in the following outline.

Multiple Objective/Multiple Attribute Decision Methods

A. Weighting Methods

1. Inferred preferences

a. Linear regression

b. Analysis of variance

c. Quasi-linear regression

2. Directly assessed preferences: general aggregation

a. Trade-offs

b. Simple additive weighting

c. Hierarchical additive weighting

d. Quasi-additive weighting

3. Directly assessed preferences: specialized aggregation

a. Maximin

b. Maximax

B. Sequential Elimination Methods

1. Alternative versus standard: comparison across attributes

a. Disjunctive and conjunctive constraints

2. Alternative versus alternative: comparison across attributes

a. Dominance

3. Alternative versus alternative: comparison across alternatives

a. Lexicography

b. Elimination by aspects

C. Mathematical Programming Models

1. Global objective function

a. Linear programming

2. Goals in constraints

a. Goal programming

3. Local objectives: interactive

a. Interactive, multi-criterion programming

D. Spatial Proximity Methods

1. Iso-preference graphs

a. Indifference map

2. Ideal points

a. Multi-dimensional, nonmetric scaling

3. Graphical preferences

a. Graphical overlays (MacCrimmon 1973 p. 38).

Starr and Zeleny express their findings about MCDM by concluding that there are two basic paradigms of modeling human decision making; (1) "outcome-oriented approaches" and (2) "process-oriented approaches" (Starr and Zeleny 1977 p. 25). The former is based on the belief that, if the process is understood, the outcome can be predicted accurately by correct measurement of each alternative. This notion fits with Diesing's Technical and Economic Rationality. The latter paradigm is based on the hypothesis that understanding the process is an alternative way of correctly predicting the choice and analyzing the underlying principles concurrently.

They stress the distinction between the process of (1) measurement; (2) search and (3) decision making.

> "What is traditionally presented as a theory of decision making is in fact a methodology of measurement. Measurement of utility, often relying on complex logical and mathematical tools, has become its (decision making's) central issue. If an adequate measurement of the net attractiveness becomes available, i.e., a single number is assigned to each alternative, the decision has been implicitly made and its selection is trivial; i.e., find the alternative corresponding to the largest (or the smallest) number. Thus, the problem of mechanical search has replaced a decision making process. No decision making has actually taken place. Technical measurement, followed

by mechanical search, designed to predict the most attractive alternative, become the substitutes for decision making.

It is important to realize that whenever we face a single attribute, an objective function, a utility function, or any other single aggregate measure, <u>there is no decision making involved.</u> The decision is implicit in the measurement and it is made explicit by the subsequent search. It is <u>only</u> when facing multiple attributes, objectives, criteria, functions, etc., that we can talk about decision making and its theory. As alternatives of choice become more complex and are characterized by multiple attributes as well as multiple objectives, the problem of combining these various aspects into a single measure of utility becomes correspondingly more difficult and impractical.

Decision making is a <u>dynamic process</u>: complex, redolent with feedback and sideways, full of search detours, information gathering and information ignoring, fueled by fluctuating uncertainty, fuzziness and conflict; it is an organic unity of both pre-decision and post-decision stages of the overlapping regions of partial decisions.

Yet we do not want to imply that there is no structure to it or that no formalization of such a process can be attempted. Surely, it cannot be captured by a decision tree, by a single mathematical function, or by other artifacts of mechanistic simplification. Its structure is functional, capable of generating its own path toward the decision. The emphasis is on the <u>process</u>, not on the <u>act</u> or the <u>outcome</u> of making a decision. The final decision unfolds through a process of learning, understanding, information processing, assessment and definition of the problem and its circumstances.

All components of the decision process are changing and evolving during its course: alternatives are added and removed, the criteria for their evaluation as well as their relative importance are in a dynamic flux, the interpretation of outcomes varies, human values and preferences are reassessed, etc. This reorientation and redefinition of the theory of decision making is reflected in the recent proliferation of terms like decision taking, decisioning, decision aiding, interactive decision making, decision management and dynamics" (Starr and Zeleny 1977 p. 25-6).

Multiple objective linear programming

As time passes, executives, administrators, and policy makers identify new complexities in the management of private and public organizations. If the people filling and studying these positions expect to retain their vitality, they must constantly be in the process of adaptation and learning. Multiple Objective Linear Programming (MOLP) is an adaption that attempts to incorporate systematic information processing into the increasing complexities and higher stakes of modern private and public operations in which the primary difficulty is the treatment of multiple conflicting objectives. It is one response to an expressed desire of executives, administrators, and policy-makers to have more and better information about the organization and its environment so they can strive to do their job better.

"The application of Multiple Objective Linear Programming (MOLP) to organizational decision analysis forces the decision maker to think of goals and constraints in terms of their importance to the organization" (Lee 1972 p.31).

Multiple Objective Linear Programming (MOLP) is a computer-assisted mathematical technique for determining the optimum allocation of scarce resources for each candidate solution of multiple objectives when there are alternative uses for the resources. Multiple Objective Linear

Programming, (MOLP) as the term is used today, includes formulating the problem in MOLP terms, finding the optimum allocation of scarce resources to achieve a desired candidate solution involving multiple objectives, and exploring the effect of changes in the value of the constraints, and the composition of the candidate solution.

Lee's definition of goal programming is accurate for Multiple Objective Linear Programming (MOLP) also. With the substitution of subjects it would read: Multiple Objective Linear Programming (MOLP) "is a linear mathematical model in which the optimum attainment of goals is achieved within the given decision environment. The decision environment determines the basic components of the model, namely the choice variables, constraints, and the objective function" (Lee 1972 p. 23).

"Choice variables are those real variables in the model whose values are arbitrarily assigned and changed in the search for the optimum set of values. The choice variables are related among themselves and to other variables whose values are specified according to the environment or technological situation. Constraints represent a set of relationships among variables, which restrict the values of choice variables" (Lee 1972 p. 23).

Multiple objective linear programming (MOLP) requires that:

(1) The problem must have definite, identified, numerical objectives.

(2) There must be separate and identifiable activities and the level of each activity must be measurable in numerical terms.

(3) The activities must be interrelated.

(4) The constraints must be identified and stated in numerical terms.

(5) The criteria that will be the basis for determining if there is a feasible or optimum solution must be identified and stated in measurable terms.

Sang M. Lee identifies additional requirements of linear programming that are fundamental to "goal programming" which are also requirements of MOLP : (1) The choice variables constituting the decision system must be homogeneous and linear. (2) There must be a set of constraints or limited resources. (3) There must be an objective(s) to achieve. ((s) my addition) 4) The objective(s) must be homogeneous in the sense that types of measuring units represented in the variables will combine to provide a consistent unit of measure for the objective(s) (Lee 1972 p. 20).

Multiple objective linear programming (MOLP) performs the same three types of analysis that goal programming does: (1) It determines the input requirements to achieve a set of objectives;

(2) It determines the degree of attainment of defined objectives with given resources, and

(3) It provides the optimum solution under the varying inputs and objective structures (Lee 1972 p.30).

There are two additional terms that are necessary to describe linear programming analysis. They are the primal simplex algorithm, which is the most common application, and the dual simplex algorithm. Simplex denotes the specific solution strategy, and primal and dual, the focus of application. The simplex algorithm is an efficient computational means for finding an optimal, feasible, basic solution by computing only a fraction (only the extreme points of the feasible region that increase the objective function of the stated linear problem) of the possible basic feasible solution. An objective function is a mathematical expression, involving some variables in the model, whose value may be computed when the values of all other variables are determined.

The primal "is a minimization problem with 'greater than' inequalities." The dual "is a maximization problem with 'less than' inequalities" (Randolph and Meeks 1978 p. 140). A. Charnes and W.W. Cooper describe the two methods in terms of their approach to problem solving. The primal (simplex) technique works upward from the inside of a convex set to determin the optimum solution and the dual (simplex) method works downward toward the same optimum solution from outside the convex set" () my addition for clarity (Charnes and Cooper 1961b p. 477).

Charles R. Carr and Charles W. Howe state that; "the dual variables (or 'shadow prices') indicate the value per unit of additional resource for each of the restraining or bottleneck resources. These prices may be compared to market prices to determine whether or not it would be profitable to obtain additional supplies. If the bottleneck resources are capital goods, the corresponding shadow prices represent the value per unit of time of increasing the stocks of these goods by one unit. The flow of these benefits, discounted over the expected life of the capital good, may then be compared to the cost of acquisition, or the internal rate of return may be computed (Carr and Howe 1964 p. 160).

In terms of this study, the primal algorithm will be utilized to solve the allocation problem which identifies the most effective levels of each activity, and the dual algorithm will be used to evaluate the solution, based on the relative value (marginal contribution) of the resources as they are used to support the primal solution, and identify the efficient matrices of unit values from the available supply of resources (Isermann 1974 p. 251).

The theory supporting MOLP is primarily of linear programming. Although George B. Dantzig "is recognized as the father of linear programming" (Keen 1977 p. 33) the team of A. Charnes and W. W. Cooper seems to have developed and proved the theory that supports the technique. Therefore the primary source of theory to support the techniques utilized in the study is explained and appropriate proofs are provided in A. Charnes and W. W. Cooper's two-volume works entitled, Management Models and Industrial Applications of Linear Programming.

Multiple Objective Linear Programming (MOLP) has the same limitations that Lee attaches to Goal Programming. The first is "proportionality." Multiple Objective Linear Programming (MOLP) is an extension of linear programming. This implies that the objective function, constraints, and objective relationships must be linear. This means that the measure of objective attainment and resource utilization must be proportional to the level of each activity conducted individually. This is consistent with the constant returns to scale assumption of classical economics. The second is "additivity." The condition that objective attainment and resource utilization be proportional to the level of each activity conducted individually does not ensure linearity. A nonlinearity may occur if there exist joint interactions among some activities of the objective attainment or the total utilization of resources. To ensure linearity, therefore, the activities must be additive in the objective function and constraints. The third is "divisibility." Another limitation of multiple objective linear programming is that fractions of decision variables must be acceptable in the solution. In other words, the optimum solution of a multiple objective linear programming problem often yields noninteger values for the decision variables. The fourth is "deterministic." In a normal Multiple Objective Linear Programming problem, all of the model coefficients must be constants. In other words, the problem requires a solution in a static decision environment (Lee 1972 p. 32-33).

Multiple Objective Linear Programming (MOLP) problem-solving strategies are described in numerous studies (Philip 1972; Evans & Steuer 1973; Isermann 1974; and Ecker and Kouada 1975). Michael Boehlje, an ISU Economist, collaborated with Wilfred Candler to apply MOLP to capital budgeting (Candler and Boehlje 1971 p. 325-30). They specified the structure of the problem but did not operationalize it. However, two applications have been worked out at Iowa State University and are reported as Journal Papers of the Iowa Agriculture and Home Economics Experiment Station. In one case, MOLP was utilized "to analyze the key variables affecting the profit levels (return) and income variability (risk) of the midwest farmer-feeder" (Iowa State

University Aug. 1977 p. 1). The trade-off between risk and return was identified as the point at which the variance is minimized for each level of income, where the farm activities included crop and livestock production, buying and selling, and investment. The variables in cropping included different classes of land, labor, alternate cropping activities, alternative uses of crops, selling the crops (wet or dry), feeding them to livestock or storing. Variables in cattle feeding activities included type of facility (open or confined) used, ration fed, sex of cattle, and time of year etc.

The other application of MOLP was used to measure the "trade-offs between cost and environmental variables in agriculture" (Iowa State University May 1977 p. 1). This study is a model of the national situation that "has approximately 24,000 variables and 1,200 equations" (Iowa State University May 1977 p. 1).

Finally, Ralph E. Steuer describes "An Interactive Multiple Objective Linear Programming Procedure" he completed in 1974 in a recent article by that title (Steuer 1977 p. 225-239). Steuer's program appears to have a couple of unique features. First, the model is structured for decision makers to interact with the program during the the procedure "in which phases of decision making are interleaved with phases of computation" (Steuer 1977 p. 227). Second, the decision maker only has to provide a value range for each objective rather than specifically weighting each objective before the computation. This value range can be increased or decreased in weight or the range narrowed during the procedure (Steuer 1977 p. 228).

The literature on MOLP in general and the three specific applications that have been briefly reviewed above seem to establish that this technique does have potential applications to problem situations structured in terms of Diesing's technical and economic rationality. The first article demonstrates the practical nature of potential applications when the authors conclude that, "the optimal organizations generated for the middle of the efficiency frontier are not dissimilar from those exhibited by numerous participants in the Iowa Farm Business Association" (Iowa State University Aug. 1977 p. 19). The second article demonstrates that very large problem situations can be modeled and run on a modern computer. The final article illustrates the rapid improvement in the available techniques that are eliminating major causes of criticism of computer models.

Summary

Goal (objective) setting and resource allocation models are accepted dimensions of higher education. The Delphi Technique, Multiple Objective Linear Programming (MOLP) and

Multiple Criteria Decision Making are theoretically supported processes. All these subjects have an application to the model of this study. Combining these subjects may initially cause some confusion because of the fine distinction between some of the concepts. An example is the classification of decision making.

Diesing, (1976) Thompson, (1973) Simon (1977) and Starr and Zeleny (1977) take the position that when each technical relationship, constraint and option are viewed as certain, the desired outcome is determined externally to the problem such that only one choice will meet the criteria of (technical) rationality: the process is calculation not decision making. A machine can make the choice. If the guiding logic of the process is an order of measurements and values based on a comparison of the exchange values of the resources consumed and the resulting public services delivered the process is one of evaluation, which is decision making. Only people can make this choice and different people will make different choices.

This model involves both concepts. The Delphi Technique can be incorporated into either process. In this study it is used to derive technical relationships between educational activities and objectives. Once these technical relationships are derived they are viewed as certain. The selection of the objectives occurred outside of the model and the alternative rankings were arbitrary to illustrate the mechanics of the model. These differences should become apparent as the development of the model is described.

CHAPTER III. METHODS AND PROCEDURES

Objectives of the methods and procedures

After reading the methods and procedures, you should:

* Be aware that some of the information critical to the formulation of an optimizing-resource allocation model of a public service is not empirically available and must be derived in the formulation process.

* Be acquainted with how a resource allocation problem of an educational institution is formulated into a linear programming format that optimizes a single objective and provides shadow prices and reduced cost information for specific characteristics in the model.

* Be acquainted with how the Delphi Technique is used to gather and classify information from a group of experts so that it is possible to restate the five (5) illustrative objectives so that they are compatible with a linear programming format.

* Be acquainted with the source of the model's constraints and activities and how the technical relationships between the resources within the activities are estimated.

* Be acquainted with how the analysis can be expanded to include multiple objectives by formulating the problem into a Multiple Objective Linear Program (MOLP) format.

* Be aware that the applications of the Delphi Method and Multiple Objective Linear Programming are the significant aspects of this chapter and that the unique values in the solutions are reasonable, but not reliable enough to support conclusions concerning the operation of the ISU College of Engineering.

Problem description and definitions

A university provides instruction, research, public service-extension and other accommodations to facilitate learning in the form of discovery, transfer and application of knowledge. As such, a university is an aggregation of physical facilities and purposeful educational activities that contribute to the maximum attainment of specific institutional objectives that express various aspects of desirable results of learning. Revenue resources to support a university come from various sources and are provided in the form of annual appropriations where the specific magnitude for any college is the result of a variety of state government, Board of Regents, and university administration political decisions.

After the Iowa legislature funds the Board of Regents' budget, the Board of Regents allocates a specific amount to Iowa State University and the university administration finally authorizes the expenditure of a specific amount by each college. The ISU College of Engineering has, in any given fiscal year, a relatively fixed quantity of resources available to achieve its educational objectives by financially funding the educational activities of the faculty of the College of Engineering.

The model assumes that this level of current operating resources[1] is less than is needed to achieve the desired level of objective attainment that might be achieved by carrying out all desirable faculty activities at a maximum level. As a result, the financial resources available to the College of Engineering are "scarce" in an economic sense. An annual problem facing the College of Engineering at Iowa State University is to determine what is the most efficient allocation of its scarce resources to effectively achieve an optimal attainment of educational objectives. The optimal

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[1] Some of the resources are in the nature of capital assets which are utilized individually or jointly with other colleges on the Iowa State University campus. Because of the method of financing these public assets through lump sum appropriations, that makes it very difficult to derive annual costs, they will not be included in this model. However, if the university was to adopt a system of benefit-cost accounting, this information could be incorporated into the model.

attainment of any single educational objective or combination of objectives requires the College to expend its finite fiscal appropriation. The question that college administrators must answer is: At what level should each faculty activity function to achieve an optimal attainment of the objectives and at the same time honor the constraints on faculty workload, college appropriations and student enrollment? Currently, administrative judgment based on organizational structure, academic tradition and past expenditures determines the magnitude of resource allocation to different faculty activities. The objective of this chapter is to formulate a linear programming model that will identify a maximum level of attainment of five (5) illustrative educational objectives together with the alternative levels of performance of each activity that support that attainment.

Intuitively, the problem is to (1) identify, establish and express the objectives and activities to be included in the model, i.e. Secure Resources; Structured Graduate Instruction, etc., (2) identify, establish and express how each activity leads to the attainment of each objective, i.e. the net return of graduate laboratory instruction to the development of a trained student, (3) identify, establish and express constraint-resources so they can be used in the model, i.e., the faculty's professional effort, the budget data etc., (4) empirically establish or derive by calculation the technical relationship between each resource-constraint and each activity, i.e., how much professional effort is required to advise ten undergraduate students, (5) restate units of professional efforts in terms of dollars, to reflect the fact that the professional effort of a Full Professor is more costly than the professional effort of an Assistant Professor and (6) structure all this information so that the results of the model's calculations can be interpreted, i.e., if faculty development is the most important objective, what will be the most technically rational allocation of the scarce resources?

This chapter technically describes how the above aspects of the model formulation are carried out. The purpose of the study is to conceptualize and formulate the model and not seek a valid solution. The fact that some specific values that represent aspects of the educational environment of the ISU College of Engineering are arbitrary should not detract from the value of the study. A value may not be empirically available because no one realized it was significant to decision making. Therefore, identifying that a specific value is critical to the decision-making process maybe a major accomplishment.

The chapter begins by determining the technical relationships between five objectives and ten activities. The budget, faculty effort, student enrollment and course offerings are restated so each factor can be formulated into the model. The model calculations are structured so they simulate the actual faculty effort, resource allocation and student-course-earned credit situation for the ISU College of Engineering in 1975. The model's calculations illustrate the resource allocation and activity levels if the College of Engineering attempted to optimize the attainment of the five objectives, singularly or as a composite utility. The data are incorporated into two scenarios. In the second scenario the undergraduate student enrollment increases and the graduate student enrollment decreases.

The techniques of the Delphi Method, Linear Programming and Multiple Objective Linear Programming are used to illustrate the composition of resource allocation to specific faculty activities if technical and economic rationalities are the prevailing motivations of the administrator's judgment rather than incrementalism. Economic rationality provides that scarce resources are allocated among alternative activities to provide maximum satisfaction. Maximum satisfaction is achieved when there is an optimal attainment of identified and prioritized institutional objectives that have been evaluated in terms of the exchange value of the objectives.

Before Linear Programming or Multiple Objective Linear Programming (MOLP) can be effectively utilized, the actual problem must be transformed into an appropriate format.

The following outline combines Kim's narrative statements and traditional identifying symbols to summarize the steps of formulating a linear programming problem (Kim 1971).

1. Formulation of the objective function(s); i.e., $fk(x) = \sum_{j=1}^{n} Ckj\ Xj$.
   a. Identify the objective underlying the problem in terms of the yardstick by which its attainment is to be measured; i.e., Ckj.
   b. Identify the activity set; i.e., j = columns.
   c. Identify the item set; i.e., i = rows.
   d. Determine the measurement item of each activity in the activity set; i.e., all non-zero aij.
   e. Assign a numerical weight to the measurement flow of each activity in the activity set; i.e., magnitude of each Ckj.
   f. Express the objective function as the weighted sum of the activity levels; i.e., $fk(x) = \sum_{j=1}^{n} Ckj\ Xj$.
2. Formulation of the system of structural constraints.
   a. Ascertain the input-output coefficients for each activity in the activity set; i.e., magnitude of each aij.

b. Establish exogenous flow requirements for each nonmeasurement item in the item set;I.e., RHS values.

c. Construct a structural constraint for every exogenous flow requirement of each nonmeasurement item in the item set. i.e., develop each i row such that $\sum_{j=1}^{n} aij\ Xj \leq bi$.

3. Establishment of boundaries of the activity levels.

a. Specify that the activity level cannot be negative for each activity; i.e., $Xj \geq 0$

b. Specify, if pertinent, other boundaries for each activity level; i.e., xj (6084) bounds.

The methods and procedures of this study will be organized and presented in this order. The coding of various steps and the symbolic notation will be coordinated with this outline. Figure 04 provides a pictorial illustration of the technical relationship of the elements identified in Kim's outline.

$$
\begin{array}{c}
\underline{\text{Columns}} \\
\begin{array}{cccccc}
 & x_1 & x_2 & x_3 & & x_{64}
\end{array}
\end{array}
$$

$$
c_{rj} \quad \begin{bmatrix}
c_1 & c_2 & c_3 & \cdots & c_{1,64} \\
\cdots & \cdots & \cdots & \cdots & \cdots \\
\cdots & \cdots & \cdots & \cdots & \cdots \\
\cdots & \cdots & \cdots & \cdots & \cdots \\
c_{51} & c_{52} & c_{53} & \cdots & c_{5,64}
\end{bmatrix}
$$

$$
a_{ij} \quad \begin{bmatrix}
a_{11} & a_{12} & a_{13} & \cdots & a_{1,64} \\
a_{21} & a_{22} & a_{23} & \cdots & a_{2,64} \\
a_{31} & a_{32} & a_{33} & \cdots & a_{3,64} \\
\cdots & \cdots & \cdots & \cdots & \cdots \\
\cdots & \cdots & \cdots & \cdots & \cdots \\
\cdots & \cdots & \cdots & \cdots & \cdots \\
a_{28,1} & a_{28,2} & a_{28,3} & \cdots & a_{28,64}
\end{bmatrix}
\qquad
b_i = \begin{bmatrix}
b_1 \\ b_2 \\ b_3 \\ \cdot \\ \cdot \\ \cdot \\ b_{28}
\end{bmatrix}
$$

Figure 04. General formulation of the model

Formulating the model

Five institutional objectives (1.a) are used in this model to illustrate examples of desirable aspects of learning that exist at a university. These five (5) institutional objectives are assumed to be important enough to significantly influence the official policy that is instrumental in guiding the courses of action at the university. The institutional objectives, identified in Table 01, were chosen from a group of goals considered "very important" by the faculty of the ISU College of Engineering in a recent study of faculty attitudes at Iowa's three state universities (Whitmer et al. 1977).

Table 01. Illustrative institutional objectives

Objective #1.	SECURE RESOURCES: To secure resources from the Iowa Legislature, through the Board of Regents, sufficient to operate this university at a near optimal level. C1=COBJSERE
Objective #2.	ACADEMIC FREEDOM: To protect the faculty's right to academic freedom. C2=COBJACFR
Objective #3.	THINKING STUDENT: To develop a student who can think, who can behave intelligently, who can respond creatively and effectively to new situations. C3=COBJTHST
Objective #4.	FACULTY DEVELOPMENT: To translate the talents and capacities of its faculty into significant educational results. C4=COBJFADE
Objective #5.	TRAINED STUDENT: To train students in methods of scholarship and/or scientific research and/or creative endeavor. C5=COBJTRST

The first objective is institution-centered, the second and fourth are faculty-centered and the third and fifth are student-centered. All the institutional objectives are stated such that, intuitively, more is preferred to less, i.e., it is desirable to have more academic freedom rather than less. Each statement implies susceptibility to measurement, or evaluation on an ordinal scale. However, nothing links these objectives in this form directly to any university activities or provides a yardstick to measure their attainment.

Therefore, the first technical procedure of this chapter is to express each of the five (5) institutional objectives as "weighted sums of the activity levels." (1.f) By definition, each objective function must be expressed in terms of the weight and level of the measurement flow for each activity that contributes to the attainment of the objective. Therefore, in this model each of the five (5) institutional objectives will be stated in terms of university activities.

The activity set used in this model is developed from eight (8) faculty activities used in program planning in the ISU College of Engineering.[1] (1.b) The eight (8) faculty activities are: (1) Classroom-Structured Instruction, including Labs; (2) Non-Classroom Unstructured Instruction - Individual Study - Advising; (3) Research; (4) Committees and Councils; (5) Administrative Activities; (6) Professional

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[1]These eight (8) faculty activities were obtained from reproduced worksheets provided by Dean Paul Morgan.

Activities; (7) Professional Development and (8) Public Service-Extension. These eight (8) faculty activities are expanded into ten (10) faculty activities by further dividing Structured Instruction and Unstructured Instruction into Graduate and Undergraduate components.

The ten (10) faculty activities are used to identify the technical relationship between the faculty activities and the institutional objectives in the model. They are: (1) Structured (classroom) graduate instruction (SGRADIN), (2) Structured undergraduate instruction (SUNGRIN), (3) Unstructured (special problems, individual study, honors, research supervision and advising) graduate instruction (UGRADIN), (4) Unstructured undergraduate instruction (UUNGRIN), (5) Research activities (RESERCH), (6) Committees and Councils Involvement (CMCLINV), (7) Administrative Activities (ADMINAT), (8) Professional Activities (PROFACT), (9) Professional Development (PRODEVL) and (10) Public Service and Extension (P3SERFX). These ten (10) faculty activities are later restated as sixty (60) faculty activities when unstructured instruction is partitioned into research supervision, special problems and student advising and most of the activities are performed by faculty holding the rank of Professor, Associate Professor, Assistant

Professor or Instructor.[1] More information about the sixty (60) activities will be reported later.

In order to express each of the five (5) institutional objectives as "weighted sums of the activity levels" it is necessary to establish a unique technical relationship between each of the ten (10) faculty activities and each of the five (5) institutional objectives.

In a physical production process this technical relationship can often be established from empirical observation, i.e., on the average, how much net income can be obtained from a specific set of land parcels which may be utilized to raise corn or soybeans, develop a feedlot on some of the parcels or sell all the parcels for urban development. However, at this time, this type of information is not available from empirical data in higher education and other public service processes. Therefore, a unique procedure is used to derive an estimate of these technical relationships for each of the five (5) institutional objectives relative to

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[1]In assigning the numerical values to the input-output coefficients, two important assumptions must be made. First, it is assumed that a given rate of measurement flow will require a set of invariant ratios among the other inflow and outflow rates associated with that activity. This is not to say that, for example, if a given amount of an output can be produced by a certain mixture of inputs, the same amount of output cannot be produced by a different mixture of inputs. However, if it can be done, then the latter mixture is assumed to correspond to an entirely different activity (Kim 1971 p. 118).

the ten (10) faculty activities in the ISU College of Engineering.

Formulating the objective function

Forty-seven (47) faculty and administrators from different colleges at ISU were asked to serve as a panel of experts to participate in a Delphi process that is designed to derive the estimates of these technical relationships (Appendix 01). Thirty-seven (37) agreed to participate in the study.

The experimental design did not attempt to directly link each faculty activity to each institutional objective. Instead, a descriptive attribute is inserted as an intermediate factor. The intermediate attribute is inserted to attempt to discourage the experts from expressing their traditional values about the educational activities rather than their evaluation of the degree of tendency relationships between each factor. The increased number of attributes also requires the experts to evaluate the tendency relationships between activities and objectives from five separate perspectives. The mechanical combination of the results of the evaluations provides a framework for extreme errors to be mediated by the law of large numbers. Figure 05 illustrates the relationship represented by the linkage.

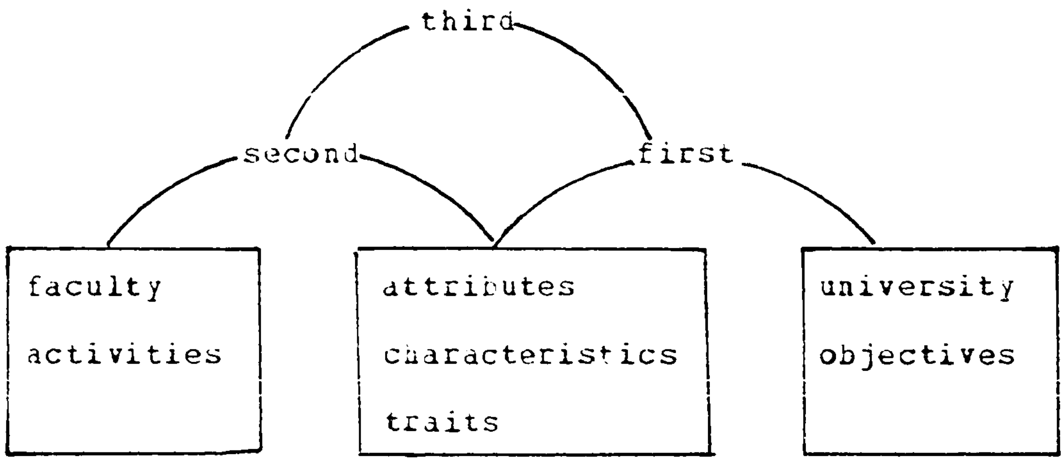

Figure 05. Linking activities to objectives

The strategy was to establish the linkage between: First, twenty-five (25) descriptive attributes and five (5) university objectives; Second, ten (10) faculty activities and twenty-five (25) descriptive attributes and; Third, using matrix algebra, derive an estimate of the overall linkage between ten (10) faculty activities and five (5) university objectives.

The first questionnaire (Appendix 02) consisted of the five (5) institutional objective statements with designated space for listing six attributes (characteristics or traits) that are likely to exist at an institution of higher education that is actively pursuing the stated university objectives. Responses to Questionnaire #1 were received from twenty-six (26) members of the panel of experts. The information contained on the responses to the first questionnaire was classified and summarized into five (5) tentative descriptive attributes for each of the five (5) institutional objectives.

This information made up the content of Questionnaire #2 (Appendix 03) which was sent to each of the thirty-seven (37) members of the expert panel. They were asked to critique the tentative descriptive attribute statements by editing (adding or deleting) and to circle the words or phrases in each statement that they believed should receive the most emphasis. This information was reviewed, summarized and edited and became the twenty-five (25) attributes that are used in the remainder of the Delphi process to estimate the technical relationship between the faculty activities and the institutional objectives.

Table 02. List of attributes

Attribute #1.1 OUTREACH EFFORT : A positive, effective, external outreach effort projecting a constructive image of the university.

Attribute #1.2 PROFESSIONAL BEHAVIOR: Professional behavior by faculty members, administrators and students that reflects an awareness that university activities are of interest to Iowans who judge the university on the information they receive.

Attribute #1.3 EXCELLENT INSTRUCTION: A widely acknowledged and broadly accepted reputation that the university provides excellent instruction to students in a positive learning environment.

Attribute #1.4 NEW & VALUABLE KNOWLEDGE: A widely acknowledged and broadly accepted reputation that the university is continuously producing new and valuable knowledge.

Attribute #1.5 VALUABLE SERVICE: A widely acknowledged and broadly accepted reputation that the university is willing to and is continuously providing valuable service and extension programs to all segments of the state.

Attribute #2.1 INTERNAL COMMUNICATIONS: A positive effective internal communications process that emphasizes the significance and rationale of academic freedom and pursues some consensus among faculty, administrators and students on a definition of academic freedom.

Attribute #2.2 PUBLIC AWARENESS PROGRAM: A specific and continuous public awareness program that describes and explains the value of academic freedom in a high quality, productive university and in society in general.

Attribute #2.3 RESPONSIBLE FACULTY BEHAVIOR: Responsible faculty behavior that reflects an awareness of the value and limits of academic freedom, including the recognition of ethical standards.

Attribute #2.4 POLICY STATEMENT: A specific policy statement of the university's position on academic freedom that top university administrators rigorously explain and defend.

Attribute #2.5 TRUST & DEMOCRACY: An atmosphere of trust and democracy that encourages objectivity with a free and open discussion of research results by faculty members, administrators and students who have confidence in their peers.

Attribute #3.1 COMPETENT FACULTY: Competent, diverse and demanding faculty members who are up-to-date in their field; who are effective in interacting with students.

Attribute #3.2 QUALIFIED & MOTIVATED STUDENTS: Qualified and motivated students who have positive attitudes about themselves, think for themselves and demonstrate the potential to change and mature.

Attributes #3.3 REWARDS FOR INSTRUCTION: Rewards for effective instruction, independent thinking, creativity and respect for different opinions.

Attribute #3.4 STUDENT CENTERED COURSES: Student centered course structure that includes comprehensive evaluation of each student's educational process.

Attribute #3.5 POST-GRADUATION EVALUATION: Post-graduation evaluation that indicates the degree of the graduates' intellectual growth and their attainment of self-actualization.

Attribute #4.1 EXPECTATIONS: High expectations of the faculty with encouragement of professional improvement and rewards for outstanding results.

Attribute #4.2 COMMITMENT TO EXCELLENCE: Highly motivated, competent, innovative faculty members who are committed to excellence and achievement of the objectives of higher education.

Attribute #4.3 UNIVERSITY IMPACT: Specific knowledge of the impact of the university beyond campus boundaries.

Attribute #4.4 COMPETENT ADMINISTRATORS: Competent administrators who have an appreciation for quality educational results and use creative management techniques.

Attribute #4.5 REWARDS FOR PRODUCTIVITY: Distribution of resources and rewards that directly support educational productivity.

Attribute #5.1 CAPABLE STUDENTS: Highly motivated, energetic, capable and creative students.

Attribute #5.2 FLEXIBLE CURRICULUM: A flexible curriculum that promotes a learning environment that emphasizes intellectual opportunities and new knowledge.

Attribute #5.3 EFFECTIVE INTERACTING: Effective interacting by competent, creative faculty and students who together enthusiastically pursue new knowledge with sophisticated techniques.

Attribute #5.4 INDIVIDUAL DISCOVERY: Individual discovery in creative courses that include the philosophic framework within which new knowledge is discovered.
Attribute #5.5 RESOURCES FOR HIGH PRODUCERS: Allocation of resources to potential and proven high producers of instruction and research results.

Each panel member was also asked to express his/her opinion, in terms of an "Attribute Achievement Scale" (AAS), on how he/she thought each tentative attribute was likely to lead to the achievement of the stated university objective and express in terms of a "Confidence of Judgement Scale" (CJS) how confident they were of their expressed judgment on the relationship. Thirty-three (33) panel members returned the completed questionnaire #2.

The information contained in the responses to questionnaire #2 was reviewed and summarized and returned to the panel members in the form of Questionnaire #3 (Appendix 04) which consisted of a reference sheet that contained the five (5) institutional objective statements and the final twenty-five (25) attribute statements plus the Attribute Achievement and Confidence of Judgment Scales. Questionnaire #3 was structured in the form of a matrix that provided a unique space to express an opinion relative to the relationship between each of the five (5) institutional objectives and each of the twenty-five (25) descriptive attributes. Statistical data (median, first and fourth quartile) summarizing the expressed relations from Questionnaire #2, were provided. Each panel member was asked to reread all the objective and attribute statements and, using the revised statements and statistical descriptions of the group judgment as references, to reconsider their judgment concerning the relationships between each objective and its five (5) attributes and to express their judgment concerning the relationship between the designated objective and the appropriate attribute in terms of the (AAS) and the (CJS). They were also asked to judge the relationships between each objective and the other twenty (20) attributes using the same scales. Completed responses to Questionnaire #3 were received from twenty-eight (28) panel members.

Questionnaire #4 (Appendix 05) followed the same format as #3 but requested the panel members to express their judgment on the relationship between the ten (10) faculty activities and the twenty-five (25) descriptive attributes in terms of an "Activity Contribution Scale" (ACS). Accompanying each Questionnaire #4 was a reference sheet that contained the twenty-five (25) descriptive attribute statements and the ten (10) faculty activity statements together with the Activity Contribution Scale (ACS) and the Confidence of Judgment Scale (CJS). The response sheet was in the form of a matrix that provided a unique space to express , in terms of the Activity Contribution Scale (ACS) the relationship between each activity and each appropriate attribute statement together with the level of confidence in their judgment expressed in terms of the CJS. Twenty-eight (28) of the panel members returned completed Questionnaires #4. This information was tabulated and summarized and returned to the panel members in Questionnaire #5a and #5b (Appendix 06) in the form of statistical descriptions of the group response on Questionnaires #3 and #4.

Questionnaire #5 contained two sets of reference sheets. The reference sheet for Questionnaire #5a contained the complete set of objective and attribute statements and the Attribute Achievement Scale (AAS) and the Confidence of Judgment Scale (CJS). The reference sheet for Questionnaire #5b contained the complete set of attribute and activity statements and the Activity Contribution Scale (ACS) and Confidence of Judgment Scale (CJS). The response form for Questionnaire #5a contained only the title of the objectives and attributes and asked the panel members to express their judgment on the relationship between each attribute and each objective in terms of the Attribute Achievement Scale (AAS) and indicate how confident they were of their judgment in terms of the Confidence of Judgment Scale (CJS). The response form for Questionnaire #5b was very similar but asked for judgment on the relationship between each activity and each attribute in terms of the Activity Contribution Scale (ACS) together with an expression of how confident they were of their judgment in terms of the Confidence of Judgment Scale (CJS). Twenty-seven (27) panel members returned completed response forms for Questionnaire #5a and #5b.

This information was tabulated, summarized and adjusted according to a procedure recommended in "The Certainty Method" by Warren and others (Warren et al. 1969). They concluded that if the respondents are offered an eleven point continuum scale, such as the one used on the Attribute Achievement Scale (AAS), the intervals between the response values will not be equal and a larger value should be assigned to the end values of the continuum. Table 03 illustrates the original values used on the scale in the study together with the adjusted values assigned according to the recommendations of Warren et al.

Table 03. Comparison of Scales

-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
					Original Scale					
-8	-5	-3	-2	-1	0	+1	+2	+3	+5	+8
					Adjusted Scale					

The results are two matrices, F and E, shown in Table 04 and 05. The first matrix F(25x5) represents the composite judgment of the panel members of the relationships between the 25 attributes and the 5 objectives in terms of the adjusted attribute achievement scale (AAAS), i.e. attribute 1.1 has a 5.0 (direct) relationship to Objective #1, but only a 1.5 (incidental or peripheral) relationship to Objective #2 etc. The second matrix E(10x25) represents the composite judgment of the panel on the relationship between each of the 10 activities and each of the 25 attributes expressed in terms of the adjusted activity contribution scale (AACS), i.e. Activity SGRADIN contributes to the presence of attribute 1.1 at 2.0 level, to attribute 1.2 at 3.0 level etc..

Table 04. Relationships between attributes and objectives

ATTRIBUTE IDENTIFICATION	COBJSERE OBJ. #1	COBJACPR OBJ. #2	COBJTHST OBJ. #3	COBJPADE OBJ. #4	COBJTBST OBJ. #5
ATT.#1.1 OUTREACH EFFORT	5.0	1.5	1.0	2.0	1.0
ATT.#1.2 PROFESSIONAL BEHAVIOR	3.5	5.0	3.0	5.0	3.0
ATT.#1.3 EXCELLENT INSTRUCTION	5.0	3.0	5.0	5.0	5.0
ATT.#1.4 NEW & VALUABLE KNOWLEDGE	3.0	3.0	3.0	5.0	5.0
ATT.#1.5 VALUABLE SERVICE	5.0	2.0	1.0	3.0	1.0
ATT.#2.1 INTERNAL COMMUNICATIONS	1.0	5.0	1.0	3.0	1.0
ATT.#2.2 PUBLIC AWARENESS PROGRAMS	2.0	3.0	1.0	2.0	1.0
ATT.#2.3 RESPONSIBLE FACULTY BEHAVIOR	3.0	5.0	3.0	5.0	3.0
ATT.#2.4 POLICY STATEMENTS	1.0	5.0	1.0	2.0	1.0
ATT.#2.5 TRUST & DEMOCRACY	1.0	5.0	3.0	5.0	3.0
ATT.#3.1 COMPETENT FACULTY	5.0	5.0	5.0	5.0	5.0
ATT.#3.2 QUALIFIED & MOTIVATED STUDENTS	3.0	1.0	5.0	3.0	5.0
ATT.#3.3 REWARDS FOR INSTRUCTION	1.0	2.0	5.0	5.0	5.0
ATT.#3.4 STUDENT CENTERED COURSES	1.0	0.0	3.0	2.0	5.0
ATT.#3.5 POST GRADUATION EVALUATION	1.5	0.0	3.0	2.0	3.0
ATT.#4.1 EXPECTATIONS	3.0	3.0	3.0	5.0	3.0
ATT.#4.2 COMMITMENT TO EXCELLENCE	3.0	5.0	5.0	5.0	5.0
ATT.#4.3 UNIVERSITY IMPACT	5.0	1.0	2.0	3.0	2.0
ATT.#4.4 COMPETENT ADMINISTRATORS	5.0	3.0	2.0	3.0	2.0
ATT.#4.5 REWARDS FOR PRODUCTIVITY	3.0	1.0	3.0	5.0	3.0
ATT.#5.1 CAPABLE STUDENTS	2.5	1.0	5.0	5.0	5.0
ATT.#5.2 FLEXIBLE CURRICULUM	1.0	1.0	5.0	3.0	5.0
ATT.#5.3 EFFECTIVE INTERACTION	2.0	1.0	5.0	5.0	5.0
ATT.#5.4 INDIVIDUAL DISCOVERY	1.0	2.0	5.0	5.0	5.0
ATT.#5.5 RESOURCES FOR HIGH PRODUCERS	2.0	1.0	3.0	5.0	5.0

Table 05. Relationships between activities and attributes

Attribute#	1.1	1.2	1.3	1.4	1.5	2.1	2.2	2.3	2.4	2.5	3.1	3.2	3.3	3.4	3.5	4.1	4.2	4.3	4.4	4.5	5.1	5.2	5.3	5.4	5.5
SGRADIN	2.0	3.0	5.0	3.0	2.0	2.0	1.0	3.0	0.5	2.0	5.0	5.0	3.0	3.0	2.0	3.0	5.0	3.0	1.0	3.0	5.0	3.0	5.0	3.0	3.0
SUNGRIN	2.0	3.0	5.0	2.0	2.0	1.0	1.0	3.0	0.0	2.0	5.0	5.0	3.0	3.0	2.0	3.0	5.0	3.0	1.0	3.0	5.0	3.0	5.0	3.0	3.0
UGRADIN	2.0	3.0	5.0	5.0	2.0	1.0	1.0	3.0	1.0	3.0	5.0	5.0	3.0	5.0	3.0	3.0	5.0	3.0	1.0	3.0	5.0	5.0	5.0	5.0	3.0
UUNGRIN	2.0	3.0	5.0	3.0	2.0	1.0	1.0	3.0	1.0	3.0	5.0	5.0	3.0	5.0	2.0	3.0	5.0	3.0	1.0	3.0	5.0	5.0	5.0	5.0	3.0
RESERCH	3.0	5.0	3.0	5.0	3.0	2.0	2.0	2.0	2.0	3.0	5.0	2.0	2.0	0.0	0.5	5.0	5.0	3.0	2.0	5.0	2.0	1.0	3.0	3.0	5.0
CMCLINV	1.0	3.0	1.0	1.0	1.0	3.0	1.0	3.0	2.0	3.0	2.0	1.0	1.0	0.0	0.0	2.0	2.0	2.0	3.0	2.0	0.0	1.0	2.0	0.0	2.0
ADMINAT	1.0	2.0	1.0	0.0	1.0	3.5	2.0	3.0	3.0	5.0	2.0	1.0	1.0	1.0	1.0	3.0	2.0	2.0	5.0	3.5	0.0	1.0	1.0	0.0	2.0
PROFACT	3.0	5.0	3.0	5.0	3.0	2.0	2.0	5.0	2.0	3.0	5.0	2.0	3.0	1.0	0.0	5.0	5.0	3.0	2.0	5.0	2.0	2.0	3.0	3.0	5.0
PRODEVL	1.0	5.0	5.0	5.0	3.0	2.0	1.0	5.0	1.0	2.0	5.0	2.5	2.0	2.0	1.0	3.0	5.0	3.0	1.5	3.0	2.0	2.0	2.0	5.0	3.0
PBSERBX	5.0	5.0	3.0	3.0	5.0	1.0	5.0	3.0	2.0	2.0	3.0	1.0	1.0	1.0	0.0	2.0	3.0	5.0	2.0	2.0	1.0	0.0	2.0	1.0	2.0

Table 06. Relationships between activities and objectives

	SGRADIN	SUNGRIN	UGRADIN	UUNGRIN	RESERCH	CMCLINV	ADMINAT	PROFACT	PRODEVE	PBSERBX		SUM
COBJSERE	216.50	212.00	230.50	223.00	232.25	113.50	130.25	234.50	215.00	203.00	=	2010.50
COBJACPR	187.50	177.00	202.00	196.00	227.50	129.50	151.50	230.50	210.50	174.50	=	1886.50
COBJTHST	285.50	281.00	323.00	314.00	252.50	116.00	132.00	246.00	256.50	167.00	=	2373.50
COBJFADE	320.00	311.00	355.00	343.00	334.00	161.00	184.00	343.00	314.00	233.00	=	2898.00
COBJTRST	303.50	297.00	349.00	336.00	272.50	122.00	138.00	286.00	276.50	179.00	=	2559.50

Table 07. Standardizied objective function coeficients

	SGRADIN	SUNGRIN	UGRADIN	UUNGRIN	RESERCH	CMCLINV	ADMINAT	PROFACT	PRODEVE	PBSERBX		SUM
COBJSERE	216.50	212.00	230.50	223.00	232.25	113.50	130.25	234.50	215.00	203.00	=	2010.50
COBJACPR	216.50	204.38	233.24	226.32	262.69	149.53	174.93	266.15	243.05	201.49	=	2178.28
COBJTHST	216.50	213.09	244.94	238.11	191.48	87.97	100.10	186.55	194.51	126.64	=	1799.89
COBJFADE	216.50	210.41	240.18	232.06	225.97	108.93	124.49	232.06	212.44	157.64	=	1960.68
COBJTRST	216.50	211.86	248.96	239.68	194.39	87.03	98.44	204.02	197.24	127.69	=	1825.81

These two matrices are multiplied together to produce the five (5) by ten (10) matrix C E(MxN) X F(NxQ) = C(MxQ) shown in Table 06. To facilitate intuitive comparison between and among objective values, the estimated values are standardized. Secure Resources - Graduate Structured Instruction is the Numeraire. Standardization is accomplished by dividing SGRADIN obj.#1 by SGRADIN obj.#2:

216.5 (SGRADIN1) / 187.5 (SGRADIN2) = 1.15467

to get the relationship between them. Then each component of Obj.#2 was multiplied by the value expressing the relationship:

187.5	177.0	202.0	...
X 1.15467	X 1.15467	X 1.15467	...
216.5	204.38	233.24	...

This process was repeated for SGRADIN Obj.#3, SGRADIN Obj.#4 and SGRADIN Obj.#5. The standardized objective function coefficients are shown in Table 07.

This study suggests that the values in Table 07 represent a reasonable estimate of the technical relationship between the five (5) original objectives and the ten (10) faculty activities, expressed in quantifiable terms. These objectives are not mutually exclusive in terms of activity contributions.

The values in this matrix can be intuitively interpreted as representing how; (1) different activities contribute to the same objective, i.e. Professional Activities (PROFACT = 234.5 contributes over twice as much toward the attainment of Objective #1 (Secure Resources) as does Committee and Council Involvement (CMCLINV at 113.5; and (2) the same activity contributes to different objectives; i.e. Committee and Council Involvement of the Academic Freedom objective (CMCLINV = 149.53) contributes 41% more toward the attainment of Academic Freedom than Committee and Council Involvement of the Thinking Student objective (CMCLINV = 87.97) contributes to the development of a Thinking Student. (87.97/ 149.53 = .588)

Standardization, arbitrarily choosing one of the values as the numeraire, in this case does appear to affect the equilibrium exchange ratios. For example, the ratios among the contribution that each activity makes to different objectives does change. Rather than a 41% difference between the contribution of CMCLINV to Academic Freedom and Thinking Student using standardized values, (87.97/149.53 = .59; 1.00 - .59 = 41%) the raw values indicate that Committee and Council Involvement of the Academic Freedom objective (CMCLINV = 129.5) only contributes 10% more toward the attainment of Academic Freedom than Committee and Council

Involvement of the Thinking Student objective (CMCLINV = 116.0) contributes to the development of a Thinking Student (116.0/129.5 = .8957; 1.00 - .896 = 10%). The sum of each objective function before standardization (Table 06) indicates that "Faculty Development" (2898.0) is the objective that contributes most to the total set of objectives. After standardization (Table 07), "Academic Freedom" (2178.28) appears to contribute the most toward the attainment of the set of objectives.

If administrative activities had been choosen as the numeraire, the standardization factor between the first two objective functions would have been .85974 rather than 1.15467. If public service-extension had been choosen as the numeraire, the standardization factor between the first two objective functions would have been 1.1633. Generally, it appears that selecting (SGRADIN, SUNGRIN, UGRADIN, UUGRIN and PBSEREX as the numeraire would result in similar relationships. However, if RESERCH, PROFACT and PRODEVE were selected as the numeraire there would be only minor differences in the resulting rank-order of the objectives. Selecting CMCLINV and ADMINAT as the numeraire would result in major differences in the rank-order of the objectives.

The sum values are the "yardstick" required in (1.a). The sum of one unit of each of the ten (10) activity values of Objective #5 is 1,825.81 units of SGRADIN (Table 07). This value is not significant except to illustrate the magnitude of the sum of one unit of each activity as an expression of the objective in terms of SGRADIN. A single objective Linear Program will seek the combination of activities that produce the largest sum. It should be apparent that if these ratios were the only criteria and all activities cost the same, the model would achieve Objective #5 by performing only Unstructured Graduate Instruction (UGRADIN = 248.96) (Table 07) because a unit of that activity contributes the most to the objective value. Other constraints keep this from happening. In this case Unstructured Graduate Instruction (UGRADIN) can not be provided to more students than are enrolled in graduate courses. The cost of providing the different activities is also a factor. It may be so much cheaper to perform an activity that contributes the least to the objective function that it is still technically rational to perform the activity that contributes the least to the objective function.

These exchange values are represented by "C" and constitute one half of the information needed to state an objective function as the "weighted sums of the activity levels". Intuitively "C" expresses the relationship of an identifiable and measurable unit of activity to an identifiable and measurable unit of the objective. By expressing the objective function, Max f(x) = C1X1 + C2X2 + C3X3 + . . .+ CjXj.

where C1 = SGRADIN

and X1 = the value of X1 activity set

it is apparent that the level of each activity is represented by "X". The value of the objective function coefficient (C) is multiplied by the number of repetitions of the activity (X) to reflect the effect of the specific activity. Using the values from Objective #1, Secure Resources, the objective function can be expressed as follows:

Max F(x) = 216.5 (X)1 + 212.0 (X)2 . . + 203.0 (X)10

The values of "C" and"X" for each activity and objective are expressed in quantifiable terms in a linear program.

The same values of "C" and "X" are the basis elements of multiple objective functions which are expressed as follows:

Max. f1(x) = C11 X1 + C12 X2 + C13 X3 + . . . +C1j Xj

Max. f2(x) = C21 X1 + C22 X2 + C23 X3 + . . . + C2j Xj

.

.

Max. f5(x) = C51 X1 + C52 Xi + C53 X3 + . . .+ C5j Xj

Alternatively, these objective statements can be expressed in an abbreviated form:

$$\text{Max } fk(x) = \sum_{j=1}^{n} Ckj\ Xj;\ k = 1, \ldots, 5$$

$$\text{s.t. } \sum_{j=1}^{n} Aij\ Xj \quad bi$$

$$\text{and } Xj \geq 0$$

where

$f^1(x)$ = Objective #1. Secure Resources

$f^2(x)$ = Objective #2. Academic Freedom

$f^3(x)$ = Objective #3. Thinking Student

$f^4(x($ = Objective #4. Faculty Development

$f^5(x)$ = Objective #5. Trained Student

Cj is the weight for the measurement flow of the j th activity.

Xj is the level of measurement flow of the j th activity.

Objective statements can also be stated in matrix notation.

Primal	Dual
Max $C X$	Min $b'Y$
S.T. $Ax \le b$	S. T. $A'Y \le C$
$X \ge 0$	$Y \ge 0$
where $C = (E10x25\ F25x5)'$[1]	where $Y = 33 \times 5$

and $X = 10X1$

$A = 33 \times 10$

$b = 33 \times 1$

Where $(EF)' = C(5x10)$

This is the form that will be used in this study. But there is one other form that must be noted because it is the form utilized by Ralph E. Steuer in his articles on multiple objective linear programming that are cited in this study.

Max $C1\ X = Z1$

Max. $C2\ X = Z2$

Max. $C3\ X = Z3$

Max $C4\ X = Z4$

Max. $C5\ X = Z5$

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[1] MAX $F(X) = (E(10x25)\ F(25x5))'\ X(10x1)$

Formulating the system of structural constraints

A group of experts using the Delphi Technique has produced a usable estimate of the "weights" (Cj) necessary to express the five (5) objectives in standard linear programming notation. The second technical procedure of this chapter is to formulate a system of structural constraints.

$$a_{ij} X_j \leq b_i$$

Formulation of the system of structural constraints for this model involves integrating budget information with reported effort summaries, class offerings and student enrollments. In order to establish "exogenous flow requirements for each nonmeasurement item in the item set" (2.b), it is necessary to reclassify the "scarce" financial resources that are utilized to carry out specific faculty and staff activities, so they can be used in the model.

The resources included in this model are the classified current expenditures for the fiscal year 1975-76 (ISU Financial Report 1975-76 p. 18-19). The "scarce" financial resources are classified as objects of expenditures for accounting purposes as salaries, wages, employee benefits, general supplies and services, travel, printing and other expenses. The expected productive effort of the faculty is expressed in the model in terms of FTE Units.[1]

The item set (1.c) contains: (1) Input Resources expressed in terms of FTE Units[2] for Full Professors, Associate Professors, Assistant Professors and Instructors; (2) Offered credits from Structured Instruction expressed in terms of Graduate Level, Upper Level and Lower Level; (3) Offered credits from Unstructured Instruction expressed in terms of Graduate and Undergraduate level; (4) Earned credits from Structured Instruction expressed as Graduate Level, Upper Level and Lower Level; (5) Earned credits from Unstructured Instruction expressed as Graduate and Undergraduate level; (6) Student enrollment expressed as Graduate and Undergraduate enrollment in structured and unstructured instruction and (7) Budgeted funds. The measurement item (1.d) will also be developed with the "system of structured constraints" because some of these items are derived in the process of developing the structural constraints.

First two general modifications are made to make the model realistic and less expensive to run. The first

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[1]For a definition and description of FTE Unit see the Report of the Ad Hoc Committee to Study Full-Time Equivalency (FTE), Sam Clark, Chairman. November 18, 1974.

[2]A normal weekly workload in the ISU College of Engineering is considered to be forty-eight (48) FTE Units.

modification is to adjust the fiscal data to reflect only the faculty activities of three academic quarters. This is the principal period of the school year and is the basis for policy decisions involving scheduling, budgeting and admissions. Also the student enrollment reports and faculty reports for this period are the most complete. The other modification was the treatment of the three academic quarters as one education cycle. Rather than teach one student three times representing three quarters, the model teaches three students one time. The FTE Units available, the classes offered, the credits earned, the students advised etc., were adjusted accordingly. This adjustment enabled the model to simulate the effects of a school year by solving one problem rather than solving three very similar but smaller problems.

The following tables identify, establish and expresss information gathered from a number of sources, in a form that the information can be formulated into a linear programming format. The first step is to classify the total faculty effort into separate specific activities expressed as per cent of the total effort and dollar value of specific activities. The values of specific resource-constraints in the model are based on this information. This information is not sufficient to structure the model. There are implicit relationships in this information, i.e. if a specific number of graduate quarter credit-courses are offered to a specific number of graduate students that take an average number of lecture-recitation and laboratory courses, there is a specific ratio of graduate students to graduate lecture-recitation and laboratory credits offered and faculty effort expended. These relationships are factual but no one has derived them. In this model these relationships are explicity expressed in terms of input/output coefficients. They are derived in the formulation process. The derived values maintain the original equilibrium relationships between and within the resource-constraints.

Faculty workload summaries provided the initial distribution of faculty efforts. Table 08 provides an average of the results from four reported quarters.[1]

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[1]Derived from the College of Engineering; Fall, 1972; Winter, 1972; Spring, 1973; and Fall, 1974. Department Faculty Workload Summaries. College of Engineering Administrative Records.

Table 08. Faculty workload summaries

	Faculty Instruction Efforts	Faculty Research Efforts	Faculty Extension Efforts
Structured Instruction	66.2%	-0-	-0-
Unstructured Instruction	11.5%	-0-	-0-
Research	-0-	77.7%	-0-
Committee & Council Involvement	8.9%	8.9%	8.9%
Administrative Activities	6.3%	6.3%	6.3%
Professional Activities	2.5%	2.5%	2.5%
Professional Development	3.2%	3.2%	3.2%
Extension Public Service	1.4%	1.4%	79.1%
Total	100.0%	100.0%	100.0%

These distributions of faculty effort are used to partition budget expenditures and full-time equivalent planning units to establish "exogenous flow requirements for each nonmeasurement item in the item set" (2.b).

The total 1975-76 annual current expenditures[1] for Instruction -College of Engineering, Organized Research - Engineering Research Institute and Public Service - Engineering Extension provides the financial parameters of the model. The seven (7) objects of expenditure for the three (3) functions of Instruction, Research and Extension are not sufficient to facilitate the formulation of a linear program of the academic activities of the faculty of the College of Engineering. Table 09 provides a further classification that reflects the adjustment of each of the eight (8)[2] objects of expenditure of each of the three (3) functional expenditure

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[1]The Iowa State University of Science and Technology FINANCIAL REPORT for the year ending June 30, 1976. (pp. 16-19)

[2]Employees benefits were divided into Faculty Benefits and Merit Employee Benefits because the distribution of benefits was not always equal for the faculty and merit employees.

to three (3) academic quarters.[1]

Table 09. Prorated allocation of resources

	Instruction	Research	Extension
Faculty Salaries			
Actual	$4,775,789.	$1,427,160.	$500,978.
Instruction @84%	$4,011,663.		
Research @75%		$1,070,370.	
Extension @ 75%			$375,733.
Faculty Benefits			
Actual	$719,857.	$203,996.	$84,085.
Instruction @84%	$604,680.		
Research @75%		$152,997.	
Extension @75%			$63,064.
Wages (Merit)			
Actual	$19,658.	$136,895.	$10,891.
Instruction @84%	$16,513.		

[1] Paul Morgan estimates that the College of Engineering expends approximately 28% of its instructional budget each academic quarter. (28% x 3 = 84%); that the Engineering Research Institute expends approximately 25% of its research budget in each of the three academic quarters, (25% x 3 = 75%); that the Engineering Extension expends approximately 25%, of its' Extension budget each of the three academic quarters. (25% x 3 = 75%).

Table 09. (Continued)

	Instruction	Research	Extension
Research @75%		$102,671.	
Extension @75%			$8,168.
Merit Benefits			
Actual	$2,964.	$21,663.	$1,891.
Instruction @84%	$2,490.		
Research @75%		$16,247.	
Extension @75%			$1,419.
Supplies & Services			
Actual	$198,851.	$42,889.	$176,250.
Instruction @84%	$167,035.		
Research @75%		$32,167.	
Extension @75%			$132,187.
Travel			
Actual	$33,703.	$28,173.	$45,311.
Instruction @84%	$28,311.		
Research @75%		$21,129.	
Extension @75%			$33,983.

Table 09. (Continued)

	Instruction	Research	Extension
Printing			
Actual	$6,193.	$19,285.	$30,519.
Instruction @84%	$5,202.		
Research @75%		$14,464.	
Extension @75%			$22,890.
Other			
Actual	$17,730.	$7,385.	$20,154.
Instruction 84%	$14,893.		
Research @75%		$5,538.	
Extension @75%			$15,115.
Total			
Actual	$5,774,745.	$1,887,445.	$870,079.
Instruction @84%	$4,850,785.		
Research @75%		$1,415,583.	
Extension @75%			$652,559.
Grand Total			
$6,918,928.			

In this model the expenditures are set slightly less than the reported amounts to allow input-output coefficients to be truncated at a maximum of four decimal places and to make the model seek an efficient and effective unique optimal solution. As a result, the total amount of dollars to be accounted for in the composite model is $6,918,928.25. The exact amount of the dollar constraint in the model is $6,893,928.25. The latter amount is $25,000.00 less than the former.

Table 10 presents the allocation of this budget total to eight (8) faculty activities based on the average reported "Faculty Workload" of the College of Engineering faculty.

For example, the total reported faculty salaries for instruction is $4,775,789.00 (Table 09). Of this amount, 84% ($4,011,663.00) is expended in three academic quarters (Table 09 and Table 10). Sixty-six and two tenths per cent (Table 08) of this latter amount is allocated to Structured Instruction. Structured Instruction/Faculty Salaries equals $2,655,720.00 (Table 10). No Research or Extension effort/expenditures is allocated to Structured Instruction. These values equal zero (Table 10). The totals serve as dollar constraints for each of the eight (8) activities within each of the three (3) functions when each activity is run separately to derive the necessary input-output coefficients.

Table 10 Activity resource allocation by object of expenditure

	Structured Instruction	Unstructured Instruction	research	committee & Councils	admin. Activities	prof. Activities	prof. Develop.	public ser. Extension
Faculty Salaries								
4011662.58	2655720.63	461341.20	-0-	357037.97	252734.74	100291.56	128373.20	56163.28
1070370.09	-0-	-0-	831677.55	95262.94	67433.32	26759.25	34251.84	14985.19
375733.47	-0-	-0-	-0-	33440.28	23671.21	9393.34	12023.74	297205.17
Faculty Benefits								
604680.11	400298.24	69538.21	-0-	53816.53	38094.85	15117.00	19349.76	8465.52
152996.66	-0-	-0-	118878.40	13616.70	9638.79	3824.92	4895.89	2141.96
63063.64	-0-	-0-	-0-	5612.66	3973.01	1576.59	2018.04	49883.34
Wages (Merit)								
16512.54	10931.30	1898.94	-0-	1469.62	1040.29	412.81	528.40	231.18
102670.92	-0-	-0-	79775.30	9137.71	6468.27	2566.77	3285.47	1437.40
8168.47	-0-	-0-	-0-	727.00	514.61	204.21	261.39	6461.26
Merit Benefits								
2489.81	1648.25	286.33	-0-	221.59	156.96	62.25	79.67	34.86
16247.42	-0-	-0-	12624.25	1446.02	1023.59	406.19	519.92	227.45
1418.61	-0-	-0-	-0-	126.26	89.37	35.46	45.40	1122.12
Supplies & Services								
167034.90	110577.10	19209.01	-0-	14866.11	10523.20	4175.87	5345.12	2338.49
32166.95	-0-	-0-	24993.72	2862.86	2026.52	804.17	1029.34	450.34
132187.47	-0-	-0-	-0-	11764.68	8327.81	3304.69	4230.00	104560.29
Travel								
28310.54	-0-	-0-	-0-	-0-	1981.74	24063.96	-0-	2264.84
21129.40	-0-	-0-	-0-	-0-	1479.06	17959.99	-0-	1690.35
33983.04	-0-	-0-	-0-	-0-	2140.93	849.58	-0-	30992.53
Printing								
5202.02	3443.74	598.23	-0-	462.98	327.73	130.05	166.46	72.83
14463.57	-0-	-0-	11238.19	1287.26	911.20	361.59	462.83	202.50
22889.52	-0-	-0-	-0-	2037.17	1442.04	572.24	732.46	18105.61
Other								
14892.87	9859.08	1712.68	-0-	1325.47	938.25	372.32	476.57	208.50
5538.39	-0-	-0-	4303.33	492.92	348.92	138.46	177.23	77.53
15115.25	-0-	-0-	-0-	1345.26	952.26	377.88	483.69	11956.16
Total								
4850785.37	3192478.34	554584.60	-0-	429200.27	305797.66	144625.82	154319.18	69779.50
1415583.38	-0-	-0-	1083490.74	124106.41	89329.67	52821.34	44622.52	21212.70
652559.49	-0-	-0-	-0-	55053.31	41111.24	16313.99	19794.45	520286.50
Grand Total								
6918928.24	3192478.34	554584.60	1083490.74	608359.99	436238.57	213761.15	218736.15	611278.68

The dollar amount associated with committee and councils, Administrative Activities, Professional Activities, Professional Development, and Public Service contain a portion of all three (3) functions; Instruction, Research and Public Service-Extension. The eight (8) objects of expenditure are available for review in this table but lose their identity in aggregated totals for each of the eight (8) activities.

Table 11 presents the College of Engineering's classification of the number, rank and reported effort of the faculty during the 1975-76 academic year.[1]

The "budgeted" values reflect the administrative assignment to selected activities. The asterisk (*) indicates that budgeted values are not available for this specific activity. The FTE Unit value provides a reflection of the reported faculty effort expressed in FTE units for each of the eight (8) activities and faculty rank.

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[1]The details of the faculty complement for 1975-76 was provided by Paul Morgan in the proportions reflected in the Financial Report and also expressed in terms of "faculty full-time equivalent weekly workload" (FTE Units.

Table 11 Full-time equivalent budgeted faculty positions.

Activity Classes	Full Professor	Associate Professor	Assistant Professor	Instructor	Total
Structured Instruction					
Budgeted	68.4	64.3	44.8	16.5	194.0
FTE Units	71,725.0	67,426.0	46,978.0	20,308.	206,435.0
Unstructured Instruction					
Budgeted	*	*	*	*	*
FTE Units	12,460.0	11,713.0	8,161.0		32,333.0
Research Activities					
Budgeted	25.6	17.0	8.0		50.6
FTE Units	34,372.0	22,825.0	10,741.0		67,939.0
Committee & Council Involvement					
Budgeted	*	*	*	*	*
FTE Units	14,349.0	12,377.0	8,330.0	2,326.0	37,[illegible].0
Administrative Activities					
Budgeted	3.2	.75	1.5		5.
FTE Units	14,458.0	9,815.0	7,311.0	1,647.0	3[illegible],7[illegible].0

Table 11 (Continued)

Activity Classes	Full Professor	Associate Professor	Assistant Professor	Instructor	Total
Professional Activities					
Budgeted	*	*	*	*	*
FTE Units	4,031.0	3,477.0	2,340.0	653.0	10,501.0
Professional Development					
Budgeted	*	*	*	*	*
FTE Units	5,159.0	4,450.0	2,995.0	836.0	13,441.0
Public Service Extension					
Budgeted	1.5	3.8	3.6		9.2
FTE Units	4,674.0	7,049.0	6,144.0	366.0	18,233.0
Total					
Budgeted	99.0	85.85	57.9	16.5	259.3
FTE Units	161,227.0	139,132.0	93,600.0	26,136.	420,031.0

The "cost" of an activity can now be expressed in terms of two units of measurement. "Structured Instruction" costs $3,192,478.34 which includes $2,655,720.63 for faculty salaries, or 206,435.1 FTE Units, 71,724.8 of which represent the efforts of Full Professors.

This information is combined with information from Departmental Program Budgets[1] that reported average salaries for each faculty rank for each department in the College of Engineering. This Program Budget information is consolidated and expressed as a value for each of the four faculty Full Time Equivalent Units (FTE Units.) The faculty salary bases are proportionally adjusted to integrate the cost of such supporting services as staff wages, employee benefits, general supplies, travel, printing and other expenses. As a result the Faculty FTE unit values are higher than values that are derived by dividing a faculty salary by the annual number of FTE units. The derived dollar cost of a FTE Unit for each faculty rank is expressed in Table 12.

Table 12 Derived cost of faculty FTE Unit by rank.

Full Professor	$18.34 per FTE Unit
Associate Professor	$16.67 per FTE Unit
Assistant Professor	$14.05 per FTE Unit
Instructor	$10.76 per FTE Unit

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[1]Reported in the ISU College of Engineering Departmental Program Budget for 1975-76.

The intuitive interpretation of these values is that the total prorated cost of a Full Professor FTE Unit effort is \$18.34; an Associate Professor is \$16.87; an Assistant Professor is \$14.05 and an Instructor is \$10.76.

Other coefficients are provided by a program planning memo, the "College of Engineering Faculty Workload Evaluation" dated 9/74. The details of those allotments are shown in Table 13.

Table 13. Allotments of FTE Units for specific activities

Credit for faculty activities is assigned as follows:

	FTE Units per offered credit
A. Structured (Classroom) Instruction	
1. Lecture, Recitation Instruction	
a. Graduate	5
b. Upper Level Undergraduate	4
c. Lower Level Undergraduate	3
2. Laboratory Instruction	
a. Graduate	2
b. Upper Level Undergraduate	2
c. Lower Level Undergraduate	2
B. Unstructured Instruction	

Table 13 (Continued)

1. Special Problems, Independent Study, Special Topics	
a. Graduate	.75
b. Undergraduate	.50
2. Research Supervision (Graduate)	.50
3. Student Advising	
a. Graduate	.375
b. Undergraduate	.25
	FTE Units per per hour of activity
C. Research Activities	1
D. Committee & Council	1
E. Administrative Activities	1
F. Professional Activities	1
G. Professional Development	1
H. Public Service	1

Full Professors, Associate Professors and Assistant Professors are allowed to participate in eight (8) activities and Instructors in six (6) activities, i.e. all but graduate instruction and research. The result is sixty (60) separate and unique activities identified and defined in Table 14.

Table 14. Table of sixty activities and their codes

STRUCTURED INSTRUCTION

GLSFPLR = Graduate Level Structured Full Professor Lecture-Recitation.

GLSFPLA = Graduate Level Structured Full Professor Laboratory.

GLSASPLR = Graduate Level Structured Associate - Professor Lecture-Recitation.

GLSASPLA = Graduate Level Structured Associate Professor Laboratory.

GLSATPLR = Graduate Level Structured Assistant Professor Lecture-Recitation.

GLSATPLA = Graduate Level Structured Assistant Professor Laboratory.

ULSFPLR = Upper Level Structured Full Professor Lecture-Recitation.

ULSFPLA = Upper Level Structured Full Professor Laboratory.

ULSASPLR = Upper Level Structured Associate Professor Lecture-Recitation.

ULSASPLA = Upper Level Structured Associate Professor Laboratory.

Table 14 (Continued)

ULSATPLR = Upper Level Structured Assistant Professor Lecture-Recitation.

ULSATPLA = Upper Level Structured Assistant Professor Laboratory.

ULSINSLR = Upper Level Structured Instructor Lecture-Recitation.

ULSINSLA = Upper Level Structured Instructor Laboratory.

LLSFPLR = Lower Level Structured Full Professor Lecture-Recitation.

LLSFPLA = Lower Level Structured Full Professor Laboratory.

LLSASPLR = Lower Level Structured Associate Professor Lecture-Recitation.

LLSASPLA = Lower Level Structured Associate Professor Laboratory.

LLSATPLR = Lower Level Structured Assistant Professor Lecture-Recitation.

LLSATPLA = Lower Level Structured Assistant Professor Laboratory.

LLSINSLR = Lower Level Structured Instructor Lecture-Recitation.

LLSINSLA = Lower Level Structured Instructor Laboratory.

Table 14 (Continued)

UNSTRUCTURED INSTRUCTION

GLSPFPU = Graduate Level Special Problems Full Professor Unstructured.

GLRSFPU = Graduate Level Research Supervision Full Professor Unstructured.

GLSAFPU = Graduate Level Student Advising Full Professor Unstructured.

GLSPASPU = Graduate Level Special Problems Associate Professor Unstructured.

GLRSASPU = Graduate Level Research Supervision Associate Professor Unstructured.

GLSAASPU = Graduate Level Student Advising Associate Professor Unstructured.

GLSPATPU = Graduate Level Special Problems Assistant Professor Unstructured.

GLRSATPU = Graduate Level Research Supervision Assistant Professor Unstructured

GLSAATPU = Graduate Level Student Advising Assistant Professor Unstructured

ULSPFPU = Undergraduate Level Special Problem Full Professor Unstructured

ULSAFPU = Undergraduate Level Student Advising Full Professor Unstructured

Table 14 (Continued)

ULSPASPU = Undergraduate Level Special Problem Associate Professor Unstructured

ULSAASPU = Undergraduate Level Student Advising Associate Professor Unstructured

ULSPATPU = Undergraduate Level Special Problem Assistant Professor Unstructured

ULSATPU = Undergraduate Level Student Advising Assistant Professor Unstructured

RESEARCH

RESOPFP = Research Output Full Professor

RESOPASP = Research Output Associate Professor

RESOPATP = Research Output Assistant Professor

COMMITTEE & COUNCIL INVOLVEMENT

CCIOPFP = Committee & Council Involvement Output Full Professor

CCIOPASP = Committee & Council Involvement Output Associate Professor

CCIOPATP = Committee & Council Involvement Output Assistant Professor

CCIOPINS = Committee & Council Output Instructor

Table 14 (Continued)

ADMINISTRATIVE ACTIVITIES

ADAOPFP = Administrative Activity Output Full Professor

ADAOPASP = Administrative Activity Output Associate Professor

ADAOPATP = Administrative Activity Output Assistant Professor

ADAOPINS = Administrative Activity Output Instructor

PROFESSIONAL ACTIVITIES

PATOPFP = Professional Activity Output Full Professor

PATOPASP = Professional Activity Output Associate Professor

PATOPATP = Professional Activity Output Assistant Professor

PATOPINS = Professional Activity Output Instructor

PROFESSIONAL DEVELOPMENT

PDVOPFP = Professional Development Output Full Professor

PDVOPASP = Professional Development Output Associate Professor

PDVOPATP = Professional Development Output Assistant Professor

PDVOPINS = Professional Development Output Instructor

Table 14 (Continued)

PUBLIC SERVICE-EXTENSION

PSROPFP = Public Service Output Full Professor

PSROPASP = Public Service Output Associate Professor

PSROPATP = Public Service Output Assistant Professor

PSROPINS = Public Service Output Instructor

In another sense the efforts of the faculty can also be expressed in terms of the number and levels of courses offered and student credits earned during the three academic-quarter school year. The number of students, credits offered, and credits earned further constrain the model. Ninty-two hundred and thirty-four (9234) undergraduate students and eleven hundred and thirty-five (1135) graduate students earned 98,400 student quarter credits during the 1975-76 academic school year. The breakdown of this data is shown in the following tables.

The College of Engineering's student enrollment for 1975-76 is shown in Table 15.

Table 15. College of Engineering student enrollment (Iowa State University July 1976)

		Undergraduate	Graduate
Fall 1975		3301	381
Freshmen	1151		
Sophomores	704		
Juniors	736		
Seniors	676		
Special	34		
Winter 1976		3054	368
Freshmen	657		
Sophomores	746		
Juniors	706		
Seniors	726		
Special	19		
Spring 1976		2879	386
Freshmen	758		
Sophomores	677		
Juniors	642		
Seniors	786		
Specials	16		
Total		9234	1135

The student quarter credits earned during the 1975-76 academic year are shown in Table 16.

Table 16 Student Quarter Credits

Student Quarter Credits	Structured		Unstructured	
Lower Level (100 & 200)	27,762	29.5%		
Undergraduate			620	
Upper Level (300 & 400)	51,833	55.1%		
Graduate (500 & 600)	14,471	15.4%	3718	
Total	94,066	100.0%	4338	98,40

These student quarter credits are earned when the College of Engineering offers ISU students 4744 class credits in the three academic quarters of 1975-76; 808 graduate credits, 2773 upper level undergraduate credits and 1163 lower level undergraduate credits. These offerings consist of lecture-recitation, laboratories, special problems and research credits in structured instruction. In the College of Engineering the approximate ratio between Lecture-Recitation offerings and laboratory offerings is four to one (4-1) at the graduate level, two and one-third to one (2.34-1) at the upper level undergraduate and two and three-quarters (2.76-1) at the lower level undergraduate.[1]

Using these data, the model's parameters and beginning points for the input-output coefficients are derived. Then each activity is simulated so that the exact attainment of all constraints is achieved. Each separate activity is simulated by utilizing a MPSX Linear Programming computer program that is programmed to restrict the deviation of fulfillment of each constraint with "limits" and "bounds" and manipulating the input-output coefficients (aij) until a unique optimal solution is obtained. The input-output coefficients that are not stipulated in the basic documents are estimated and then varied until all the parameters of the model are satisfied to within .005 of the constraint-resources consumed in the process. This is very time consuming as many of the input-output coefficients had to be expressed to four decimal places to achieve a unique optimal solution. Each coefficient represents the technical input-output relationship between a resource and a single unit of a specific activity or a technical ratio between specific activities or specific constraints.

An optimal solution is obtained for each of the ten (10) activities[1] without using the derived objective function values. The model is structured with each activity treated as a separate program with a dummy objective function value. This results in the model being controlled by the stipulated constraints.

The optimal solutions express the activity levels for the ten (10) activities that this study suggests are the allocation and performance level of the faculty resources during the 1975-76 academic year. Table 17 reports these values as the "Present Level" together with arbitrarily set upper and lower limits.

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[1]Structured Instruction is divided into Structured Graduate and Structured Undergraduate Graduate Instruction and Unstructured Instruction is divided into Unstructured Graduate and Unstructured Undergraduate Instruction.

Table 17 Activity levels.

Activity Identity	75% Zero-base	Present Level	200% Ceiling
Structured Graduate Instruction	18,735.5	24,980.6	49,961.2
Structured Undergraduate Instruction	22,502.6	30,003.4	60,006.8
Unstructured Graduate Instruction	16,224.8	21,633.0	43,266.0
Unstructured Undergraduate Instruction	16,554.8	22,073.0	44,146.0

Table 17 Activity levels.

Research Activity	49,123.0	65,497.0	130,994.0
Committee & Council Involvement	28,037.0	37,382.0	74,764.0
Administrative Activities	21,123.0	28,164.0	56,328.0

Table 17 (Continued)

Activity Identity	75% Zero-base	Present Level	200% Ceiling
Professional Activities	7,876.0	10,501.0	21,002.0
Professional Development	10,080.0	13,440.0	26,880.0
Public Service Extension	13,675.0	18,233.0	36,466.0

The 1975-76 activity levels are established as the 100% base the model is structured to simulate. A Zero-Base Budget strategy is applied to this base with the lower limits set at 75% and the upper limits set at 200%.

After this information was obtained all ten (10) activities were combined into a single composite model. Table 18 represents the structure, logic and content of the composite model.

Table 18 Diagram of the final composite linear program matrix

	GLSPPLR	GLSPPLA	GLSASPLR	GLSASPLA	GLSATPLR	GLSATPLA	ULSPPLR	ULSPPLA	ULSASPLR	ULSASPLA	ULSATPLR
COBJSBRE	1125.8	450.40	1104.15	441.66	1082.5	433.0	881.92	440.96	864.96	432.48	848.00
COBJACFR	1125.8	450.40	1104.15	441.66	1082.5	433.0	850.22	425.11	833.87	416.94	817.52
COBJTHST	1125.8	450.40	1104.15	441.66	1082.5	433.0	886.47	443.23	869.41	434.70	852.36
COBJPADE	1125.8	450.40	1104.15	441.66	1082.5	433.0	875.31	437.65	858.47	429.24	841.64
COBJTRST	1125.8	450.40	1104.15	441.66	1082.5	433.0	881.34	440.67	864.39	432.19	847.44
XRPPPTE	-5.0	-2.0					-4.0	-2.0			
XRASPPTE			-5.0	-2.0					-4.0	-2.0	
XRATPPTE					-5.0	-2.0					-4.0
XRINSPTE											
GLSCRTRR	.0322	.0322	.0322	.0322	.0322	.0322					
ULSCRTRR							.149	.149	.149	.149	.149
LLSCRTRR											
LABRQGL	1.0	-4.08	1.0	-4.08	1.0	-4.08					
LABRQUL							1.0	-2.34	1.0	-2.34	1.0
LABRQLL											
GLESPTFS											
GLPRSTSA											
ULESPTSA											
GLSTSCRT	.495	.9	.495	.9	.495	.9					
ULSTSCRT							2.759	2.871	2.759	2.871	2.759
LLSTSCRT											
GLSTUCRT											
ULSTUCRT											
SGRADSTU	.0388	.0706	.0388	.0706	.0388	.0706					
SUNGRSTU							.32	.333	.32	.333	.32
UGRADSTU											
UUNGRSTU											
CEXPPCEE											
PPPTEUT											
ASPPTEUT											
ATPPTEUT											
INSPTEUT											
RESRCTRW											
CCINCTRW											
ADACCTRW											
PPACCTRW											
PPDECTRW											
PBSPCTRW											

Table 18 (Continued)

	ULSATPLA	ULSINSLR	ULSINSLA	LLSPPLR	LLSPPLA	LLSASPLR	LLSASPLA	LLSATPLR	LLSATPLA	LLSINSLR	LLSINSLA
COBJSERR	424.05	831.04	415.52	651.44	440.96	648.70	432.44	636.00	424.00	623.28	415.52
COBJACPR	408.76	801.17	400.58	637.67	425.11	625.40	416.94	613.14	408.76	600.88	400.58
COBJTHST	426.18	835.31	417.66	654.84	443.23	652.06	434.70	639.27	426.18	626.48	417.66
COBJPADR	420.80	824.81	412.40	656.48	437.65	643.87	429.24	631.23	420.81	618.61	412.40
COBJFRST	423.72	830.49	415.25	651.00	440.67	648.29	432.19	635.58	423.72	622.87	415.25
IRPPPTE				-3.0	-2.0						
IRASPPTE						-3.0	-2.0				
IRATPPTE	-2.0							-3.0	-2.0		
IRINSPTE		-4.0	-2.0							-3.0	-2.0
GLSCRTRR											
ULSCRTRR	.149	.149	.149								
LLSCRTRR				.0995	.0995	.0995	.0995	.0995	.0995	.0995	.0995
LABRQGL											
LABRQUL	-2.34	1.0	-2.34								
LABRQLL				1.0	-2.76	1.0	-2.76	1.0	-2.76	1.0	-2.76
GLRSPTRS											
GLRRSTSA											
ULRSPTSA											
GLSTSCRT											
ULSTSCRT	2.671	2.759	2.87[illegible]								
LLSTSCRT				2.29	2.64	2.29	2.64	2.29	2.64	2.29	2.64
GLSTUCRT											
ULSTUCRT											
SGRADSTU											
SUNGRSTU	.333	.32	.333	.2656	.3062	.2656	.3062	.2656	.3062	.2656	.3062
UGRADSTU											
UUNGRSTU											
CEXPFCEE											
PPFTEUT											
ASPPTEUT											
ATPPTEUT											
INSPTEUT											
RESRCTRW											
CCINCTRW											
ADACCTRW											
PPACCTRW											
PPDECTRW											
PBSRCTRW											

Table 18 (Continued)

	GLSPFPU	GLRSFPU	GLSAFPU	GLSPASPU	GLRSASPU	GLSAASPU	GLSPATPU	GLRSATPU	GLSAATPU	ULSPFPU	ULSAFPU
COBJSERE	179.79	119.86	89.90	176.33	117.56	88.17	172.88	115.25	86.44	115.96	57.98
COBJACPR	181.93	121.28	90.96	178.43	118.95	89.21	174.93	116.62	87.47	117.69	58.84
COBJTHST	191.05	127.37	95.53	187.38	124.92	93.69	183.71	122.47	91.85	123.82	61.91
COBJPADE	187.34	124.89	93.67	186.80	122.49	91.87	180.14	120.09	90.07	120.67	60.34
COBJTRST	194.19	129.46	97.09	190.45	126.97	95.23	186.72	124.48	93.36	124.63	62.32
IRPPFTE	-.75	-.50	-.375							-.50	-.25
IRASPFTE				-.75	-.50	-.375					
IRATPFTE							-.75	-.50	-.375		
IRINSFTE											
GLSCRTRR											
ULSCRTRR											
LLSCRTRR											
LABRQGL											
LABRQUL											
LABRQLL											
GLRSPTRS	-1.329	1.0		-1.329	1.0		-1.329	1.0			
GLRRSTSA		1.0	-4.7142		1.0	-4.7142		1.0	-4.7142		
ULRSPTSA										-9.979	1.0
GLSTSCRT											
ULSTSCRT											
LLSTSCRT											
GLSTUCRT	.1768	.1768		.1768	.1768		.1768	.1768			
ULSTUCRT										.0981	
SGRADSTU											
SUNGRSTU											
UGRADSTU			.4459			.4459			.4459		
UUNGRSTU											.146
CEXPPCEE											
PPPTEUT											
ASPFTEUT											
ATPFTEUT											
INSPTEUT											
RESRCTRW											
CCINCTRW											
ADACCTRW											
PPACCTRW											
PPDECTRW											
PBSRCTRW											

Table 18 (Continued)

	ULSPASPU	ULSAASPU	ULSPATPU	ULSAATPU	RESOPPP	RESOPASP	RESOPATP	CCIOPPP	CCIOPASP	CCIOPATP	CCIOPINS
COBJSERR	113.73	56.87	111.50	55.75	241.54	236.90	232.25	118.04	115.77	113.50	111.23
COBJACPR	115.42	57.71	113.16	56.58	273.20	267.94	262.69	155.51	152.52	149.53	146.54
COBJTHST	121.44	60.72	119.06	59.53	199.14	195.31	191.48	91.49	89.73	87.97	86.21
COBJPADE	118.35	59.18	116.03	58.02	235.00	230.49	225.97	113.29	111.11	108.93	106.75
COBJTRST	122.24	61.12	119.84	59.92	202.17	198.28	194.39	90.51	88.77	87.03	85.29
IRPPPTE					-1.0			-1.0			
IRASPPTE	-.50	-.25				-1.0			-1.0		
IRATPPTE			-.50	-.25			-1.0			-1.0	
IRINSPTE											-1.0
GLSCRTRR											
ULSCRTRR											
LLSCRTRR											
LABRQGL											
LABRQUL											
LABRQLL											
GLRSPTRS											
GLRRSTSA											
ULRSPTSA	-9.979	1.0	-9.979	1.0							
GLSTSCRT											
ULSTSCRT											
LLSTSCRT											
GLSTUCRT											
ULSTUCRT	.0981		.0981								
SGRADSTU											
SUNGRSTU											
UGRADSTU											
UUNGRSTU		.146		.146							
CEXPPCEE											
PPPTEUT											
ASPPTEUT											
ATPPTEUT											
INSPTEUT											
RESRCTRW					1.0	1.0	1.0				
CCINCTRW								1.0	1.0	1.0	1.0
ADACCTRW											
PPACCTRW											
PPDECTRW											
PUSRCTRW											

Table 18 (Continued)

	ADAOPPP	ADAOPASP	ADAOPATP	ADAOPINS	PATOPPP	PATOPASP	PATOPATP	PATOPINS	PDVOPPP	PDVOPASP	PDVOPATP
COBJSERB	135.46	132.86	130.25	127.65	243.88	239.19	234.50	229.81	223.60	219.30	215.00
COBJACPR	181.93	178.43	174.93	171.43	276.80	271.47	266.15	260.83	252.77	247.91	243.05
COBJTHST	104.10	102.10	100.10	98.10	194.01	190.28	186.55	182.82	202.29	198.40	194.51
COBJFADE	129.47	126.98	124.49	122.00	241.34	236.70	232.06	227.42	220.94	216.69	212.44
COBJTBST	102.38	100.41	98.44	96.47	212.18	208.10	204.02	199.94	205.13	201.18	197.24
XRPPPTE	-1.0				-1.0				-1.0		
XRASPPTE		-1.0				-1.0				-1.0	
XRATPPTE			-1.0				-1.0				-1.0
XRINSPTE				-1.0				-1.0			
GLSCRTRR											
ULSCRTRR											
LLSCRTRR											
LABRQGL											
LABRQUL											
LABRQLL											
GLRSPTRS											
GLRRSTSA											
ULRSPTSA											
GLSTSCRT											
ULSTSCRT											
LLSTSCRT											
GLSTUCRT											
ULSTUCRT											
SGRADSTU											
SUNGRSTU											
UGRADSTU											
UUNGRSTU											
CDXPPCRE											
PPPTEUT											
ASPPTEUT											
ATPPTEUT											
INSPTEUT											
RESRCTRW											
CCINCTRW											
ADACCTRW	1.0	1.0	1.0	1.0							
PPACCTRW					1.0	1.0	1.0	1.0			
PPDECTRW									1.0	1.0	1.0
PBSRCTRW											

Table 18 (Continued)

	PDVOPINS	PSROPPP	PSROPASP	PSROPATP	PSROPINS	RCOSTPP	RCOSTASP	RCOSTATP	RCOSTINS		RHS VALUES
COBJSRBS	210.70	211.12	207.06	203.00	198.94						
COBJACPR	238.19	209.55	205.52	201.49	197.46						
COBJTHST	190.62	131.71	129.17	126.64	124.11						
COBJPADE	208.19	163.95	160.79	157.64	154.49						
COBJTRST	193.30	132.80	130.24	127.69	125.14						
IRPPPTE		-1.0				1.0				=	0.0
IRASPPTE			-1.0				1.0			=	0.0
IRATPPTE				-1.0				1.0		=	0.0
IRINSPTE	-1.0				-1.0				1.0	=	0.0
GLSCRTRR										<	808.0
ULSCRTRR										<	2773.0
LLSCRTRR										<	1163.0
LABRQGL										=	0.0
LABRQUL										=	0.0
LABRQLL										=	0.0
GLRSPTRS										=	0.0
GLFPSTSA										=	0.0
ULRSPT										=	0.0
GLSTSCRT										<	14471.0
ULSTSCRT										<	51833.0
LLSTSCRT										<	27762.0
GLSTUCRT										<	3718.0
ULSTUCRT										<	620.0
SGRADSTU										<	1135.0
SUNGRSTU										<	9234.0
UGRADSTU										<	1135.0
UUNGRSTU										<	9234.0
CEXPFCEE						18.34	16.87	14.05	10.76	<	6893928.25
PPFTEUT						1.0				<	161222.4
ASPPTEUT							1.0			<	139072.3
ATPPTEUT								1.0		<	93600.0
INSPTEUT									1.0	<	26136.0
RESRCTRW										>	49123.0
CCINCTRW										>	28037.0
ADACCTRW										>	21123.0
PPACCTRW										>	7876.0
PPEECTRW	1.0									>	10080.0
PBSRCTRW		1.0	1.0	1.0	1.0					>	13675.0

The first sixty (60) column headings (see Table 14 for definitions) identify the activities and the remaining four (4) handle internal accounting procedures. The first five (5) rows identify the objective functions. The following thirty-three (33) rows identify the resources, constraints and derived technical relationships. Table 19 defines these row variables.

Table 19 Definitions of row names.

IRFPFTE	Input Resource Full Professor in FTE Units.
IRASPFTE	Input Resource Associate Professor in FTE Units.
IRATPFTE	Input Resources - Assistant Professor in FTE Units.
IRINSFTE	Input Resource - - Instructor in FTE Units.
GLSCRTRR	Graduate Level - Structured Credit Transfer Row.
ULSCRTRR	Upper Level - Structured Credit Transfer Row.
LLSCRTRR	Lower Level - Structured Credit Transfer Row.
LABRQGL	Laboratory Requirement for Graduate Level.
LABRQUL	Laboratory Requirement for Upper Level.
LABRQLL	Laboratory Requirement for Lower Level.
GLRSPTRS	Graduate Level Ratio of Special Problems to - Research Supervision.
GLRRSTSA	Graduate Level Ratio of Research Supervision to Student Advising.
ULRSPTSA	Undergraduate Level Ratio of Special Problems to Student Advising.

Table 19 (Continued)

GLSTSCRT	Graduate Level Student Structured Credits Taken.
ULSTSCRT	Upper Level Student Structured Credits Taken.
LLSTSCRT	Lower Level Student Structured Credits Taken.
GLSTUCRT	Graduate Level Student Unstructured Credits Taken.
ULSTUCRT	Undergraduate Level Student Unstructured Credits
SGRADSTU	Structured Instruction - Graduate Student Count.
SUNGRSTU	Structured Instruction - Undergraduate Student Count
UGRADSTU	Unstructured Instruction - Graduate Student Count.
UUNGRSTU	Unstructured Instruction - Undergraduate Student Count
CEXPFCEE	Current Expenses for the College of Engineering.
FPFTEUT	Full Professor FTE Unit Total.
ASPFTEUT	Associate Professor FTE Unit Total.
ATPFTEUT	Assistant Professor FTE Unit Total.
INSFTEUT	Instructor FTE Unit Total.
RESRCTRW	Research Activity Count Row.
CCINCTRW	Committee and Council Involvement Count Row.
ADACCTRW	Administrative Activities Count Row.
PFACCTRW	Professional Activities Count Row.
PPDACTRW	Professional Development Count Row.
PBSRCTRW	Public Service - Extension Count Row.

After this model is validated, the dummy objective function values are replaced with the derived objective values. Then each of the five (5) objectives are optimized within the original constraint values.

This step initially caused considerable difficulty because the model, as formulated at this stage, did not produce a unique optimal solution. When all ten (10) activities were combined into one comprehensive model, the results of the Linear Programming computer run indicated multiple optimal solutions. The information provided on the Faculty Workload Guide resulted in all faculty ranks being equally productive for each specific activity. The Faculty Workload Guide provided that any faculty member that provides the instruction in a Graduate lecture/seminar class fulfilled five (5) of his required FTE Units for each credit of the course. However, the cost of five (5) FTE Units varied from 91.70 to 84.35 to 70.25 depending on which rank (Full Professor, Associate Professor or Assistant Professor) provided the instruction.[1] This structure created a situation in which the same unit of output could have three different input resource costs; i.e. no unique optimal solution. Under these conditions, the solution did not contain any dual

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[1]The model did not allow Instructors to participate in graduate instruction.

values - shadow prices that represented the marginal value product - or any reduced cost information that identified the change in value of the objective function if a specific activity is forced into solution.

The absolute necessity of differentiated levels of productivity among different inputs relative to the same output is a major finding of this study. Intuitively, a resource is more economically valuable only if it is more productive. Productivity is the focus of considerable research in the public sector but the type of information needed for this study is not presently available or able to be derived from the available information. Estimates of this factor could be obtained using the Delphi Technique much the same way the objective coefficients were obtained. However, there was not sufficient time to attempt to undertake such an exercise. Therefore, after consultation with Dr. Michael D. Boehlje and Dr. Dennis Starleaf, arbitrary productive values were assigned to each faculty rank as follows: Instructors 98%; Assistant Professors 100%; Associate Professors 102% and Full Professors 104%.

This arbitrary assignment does not distract from the purpose of the study, i.e. to conceptualize and formulate existing methodologies into an optimizing-resource allocation model of a public service delivery function.

This information was incorporated into the model by taking the values in Table 07 page 125 and multiplying them by the appropriate productivity factor. For example, the C value of SGRADIN for Obj. #1 is 216.5 and from Table 13 page 147 it requires five (5) FTE's to provide one unit of SGRADIN. With the productivity adjustment it turns out that if the unit of SGRADIN is achieved with Full Professor's FTE's, the objective coefficient GLSFPLR is 1125.8; i.e. 5.0 times 1.04 = 5.2; 216.5 times 5.2 = 1125.8. If that unit of SGRADIN was achieved with Associate Professor FTE's, the objective coefficient GLSASPLR is 1104.15; i.e. 5.0 times 1.02 = 5.1; 216.5 times 5.1 = 1104.15. This adjustment was made to every standardized objective coefficient.

Table 20 expresses the resulting three hundred (300) objective function values that are used in the model of this study.

The adjustment of the objective function coefficients completed the formulation of the problem into a linear programming format. With these productivity differentials, the composite model produced an optimal solution together with shadow prices and reduced cost information.

Table 20 Activity contribution to an objective function.

Activity Title	Secure Resources	Academic Freedom	Thinking Student	Faculty Development	Trained Student
GLSFPLR	1125.8	1125.8	1125.8	1125.8	1125.8
GLSFPLA	450.4	450.4	450.4	450.4	450.4
GLSASPLR	1104.15	1104.15	1104.15	1104.15	1104.15
GLSASPLA	441.66	441.66	441.66	441.66	441.66
GLSATPLR	1082.5	1082.5	1082.5	1082.5	1082.5
GLSATPLA	443.0	433.0	433.0	433.0	433.0
ULSFPLR	881.92	850.22	886.45	875.31	881.34
ULSFPLA	440.96	425.11	443.23	437.65	440.67
ULSASPLR	864.96	833.87	869.41	858.47	864.39
ULSASPLA	432.48	416.94	434.7	429.24	432.19
ULSATPLR	848.0	817.52	852.36	841.64	847.44
ULSATPLA	424.05	408.76	426.18	420.82	423.72
ULSINSLR	831.04	801.17	835.31	824.81	830.49
ULSINSLA	415.52	400.58	417.66	412.40	415.25
LLSFPLR	661.44	637.67	664.84	656.48	661.0
LLSFPLA	440.96	425.11	443.23	437.65	440.67
LLSASPLR	648.7	625.4	652.06	643.85	648.29
LLSASPLA	432.44	416.94	434.7	429.24	432.19
LLSATPLR	636.0	613.14	639.27	631.23	635.58
LLSATPLA	424.0	408.76	426.18	420.82	423.72
LLSINSLR	623.28	600.88	626.48	618.61	622.87
LLSINSLA	415.52	400.58	417.66	412.4	415.25

Table 20 (Continued)

Activity Title	Secure Resources	Academic Freedom	Thinking Student	Faculty Development	Trained Student
GLSPFPU	179.79	181.93	191.05	187.34	194.19
GLRSFPU	119.86	121.28	127.37	124.89	129.46
GLSAFPU	89.9	90.96	95.53	93.67	97.09
GLSPASPU	176.33	178.43	187.38	186.8	190.45
GLRSASPU	117.56	118.95	124.92	122.49	126.97
GLSAASPU	88.17	89.21	93.69	91.87	95.23
GLSPATPU	172.88	174.93	183.71	180.14	186.72
GLRSATPU	115.25	116.62	122.47	120.09	124.48
GLSAATPU	86.44	87.47	91.85	90.07	93.36
ULSPFPU	115.96	117.63	123.82	120.67	124.63
ULSAFPU	57.98	58.84	61.91	60.34	62.32
ULSPASPU	113.73	115.42	121.44	118.35	122.24
ULSAASPU	56.87	57.71	60.72	59.18	61.12
ULSPATPU	111.5	113.16	119.06	116.03	119.84
ULSAATPU	55.75	56.58	59.53	58.02	59.92
RESOPFP	241.54	273.2	199.14	235.0	202.17
RESOPASP	236.9	267.94	195.31	230.49	198.28
RESOPATP	232.25	262.69	191.48	225.97	194.39
CCIOPFP	118.04	155.51	91.49	113.29	90.51
CCIOPASP	115.77	152.52	89.73	111.11	88.77
CCIOATP	113.5	149.53	87.97	108.93	87.03
CCIOPINS	111.23	146.54	86.21	106.75	85.29

Table 20 (Continued)

Activity Title	Secure Resources	Academic Freedom	Thinking Student	Faculty Development	Trained Student
ADAOPFP	135.46	181.93	104.10	129.47	102.38
ADAOPASP	132.86	178.43	102.1	126.98	100.41
ADAOPATP	130.25	174.93	100.1	124.49	98.44
ADAOPINS	127.65	171.43	98.1	122.0	96.47
PATOPFP	243.88	276.8	194.01	241.34	212.18
PATOPASP	239.19	271.47	190.28	236.7	208.1
PATOPATP	234.5	266.15	186.55	232.06	204.02
PATOPINS	229.81	260.83	182.82	227.42	199.94
PDVOPFP	223.6	252.77	202.29	220.94	205.13
PDVOPASP	219.3	247.91	198.4	216.69	201.18
PDVOPATP	215.0	243.05	194.51	212.44	197.24
PDVOPINS	210.7	238.19	190.62	208.19	193.3
PSROPFP	211.12	209.55	131.71	163.95	132.6
PSROPASP	207.06	205.52	129.17	160.79	130.24
PSROPATP	203.0	201.49	126.64	157.64	127.69
PSROPINS	198.94	197.46	124.11	154.49	125.14

The summary description of the model follows:

$$\text{Max } fk(x) = \sum_{j=1}^{n} Ckj\ Xi$$

$$\text{s.t.} \quad \sum_{j=1}^{n} Aij\ Xj \leq bi$$

$$\text{and } Xj \geq 0$$

The ISU College of Engineering has m types of resources R, Full Professors, Associate Professors, Assistant Professors, and Instructors, in quantities BI (where I= 1,. . m) and N possible activities (P), Structured Instruction, Unstructured - Instruction, Research Activities, Administrative Activities, Professional Activities etc., on which to assign the resources. Therefore, if we let Xj (where J = 1, . . . , n) specify the nonnegative activity level of the j th activity then each unit of the j th activity (P) absorbs aij quantity units of the i th resource (i = 1, . . . , m) and contributes ckj (l = 1, . . . , k) value units of the value of the k th objective function (Secure Resources, Academic Freedom, etc.,).

Processing data with a single objective

The data of the composite model are processed utilizing a MPSX Linear Programming computer program to obtain solution values. The following section reports the results of the various computer runs where the only model constraints are total students, credits offered and earned, budget, and total FTE Units by rank. The model is run ten (10) times in this form using the original and adjusted data with each of the five (5) illustrative objectives. The description of these ten (10) runs begins with the results in terms of total objective values followed by a description of each objective function total stated as activity totals of each objective. The activity totals are further described in terms of the level of each resource within each activity. This information is provided for the original and alternative scenario data from the single objective model.[1] Because of the similarity of the objective function coefficients and the tight constraints in the model there is not a lot of difference in the activity levels, the shadow prices and reduced cost factors for the separate objectives. However, the existence and nature of the resulting differences does illustrate that the model is capable of providing meaningful information.

If the values resulting from the calculations were valid, officials in the College of Engineering might interpret the values to answer questions such as (1) which objective reflects the highest level of achievement when all the efforts and expenditures are directed toward one

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[1]An alternative scenario adjusted the parameters to reflect a 11.25% increase in undergraduate students and a 5.5% decrease in graduate students.

objective? (1a) would the result change if the student enrollment varied? (2) what is the activity level necessary to attain an optimal level of achievement of each objective? (2b) why do the calculations indicate different levels of activities for different objectives? (2c) why are some classifications of activities never used in the attainment of some objectives? (2d) how much do activity levels change when student enrollments vary? (3)if there is money to increase one resource-constraint, which one would return the greatest value, i.e. if one faculty member is added, what activity should that faculty member be assigned to? (3a) conversly, if the resource-constraint capacity is reduced by one faculty member, where would the reduction affect the output value the least? The same types of questions would be appropriate if all five objectives were optimized as a composite value.

The five (5) objective function values for the original and alternative scenarios are reported in Table 21.

Table 21 Objective function values.

Objective Identity	Original Scenario	Alternative Scenario
Secure Resources	89,648,118.2	89,558,549.5
Academic Freedom	94,742,049.5	94,484,353.2
Thinking Student	83,078,076.1	83,145,875.5
Faculty Development	88,309,088.2	88,204,742.6
Trained Student	83,589,063.4	83,640,342.2

An illustrative interpretation of the values in Table 21 indicates that if only one objective were to be pursued, Academic Freedom would be a technically rational first choice. It produces the highest total objective value,i.e. 94,742,049.5. Varying the student enrollment does not appear to alter the value of Academic Freedom. This would be an economically rational choice if all five objectives were equally important, i.e. provided equal amounts of satisfaction.

The validity of this illustrative interpretation and all subsequent interpretations are directly proportional to the accuracy of the structure and components of the model. Table 22 reports the results of the original scenario in terms of the sixty (60) activity levels within each of the five (5) illustrative objectives.

Table 22 Activity levels from the original scenario.

Activity Title	Secure Resources	Academic Freedom	Thinking Student	Faculty Development	Trained Student
Structured Graduate					
GLSFPLR	1753.5		20153.6	3107.8	20153.6
GLSFPLA	4917.5	4261.1	4939.6	4917.5	4939.6
GLSASPLR	18309.8	20063.2		16955.4	
GLSASPLA		656.4			
GLSATPLR					
GLSATPLA					
Instruction	24,981	24,981	25,093	24,981	25,093
Structured Undergraduate					
ULSFPLR			79.9		2858.6
ULSFPLA			5557.3		
ULSASPLR	9360.9	3004.5	12924.1		10145.5
ULSASPLA				5526.2	5557.3
ULSATPLR	3570.4	9926.8		12931.3	

Table 22 (Continued)

Activity Title	Secure Resources	Academic Freedom	Thinking Student	Faculty Development	Trained Student
ULSATPLA	5526.2	5526.2			
ULSINSLR					
ULSINSLA					
LLSFPLR					
LLSFPLA			3098.3		3098.3
LLSASPLR		8475.2	8551.3	6749.9	8551.3
LLSASPLA				3070.7	
LLSATPLR	8475.2			1725.3	
LLSATPLA	3070.7	3070.7			
LLSINSLR					
LLSINSLA					
Instruction	30,003	30,003	30,211	30,003	30,211
Unstructured					
Graduate					
GLSPFPU	8941.5	8941.5	9029.0		9029.0
GLRSFPU	11883.3	11883.3	11999.6	11999.6	11999.6
GLSAFPU	630.2	630.2	636.4	636.4	636.4
GLSPASPU				9029.0	
GLRSASPU					
GLSAASPU					
GLSPATPU					
GLRSATPU					
GLSAATPU					
Instruction	21,455	21,455	21,665	21,665	21,665

Table 22 (Contiuued)

Activity Title	Secure Resources	Academic Freedom	Thinking Student	Faculty Development	Trained Student
Unstructured Undergraduate					
ULSPFPU	6274.8	6274.8	6320.1	6320.1	6320.1
ULSAFPU	15654.1	15654.1	15767.0	15767.0	15767.0
ULSPASPU					
ULSAASPU					
ULSPATPU					
ULSAATPU					
Instruction	21,929	21,929	22,087	22,087	22,087
Research					
RESOPFP	88942.0	88942.0		88673.0	
RESOPASP			34842.0		13839.8
RESOPATP			49025.0		56901.0
Activity	88,942	88,942	83,867	88,673	70,741
Committee & Council					
CCIOPFP					
CCIOPASP					
CCIOPATP	1901.0	1901.0	1901.0	1901.0	1901.0
CCIOPINS	26136.0	26136.0	26136.0	26136.0	26136.0
Involvement	28,037	28,037	28,037	28,037	28,037
Administrative					
ADAOPFP					
ADAOPASP					

Table 22 (Continued)

Activity Title	Secure Resources	Academic Freedom	Thinking Student	Faculty Development	Trained Student
ADAOPATP	21123.0	21123.0	21123.0	21123.0	21123.0
ADAOPINS					
Activities	21,123	21,123	21,123	21,123	21,123
Professional					
PATOPFP	21002.3	21002.3		21002.3	
PATOPASP					21002.3
PATOPATP			7876.0		
PATOPINS					
Activities	21,002	21,002	7,876	21,002	21,002
Professional					
PDVOPFP		10080.0			
PDVOPASP	10080.0		26880.0	10080.0	26880.0
PDVOPATP					
PDVOPINS					
Development	10,080	10,080	26,880	10,080	26,880
Public Service					
PSROPFP					
PSROPASP					
PSROPATP	13675.0	13675.0	13675.0	13675.0	13675.0
PSROPINS					
Extension	13,675	13,675	13,675	13,675	13,675

An interpretation of Table 22 reveals, among other things, that more resources are allocated to structured and unstructured graduate and undergraduate instruction activities when either the thinking student or the trained student objective functions are used than when any of the other three objective functions are used.

The calculations resulting from the alternative scenarios where the undergraduate student enrollment increased and graduate student enrollment decreased show that undergraduate instruction activities (30,211 compared to 32,893) increased and graduate instruction (25,093 compared to 23,696) decreased. The sixty activity levels within each of the five illustrative objectives of the alternative scenario are reported in Table 23.

Table 23 Activity levels of the alternative scenario.

Activity Title	Secure Resources	Academic Freedom	Thinking Student	Faculty Development	Trained Student
Structured Graduate					
GLSFPLR	2269.7	253.7	19031.2	3550.1	19031.2
GLSFPLA	4653.4	4653.4	4664.5	4653.4	4664.5
GLSASPLR	16716.1	18732.1		15435.7	
GLSASPLA					
GLSATPLR					
GLSATPLA					
Instruction	23,639	23,639	23,696	23,639	23,696

Table 23 (Continued)

Activity Title	Secure Resources	Academic Freedom	Thinking Student	Faculty Development	Trained Student
Structured					
Undergraduate					
ULSFPLR					
ULSFPLA			5557.3		5557.3
ULSASPLR	11353.0	3463.0	13004.0	6668.6	13004.0
ULSASPLA				5557.2	
ULSATPLR	1650.8	9540.9		6335.2	
ULSATPLA	5557.2	5557.2			
ULSINSLR					
ULSINSLA					
LLSFPLR			1205.3		1205.3
LLSFPLA			3811.6		3811.6
LLSASPLR		10520.1	9314.8		9314.8
LLSASPLA				3811.6	
LLSATPLR	10520.1			10520.1	
LLSATPLA	3811.6	3811.6			
LLSINSLR					
LLSINSLA					
Instruction	32,893	32,893	32,893	32,893	32,893
Unstructured					
Graduate					
GLSPFPU	8507.2	8507.2	8535.8		8535.8
GLRSPPU	11306.1	11306.1	11344.1	11344.1	11344.1
GLSAPPU	599.6	599.6	601.6	601.6	601.6
GLSPASPU				8535.8	

Table 23 (Continued)

Activity Title	Secure Resources	Academic Freedom	Thinking Student	Faculty Development	Trained Student
GLRSASPU					
GLSAASPU					
GLSPATPU					
GLRSATPU					
GLSAATPU					
Instruction	20,413	20,413	20,482	20,482	20,482
Unstructured Undergraduate					
ULSPFPU	6988.0	6988.0	7051.1	7051.1	7051.1
ULSAFPU	17433.2	17433.2	17590.8	17590.8	17590.8
ULSPASPU					
ULSAASPU					
ULSPATPU					
ULSAATPU					
Instruction	24,421	24,421	24,642	24,642	24,642
Research					
RESOPFP	85413.4	85413.4		85180.9	
RESOPASP			32231.0		11229.7
RESOPATP			49025.0		56901.0
Activity	85,413	85,413	81,256	85,181	68,131
Committee & Council					
CCIOPFP					
CCIOPASP					

Table 23 (Continued)

Activity Title	Secure Resources	Academic Freedom	Thinking Student	Faculty Development	Trained Student
CCIOPATP	1901.0	1901.0	1901.0	1901.0	1901.0
CCIOPINS	26136.0	26136.0	26136.0	26236.0	26136.0
Involvement	28,037	28,037	28,037	28,037	28,037
Administrative					
ADAOPFP					
ADAOPASP					
ADAOPATP	21123.0	21123.0	21123.0	21123.0	21123.0
ADAOPINS					
Activities	21,123	21,123	21,123	21,123	21,123
Professional					
PATOPFP	21002.3	21002.3		21002.3	
PATOPASP					21002.3
PATOPATP			7876.0		
PATOPINS					
Activities	21,002	21,002	7,876	21,002	21,002
Professional					
PDVOPFP		10080.0			
PDVOPASP	10080.0		26880.0	10080.0	26880.0
PDVOPATP					
PDVOPINS					
Development	10,080	10,080	26,880	10,080	26,880

Table 23 (Continued)

Activity Title	Secure Resources	Academic Freedom	Thinking Student	Faculty Development	Trained Student
Public Service					
PSROPFP					
PSROPASP					
PSROPATP	13675.0	13675.0	13675.0	13675.0	13675.0
PSROPINS					
Extension	13,675	13,675	13,675	13,675	13,675

The results of the calculations reported in Table 24 indicate that the efforts of an additional faculty member will be utilized most effectively when pursuing Academic Freedom, i.e. the marginal value is largest for each rank in that objective. It also appears that the difference between the marginal value of different faculty ranks parallels the difference of the arbitrarily assigned productive values rather than the dollar value of the different ranks. Table 24 reports the values of the marginal value product (shadow prices) which are identical for the orginal and alternative scenarios.

Table 24. Shadow prices - marginal product

Model Resources	Secure Resources	Academic Freedom	Thinking Student	Faculty Development	Trained Student
Full Professor FTE Unit	241.54	273.2	199.58	235.0	262.52
Associate Professor FTE Unit	237.21	268.83	195.31	230.67	198.28
Assistant Professor FTE Unit	232.97	264.74	191.48	226.46	194.39
Instructor FTE Unit	230.7	261.75	189.72	224.28	192.65

The results of the calculations reported in Table 25 indicate that if the number of Instructors is reduced by one and reassignment is necessary, the number of Instructors providing upper level Lecture-Recitation instruction should be the last to be reassigned (ULSINSLR).

The reduced cost information from both scenarios is reported in Table 25. The values resulting from the original scenarios are reported under the heading "orig." and those from the alternative scenario under "adj.".

Table 25 Reduced cost information.

Activity Title	Secure Resources		Academic Freedom		Thinking Student		Faculty Development		Trained Student	
	orig.	adj.	orig.	adj.	orig.	adj.	orig.	adj.	orig.	adj.
GLSFPLR			.20							
GLSFPLA										
GLSASPLR					.33	.35			.46	.43
GLSASPLA	.08	.08		.06	.21	.22	.06	.08	.27	.25
GLSATPLR	.45	.45	1.21	1.21	2.63	2.65	.58	.61	2.66	2.63
GLSATPLA	.26	.26	.49	.57	1.21	1.22	.31	.33	1.15	1.13
ULSFPLR	.36	.36	1.13	.97			.50	.48		.02
ULSFPLA	.23	.23	.57	.49			.25	.25		
ULSASPLR							.02			
ULSASPLA	.05	.05		.02		.01				
ULSATPLR					1.73	1.73			1.39	1.39
ULSATPLA					.86	.87	.01		.69	.69
ULSINSLR	7.88	7.88	4.39	4.39	11.74	11.74	8.11	8.11	11.38	11.38
ULSINSLA	3.99	3.99	2.20	2.20	5.86	5.87	4.05	4.07	5.68	5.68
LLSFPLR	.27	.27	.84	.72	.02		.38	.36		
LLSFPLA	.18	.18	.57	.49			.25	.25		
LLSASPLR	.02	.02								
LLSASPLA	.04	.04		.02		.01				
LLSATPLR				5.76	1.30	1.30			1.04	1.04
LLSATPLA					.86	.87			.70	.68
LLSINSLR	5.91	5.91	3.29	3.29	8.81	8.81	6.08	6.08	8.53	8.53
LLSINSLA	3.94	3.94	2.20	2.20	5.86	5.87	4.05	4.07	5.69	5.67

Table 25 (Continued)

Activity Title	Secure Resources		Academic Freedom		Thinking Student		Faculty Development		Trained Student	
GLSPFPU							2.71	2.71		
GLRSFPU										
GLSAFPU										
GLSPASPU	.21	.21	.22	.25	.47	.48			.56	.56
GLRSASPU	.14	.14	.15	.17	.32	.32	.24	.24	.37	.37
GLSAASPU	.11	.11	.11	.13	.24	.24	.18	.18	.27	.27
GLSPATPU	.48	.48	.66	.69	1.27	1.27	3.50	3.50	1.37	1.37
GLRSATPU	.33	.33	.43	.45	.85	.86	.53	.53	.92	.91
GLSAATPU	.25	.25	.32	.33	.64	.65	.40	.40	.68	.68
ULSPFPU										
ULSAFPU										
ULSPASPU	.07	.07	.09	.11	.25	.25	.16	.16	.27	.27
ULSAASPU	.03	.03	.04	.05	.12	.13	.08	.08	.14	.14
ULSPATPU	.18	.18	.30	.32	.71	.72	.37	.37	.73	.72
ULSAATPU	.09	.09	.15	.16	.36	.36	.18	.19	.37	.37
RESOPFP,					.44	.43			.35	.35
RESOPASP	.31	.31	.89	.93			.18	.18		
RESOPATP	.72	.72	2.05	2.09			.49	.49		
CCIOPATP	1.97	1.97	1.10	1.10	2.07	2.07	2.03	2.03	2.15	2.15
CCIOPATP										
CCIOFINS										

Table 25 (Continued)

Activity Title	Secure Resources		Academic Freedom		Thinking Student		Faculty Development		Trained Student	
ADAOPFP	3.36	3.36	1.46	1.42	4.09	4.09	3.56	3.56	4.19	4.19
ADAOPASP	1.63	1.63	.59	.59	1.83	1.83	1.72	1.72	1.92	1.92
ADAOPATP										
ADAOPINS	.33	.33	.51	.51	.24	.24	.31	.31	.23	.23
PATOPFP					.64	.63			.16	.16
PATOPASP	.36	.36	.96	1.00	.10	.10	.31	.31		
PATOPATP	.81	.81	2.19	2.23			.74	.74	.19	.19
PATOPINS	3.23	3.23	4.52	4.56	1.97	1.97	3.20	3.20	2.53	2.53
PDVOPFP	.03	.03			.38	.37	.08	.08	.29	.29
PDVOPASP			.49	.53						
PDVOPATP	.06	.06	1.26	1.30	.06	.06	.04	.04	.05	.05
PDVOPINS	2.09	2.09	3.13	3.17	2.19	2.19	2.11	2.11	2.25	2.25
PSROPFP	.45	.45	.40	.36	3.03	3.02	2.23	2.23	3.02	3.02
PSROPASP	.18	.18	.06	.06	1.30	1.30	1.06	1.06	1.34	1.34
PSROPATP										
PSROPINS	1.79	1.79	1.04	1.04	.77	.77	.97	.97	.81	.81

Processing the data with a multiple objective

The same parameters and input-output coefficients were restructured to be compatible with a multiple objective linear programming computer program that is redimensioned to accommodate this specific model. The MOLP computer program, "An Adjacent Efficient Extreme Point Algorithm for Vector-Maximum and Interval Weighted-Sums Linear Programming Problems", was developed by Ralph E. Steuer at the University of Kentucky. It is written in FORTRAN IV and identified as ADEX. This program was modified in several ways by Dr. James A. Hoekstra of the ISU Computer Center to be compatible with the ISU hardware and to accommodate the specific data of this model. The resulting computer program is identified as ISUADEX.

This program allows each objective to be weighted to achieve a priority ranking. The weight does not have to be a single value but can be a range. The upper values of the ranges may sum to more than one and the lower values of the ranges must sum to less than one. The solution will reflect the ranking of each objective within its range but the sum of the weights will always equal one in the solution.

The original data was run in ISUADEX as a multiple objective problem with five (5) objectives in the following rank/priority order. Secure Resources - highest priority; Academic Freedom - second highest priority; Thinking Student and Faculty Development equal priority with Trained Student - lowest priority. The run produced eighteen (18) different solutions (efficient extreme points). These eighteen (18) solutions are reviewed and only objective values from eleven (11) solutions are included in the analysis. The eleven (11) objective values report the first solution of the computation and the other objective values are selected from the remaining solutions to identify the highest and lowest objective value for each of the five (5) objectives. The values of the objective functions from the first solution and the solutions where the value of the "Secure Resources" objective function is the largest and the smallest are reported in Table 26.

Similar information is available for the biggest and smallest values of the other four illustrative objectives but is not reported here because of the similarity of the values. The existence and nature of the difference reported in Table 26 illustrate that the model is capable of providing meaningful information about the variables in this type of problem.

Table 26 Objective function values.

Objective Identity	First Sol.	Biggest SERE	Smallest SERE
Secure Resources	89,594,438.9	89,597,169.5	89,593,074.0
Academic Freedom	94,693,714.0	94,701,788.0	94,688,562.6
Thinking Student	79,098,490.0	79,095,212.7	79,105,109.7
Faculty Development	88,239,068.0	88,213,467.8	88,239,990.7
Trained Student	83,354,545.2	83,351,901.1	83,360,937.9

The original data were then rerun in ISUADEX as a multiple objective problem with the five (5) objectives ranked in reverse order with the same weight ranges for the highest ranked objective etc. This run produced sixty-three (63) solutions. Based on the same criteria only objective values from eleven (11) solutions are included in the analysis. The values of the objective functions from the first solution and the solutions in which the value of the "Secure Resources" objective function sum is the largest and smallest are reported in Table 27.

Table 27. Objective sums; rank-order reversed

Trained Student ranked highest

Objective Identity	First Sol.	Biggest SERE	Smallest SERE
Secure Resources	89,609,197.9	89,644,653.0	89,565,912.8
Academic Freedom	94,614,844.5	94,725,296.4	94,492,489.1
Thinking Student	82,907,511.1	82,848,465.0	82,954,493.0
Faculty Development	88,288,503.0	88,308,784.3	88,253,763.9
Trained Student	83,502,661.9	83,451,003.9	83,534,748.3

These values are comparable to the values from the original scenario in Table 26.

Each set of objective values is achieved with a different combination of activities. Table 28 reports the supporting activities for the original scenario objective values of the first solution, the largest and smallest value of "Secure Resources" and "Thinking Student" to demonstrate the alternative utilization of activities.

Table 28 Alternative utilization of activities.

Activity Identity	First Value	SECURE RESOURCES Largest Value	Smallest Value	THINKING STUDENT Largest Value	Smallest Value
Structured Graduate					
GLSFPLR					
GLSFPLA					
GLSASPLR	2792.2	2792.2	1343.2	2792.2	1343.2
GLSASPLA	1295.0	1295.0	4917.5	1295.0	4917.5
GLSATPLR	17271.0	17271.0	18720.0	17271.0	18720.0
GLSATPLA	3622.5	3622.5		3622.5	
Instruction	24,981				
Structured Undergraduate					
ULSFPLR			2288.1	595.2	
ULSFPLA					
ULSASPLR	12931.3	12931.3	10643.1	12336.1	12931.3
ULSASPLA	5526.2	5526.2	5526.2	5526.2	5526.2
ULSATPLR					
ULSATPLA					
ULSINSLR					
ULSINSLA					
LLSFPLR	3050.8	793.6			3028.5
LLSFPLA	3070.7	3070.7	3070.7	3070.7	3070.7
LLSASPLR	5424.4	7681.6	8475.2	8475.2	5446.8
LLSASPLA					

Table 28 (Continued)

Activity Identity	First Value	SECURE RESOURCES Largest Value	SECURE RESOURCES Smallest Value	THINKING STUDENT Largest Value	THINKING STUDENT Smallest Value
LLSATPLR					
LLSATPLA					
LLSINSLR					
LLSINSLA					
Instruction	30,003				
Unstructured					
Graduate					
GLSPFPU		8939.5		9029.0	
GLRSFPU	11999.6	11880.6	11999.6	11999.6	11880.6
GLSAFPU	2545.4	2520.2	2545.4	2545.4	2520.2
GLSPASPU	9029.0		9029.0		8939.5
GLRSASPU					
GLSAASPU					
GLSPATPU					
GLRSATPU					
GLSAATPU					
Instruction	23,574				
Unstructured					
Undergraduate					
ULSPFPU	6274.8	6274.8	6320.1	6320.1	6274.8
ULSAFPU	15654.1	15654.1	15767.0	15767.0	15654.1
ULSPASPU					

Table 28 (Continued)

Activity Identity	First Value	SECURE RESOURCES Largest Value	SECURE RESOURCES Smallest Value	THINKING STUDENT Largest Value	THINKING STUDENT Smallest Value
ULSAASPU					
ULSPATPU					
ULSAATPU					
Instruction	21,929				
Research					
RESOPPP	88809.2	88945.3	88673.7	88673.7	88945.3
RESOPASP					
RESOPATP					
Activity	88,809				
Committee & Council					
CCIOPPP					
CCIOPASP	1901.0	1901.0	1901.0	1901.0	1901.0
CCIOPATP					
CCIOPINS	26136.0	26136.0	26136.0	26136.0	26136.0
Involvement	28,037				
Administrative					
ADAOPPP					
ADAOPASP	21123.0	21123.0	21123.0	21123.0	21123.0
ADAOPATP					

Table 28 (Continued)

Activity Identity	First Value	SECURE RESOURCES Largest Value	Smallest Value	THINKING STUDENT Largest Value	Smallest Value
ADAOPINS					
Activities	21,123				
Professional					
PATOPFP	21002.0	21002.0	21002.0	21002.0	21002.0
PATOPASP					
PATOPATP					
PATOPINS					
Activities	21,002				
Professional					
PDVOPFP	10080.0	10080.0	10080.0	10080.0	10080.0
PDVOPASP					
PDVOPATP					
PDVOPINS					
Development	10,080				
Public Service					
PSROPFP					
PSROPASP	13675.0	13675.0	13675.0	13675.0	13675.0
PSROPATP					
PSROPINS					
Extension	13,675				

Similar information is available for all the other highest and lowest values for all objective function sums computed for both priority rankings. Shadow prices - marginal value product and reduced cost information for any specific objective value are also readily available. However, because of the cost of making all the computer runs using the alternative scenarios and the space required to report all the results, the foregoing is offered as sufficient documentation that this model is capable of processing a resource allocation problem and providing meaningful information that can enhance the capability of decision makers.

Summary

The Delphi technique, linear programming, multiple objective linear programming and multiple criteria decision making are the notable components of the prescribed technology to develop an optimizing - resource allocation model of a public service delivery function. The structural, technical composition of this type of model is complex. A group of experts, using the Delphi technique, provided estimates of the internal technical relationships between organizational objectives and activities. The other technical relationships were derived as the model was formulated in a linear programming format.

Once the internal technical relationships were established it was a relatively simple operation to calculate the unique values for alternative scenarios in the study. A total of twelve (12) scenarios were calculated; ten as single objective situations and two as multiple objective situations.

It is important to reemphasize that the development of the technical composition of an optimizing - resource allocation model of a public service delivery function is complex and difficult. However, once the model is structured, its utilization in appropriate settings should be relatively simple.

CHAPTER IV. OPERATION AND FINDINGS

Objectives of the operation and findings

After reading the discussion of the operation, findings, limitations and implications of the study, you should:

* Be aware that objectives must be expressed in two dimensions, with a common unit of value that reflects the linkage of resources to activities to outcomes.

* Be aware that the finite specificity of the values in the model must not be interpreted as valid but rather as evidence that this type of information can be handled in an optimizing model.

* Be aware that the process of filling the voids in information in an optimizing-resource allocation model of public service delivery is not nearly as difficult, complex or time consuming as structuring the model.

* Be aware that the five illustrative objectives demonstrate that different types of outcome statements can express alternative perspectives and be handled in the same model.

* Be aware that public officials will have to discard traditional myths about computers and acquire simple skills so that they can operate optimizing-resource allocation

models of public service delivery functions.

* Be aware that the estimates of the linkages between specific activities and outcomes are used only because documented relationships are not available.

* Be aware that the scope and magnitude of the expert judgment sought in the Delphi exercise must be carefully limited so that the panel is not overburdened.

* Be aware that an optimizing model provides an estimate of maximum program attainment of public service delivery activities that may have value as a comparative standard for program planning or evaluation.

* Be aware that this model extends the state of the art of optimizing-resource allocation model in higher education by formulating the results of present planning models into the optimizing format of multiple objective linear programming.

<u>What was available to start with</u>

The review of literature documents that higher education and other public service delivery agencies have attempted to utilize the concept of outcome identification in organizational policy and administration for approximately two decades. The literature reviewed also reveals that outcome statements are written to represent many aspects of an organization's purpose and direction and are called by many different names. A model that portrays an organization's functions needs to be able to consider and handle many features of its results simultaneously.

The literature also describes numerous varieties of models utilized in higher education. Although some planning models are being used in the public sector, there is an expressed need for an optimizing model. Optimizing models are fairly commonplace in enterprise systems but are nonexistent in the public sector because of voids in information.

The Delphi literature suggests that the Delphi technique can be used to fill voids in information by expressing the judgment of experts in quantifiable terms. The linear programming literature describes a calculating procedure that will optimize outcome statements that are technically expressed. Even if the technical relationships are identified and expressed so they can be formulated into a single objective linear programming format, the multiple criteria decision-making literature demonstrates that single objective linear programming is not adequate in public service. The multiple objective linear programming literature provides the multiple outcome capacity.

The review of literature identifies all the apparent elements of an optimizing-resource allocation model of a public service delivery function. However, when the elements are formulated together into a single model, attempts to interpret the results indicate that the indispensable tenacious bond is the need to express the outcome statements in two dimensions: (1) one dimension is expressing the outcome statement so that it can be evaluated in terms of its exchange value with the other outcome statements and (2) the second dimension is expressing the outcome statement as a system of technical relationships that reflect the linkage of resources to activities to outcomes. Finally, both dimensions must include a common unit or value so that the activities and the outcomes can be subjected to mechanical calculation.

Findings of the methods and procedures

The methods and procedures of this study establish that an optimizing-resource allocation model of a public service delivery function is technically feasible. The gathering of information and data from the ISU College of Engineering is motivated by convenience rather than the logic and validity of the results of the calculations. Therefore, the results can not be taken seriously but are offered as evidence that this type of information can be handled in an optimizing-resource allocation model of a public service function.

Gathering, coding, recording and processing the judgments of experts relative to the technical relationships between activities and outcomes was a time-consuming task but proceeded without any major problem other than having to constantly follow up to get the Delphi questionnaire back. All calculations in this model are performed by an IBM Model 360-65 using the IBM MPSX Linear Programming package or Ralph E. Steuer's ADEX Adjacent Efficient Extreme Point Algorithm for Vector Maximum and Interval Weighted-Sums Linear Programming package.

In order to have practical application in resource allocation decisions the model must be capable of handling different types of objective function statements. This model illustrates three different kinds; (1) faculty oriented, (2) student oriented and (3) institution oriented. Other orientations are also possible. The logic of the model expects public policy makers, using information generated by the model, to be able to establish a rank order priority for the objectives. The results of this study illustrate the need to have the outcome statements expressed to faciliate their evaluation in terms of their exchange value. The exchange ratios of the five (5) objectives in this study are technically expressed in terms of the value of a unit of Structured Graduate Instruction. However, this form of expression is not intuitively easy to understand. It would help if the outcome statement also had a horizontal common unit of value such as stating all the outcomes in terms of the probabilities of risk of an event occurring on a per capita basis. The fundamental design of the model should be transferable to other public service delivery functions, such as local government community protection, and regional health services, such as health maintenance organizations, where the outcome statements could be stated in terms of the probability or risk of some event occurring in the model's environment during a specific time period.

Operation of the model

To derive benefit from the operation of an optimizing-resource allocation model of a public service delivery function, public officials must be able to: (1) identify, express and rank specific organizational objectives, (2) provide specific information about the magnitude of present resources and (3) be able to interpret the results of the calculations. This skill or ability will have to be developed parallel to the development of the technical capacity. Because of tradition and mental blocks based on myths about computers, the development of these skills may be more difficult than the refinement of the technology. However, I believe the development of skills sufficient to utilize an optimizing-resource allocation model of a public service delivery function is an achievable objective.

There are numerous examples of people operating and applying devices to meet their needs without understanding their complex construction and technical functions. For example, very few people understand exactly how the modern telephone system technically functions; yet, almost anyone can learn how to use a telephone and once the repetitive operation is mastered they readily use it to add a dimension to their communications. In much the same circumstance people drive automobiles, watch television, use copy machines and, one step removed, ride in airplanes.

An example that involves more complicated operating procedures is the use of hand-held calculators by farmers. A very large number of farmers presently use complex models pre-programmed in these calculators to determine livestock rations, fertilizer applications and capital investments in expensive equipment. At least one model of hand-held calculators has the capacity to perform the calculations of a very small linear program model. These circumstances and advancing technology contribute to the logic that an optimizing-resource allocation model of public service delivery functions can be utilized as soon as it is developed and validated.

Two dimensional outcome statements

This study illustrates very clearly that outcome statements must be conceptualized in two very specific dimensions before an optimizing model can be developed: first (1) in terms of an identifiable, observable and measurable impact, behavior change or other tangible criteria that can be used to evaluate the total outcome in terms of its total exchange value with other alternative outcomes; second (2) in terms of a linear sum of a combination of activities that are performed by the organization.

Outcome statements can be stated so that they can be evaluated over time and in terms of their exchange value. But general practice of this type of expression and evaluation is the exception rather than the rule. Experience gained in efforts to orient public service policymakers and administrators to the application of outcome statements to resource allocation decisions reveals that their experience prompts them to attempt to express outcome in terms of desired levels of activities. This approach fulfills the second dimension if the activity centered outcome statement reflects the technical relationship between each activity and the impact of the outcome statement. However, presently practicing public officials do not attempt to identify any technical relationships between any activities. Efforts to get public officials to state desired outcomes in terms of desired results, such as behavior change or change of situation, have been very ineffective. Therefore, a major portion of this study is to develop a technique to accomplish these two dimensions.

These two perspectives are analogous to the output and production functions of an enterprise. The outcome statements and the technical relationships in an enterprise model are expressible because of the wide knowledge and acceptance of the dollar as the standard unit of value and the market system. These characteristics of the enterprise system enable all factors to be expressed in terms of the dollar cost per unit of resource, activity or outcome. These same characteristics provide the framework for evaluating the outcome in terms of the exchange value of alternative outcomes. The same holds for cost-benefit analysis of alternative activities relative to specific outcomes. In an enterprise system the profit motivation (desired outcome) requires that the minimum allocation of resources, as combined into specific activities (efficiency/productivity),[1] be used to produce the outcomes that return the most revenues in dollars (effectiveness)[2]. Ideally, the last unit will be produced at a level of activity where marginal revenue equals marginal costs.

The public sector does not have an accepted uniform unit of value that transcends all the aspects of outcome statements and activity features and there is no public sector market system. However, there are technical relationships between all the variables in all public service delivery functions. The problem is to identify, describe and classify the variables and estimate or document their relationships. This is easier said than done. The variables can be classified as outcome statements, activities and resource/constraints. The more complete the inclusion of variables the more valid the model. However, some variables can knowingly be ignored and not materially affect the interpretation of the results of the simulation.

The more accurate the technical relationships, the more

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[1]Efficiency/productivity refers to the optimal mix of resources into activities based on the comparative value of the activities expressed in terms of resources consumed in the process.

[2]Effective refers to the optimal mix of activities to outcomes based on the exchange value of resources and outcomes.

valid the model. The ultimate validity would result from empirically documented and tested relationships. However, unlike variables, relationships must be expressed or the model will not perform any calculations. Therefore, if documented and tested relationships are not available then the best estimates can be used as a beginning point. In order to formulate a public service delivery function into an optimizing format that is adaptable to mechanical calculations, all technical relationships must be expressed in quantifiable terms. The Delphi technique is used to identify and express the estimated technical relationships in quantifiable terms.

It must be emphasized that the Delphi technique is used to derive estimated technical relationships only because documented relationships are not empirically identifiable at this time. However, the technical relationships may not be empirically available because no one has tried to identify them or even knows where to look for them. Therefore, one of the real values of estimated technical relationships derived from expert judgment may be their role as hypothesis of these relationships that can be tested and refined by empirical research later on. Validating the relationships between common activities and widely accepted outcome statements can be an accumulative process and the validity of the results of the model will become more valid as more and more of the technical relationships are empirically documented.

The logic of having a panel of experts utilize the Delphi technique to identify and estimate the technical relationships between specific identifiable activities and precisely stated organizational outcome statements is to divorce the total policy implications from the estimation of the technical relationships.[1] This pure judgment poses another problem. Where expert judgment establishes the technical relationships between specific activities and specific outcomes independently and without any reference to a common unit of value we have to assume that each technical relationship is expressed in terms of different units of value. This makes it impossible to make any kind of comparisons.

Attempting to incorporate these unscaled technical relationships into a multiple objective linear programming format produced two major problems. First was the problem of expressing all the technical relationships between outcome

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[1]Some separation appears to have been achieved in this study. The experts were so overwhelmed with the number of judgments they had to make that I feel confident that they did not attempt to envision the resulting policy implications. The relationships involved in ten (10) activities to twenty-five (25) attributes to five (5) objectives are too extensive for the same Delphi exercise. A preferable alternative would be a number of different groups working on the relationships of ten (10) activities to nine (9) attributes to three (3) objectives and then combining the results.

statements in a common unit of value. For example, in this study the original sums of the objective function coefficients in Table 06 are not comparable because they are not expressed in a common unit of value. This situation is corrected by standardization and the sums of the objective function coefficients in Table 07 are expressed in terms of Structured Graduate Instruction.

Structured Graduate Instruction was arbitrarily chosen as the numeraire in this study. As a result the total value of the objective functions is expressed in terms of the value of one unit of Structured Graduate Instruction. There may be alternative units of value that may be intutitively easier to understand and therefore facilitate the evaluation of the objectives in terms of their exchange value.

The second problem is differentiating between similar activities performed by faculty members of different ranks, and therefore different pay rates. For example, in this study the per FTE unit cost of a Full Professor is $18.34; an Associate Professor is $16.87; an Assistant Professor is $14.05; and an Instructor is $10.76 (Table 12). As the model was originally formulated, any class of activity could be performed by any of the above ranks of faculty. But all these sub-classes, within an activity, contributed the same amount to the objective function. This resulted in the calculations indicating that there is not a unique optimal solution. The only way the calculations would identify a unique optimal solution is to arbitrarily establish four levels of productivity for each activity. Productivity levels were set as follows: Instructor was set at .98; Assistant Professor was set at 1.00; Associate Professor was set at 1.02; and Full Professor was set at 1.04. This adjustment resulted in expanding the number of sub-activities to three hundred (300). The calculation then identified a unique optimal solution.

Production divisions in the enterprise system spend considerable effort to influence these levels of productivity. They seek to increase the efficiency of specific activities by divisions of labor; making activities more capital intensive or taking advantage of economies of scale. The final determination is made based on marginal value in units of dollars.

These efforts in the public sector would be greatly facilitated if the objective function coefficients were standardized such that the total objective function values were derived using a uniform unit of value and the exchange ratios between outcome statements are intuitively obvious. The study illustrates that the unit of value chosen as the numeraire greatly affects the exchange ratios between each objective function. Therefore, the choice of the activity to be designated as the numeraire is very critical to the validity of the results of the calculations. The technical expressions of the activities in terms of a common unit of value need to be standardized so that the stability of the relationship is not upset. The Walrasion assumption, together with the lack of effect on the absolute exchange ratios by the transformation resulting from identifying one of the activities as the numeraire, facilitates this. This is the transformation that enables the model to handle outcome statements expressing different subjective values in an optimizing framework. This transformation does not carry over and facilitate the evaluation of the outcomes in terms of their exchange value. Another uniform unit of value (expression) such as probability or risk is needed to do this.

The results of the calculations

The first formulation of the model structures each activity (Structured Instruction, Unstructured Instruction, etc.) and its sub-classes (Full Professors, Associate Professors, etc.) separately with a single-weighted objective function summing the calculations. The constraints in these calculations are the actual reported allocated resources expended for each activity. The designated amount of each resource is exhausted by controlling its level of simulated expenditures to a very narrow range around the actual reported level of utilization. This calculation reverses the normal logic of linear programming and the objective function value is determined by the allocation of resources, not the other way around.

The results of this calculation, when combined with the technically expressed coefficients of the objective function, can be used to produce a reasonable estimation of the activity level based on the existing allocation of resources. The levels of simulated activities are counted, summed and reported as an objective function total value. When this has been completed for each class of activity, the coefficients of each standardized objective function can be multiplied by the appropriate simulated activity levels to derive the total objective function values. The arrangement of the total objective function values in order of magnitude from highest to lowest value is an estimate of the organization's revealed preference of desired objective attainment.

An intuitive explanation of this calculation reasons that if: (1) the technical relationships between resources and activities are accurate and given; (2) the resources assigned to each activity are exhausted on that activity; and (3) the calculations on each activity are done separately, the resulting, derived level of each activity is a reasonable estimate of the actual level of the activity.

The second formulation combined all the classes of activities into one model where the resource constraints are reaggregated and the model is driven by one of the formulated-standardized objective functions. This is the first optimizing calculation, i.e. the model will allocate resources in proportion to their contribution to the unique formulated-standardized objective function.

This formulation consisted of ten (10) separate calculations. Each of the five (5) objective functions produced a different total objective function value (Table 21) and different resource allocations (Table 22). Each of the five (5) alternative scenarios, where the number of undergraduate students was increased by 11.25% and the number of graduate students was decreased by 5.5%, also produced a different total objective function value (Table 21) and different resource allocations (Table 23). The computer charge for each of these calculations was approximately $2.50 and the turnaround time was about ten (10) minutes.

The third formulation structured the same unique resource constraints, technical relationships and objective functions so that the the appropriate calculations can be made by a multiple objective linear programming package. This required that an experimental package be adapted to the ISU computer, the data be reorganized and coded slightly differently. The package and the data were verified as compatible and the calculations were completed on the scenario that contained the increased undergraduates and decreased graduate students and had the objective function "Secure Resources" ranked first and weighted considerably heavier than the other objectives. Secure Resources was assigned the weight range .3 to .4; Academic Freedom was assigned the weight range .2 to .3; Thinking Student was assigned the weight range .1 to .2; Faculty Development was assigned the weight range .1 to .2; Trained Student was assigned the weight range .0 to .1. The calculations produced sixty-three (63) extreme points (solutions) at a cost of $33.85. The multiple objective linear program calculations were repeated with the objective weights reversed. This calculation produced eighteen (18) extreme points at a cost of $9.61. Numerous observations can be obtained from the results of these calculations.

<u>Pie in the sky</u>

If this avenue of research is successfully pursued to the ultimate attainment, public policy decisionmakers will have available, as an alternative strategy, an optimizing-resource allocation model to assist them. Their first step would be to review a library of outcome statements classified by different aspects of impact. This review would broaden their perspectives and may ultimately result in their choosing six (6) or eight (8) outcome statements that best express their subjective preference of desired results. The next step will be to study a library of standard activities and identify those activities that are actually carried on by their organization. The third step will be to identify and classify the constraint level of their actual resources that are required to perform the activities they identified in the second step. A special review of existing resources not attributed to any of the model's activities will be necessary to determine if the model is inappropriate or if the policymakers are willing to tolerate the broad deviations in the validity of the results or the calculations. The fourth step is to submit the above information to a mechanical computer or calculator for processing. The next step is to verify that the model has arrived at an optimal solution with a tolerable amount of slack. Finally, the decisionmakers will have to be able to interpret the results of the calculations and use the results as estimates of projected consequences of simulated action.

The model can be quickly rerun with alternative outcome statements and/or modified resources constraints. These results can be compared to the results of the previous calculation and judgments made.

Limitations and implications

This type of model can be readily adapted to other levels of education (elementary, secondary and adult), community protection, public health and transportation. Other areas such as recreation/culture and environmental programs will be more difficult. If community protection and public health outcomes can be stated in probabilities/risks of encountered threats, the information should be very susceptible to mechancial optimization and human interpretation. The logic of the model would be to maximize or minimize the sum of the probabilities of the events, depending on their desirability.

Five (5) or six (6) objectives (outcome statements) in a single exercise appear to be the present upper limit for mechanical calculation. This is not an absolute limiting structure because different combinations of five (5) or six (6) objectives can be formulated so that there is overlap or duplication between some of the elements in the sets. This would enable the limit to be extended without bound.

The study reveals that it is necessary to be able to identify different levels of productivity and contribution to the organization's purpose, if any attempt to apply optimizing models to resource allocation decisions in public service delivery functions is to be successful. This means that there must be an alternative justification, rather than the traditional time in rank, for paying some faculty members more than others; i.e. the merit rationale will have to be refined and supported by verifiable evidence that is open to challenge and measurement.

Summary

The study identifies the Delphi technique, multiple objective linear programming and their related concepts as the apparent elements of an optimizing-resource allocation model of a public service delivery function. The study concludes that this type of model is technically feasible and can contain outcome statements that express a variety of types of objectives. A critical aspect of the findings is that outcome statements of public service delivery functions must be expressed in two dimensions; (1) one dimension faciliates evaluation of each objective in terms of its exchange value with other outcome statements; (2) the other dimension must be a system of technical relationships that reflects the linkage of resources to activities to outcomes, i.e. the net return of each activity. Both dimensions must be expressed in terms of a common numeraire before optimizing calculations are possible.

Public officials will have to be oriented to the logic of the model and trained in the skills of submitting the data to calculation. However, they will not have to become computer programmers before they can utilize the model and interpret its results.

Universities will have to develop libraries of outcome statements that are based on research of the productivity of public service activities and the tendency-causal relationships between activities and objectives before the orientation and training of public officials can begin.

The technology is presently available to handle five objectives on large computers and small single objectives on hand-held calculators.

CHAPTER V NEEDED RESEARCH

Objectives of the needed research

After reading the identification and description of the needed research, you should:

* Be aware that research is needed to develop a classification of properly worded outcome statements for each category of public service delivery functions.

* Be aware that research is needed to develop a classification of standard organizational activities that are unique to each public service delivery function.

* Be aware that research is needed to establish estimates of the linkages between specific activities and specific outcomes within each public service delivery function.

* Be aware that the estimated linkage between specific organizational activities and outcome statements may have value as hypotheses to be tested by empirical research.

* Be aware that the ultimate objective of the empirical research is to document each specific technical relationship between each activity and each outcome statement.

* Be aware that it may be necessary to use the Delphi technique to estimate distinguishing levels of productivity for each activity if they are not available from empirical research.

* Be aware that research is needed to identify the most explanatory numeraire for each public service.

* Be aware that research is needed to identify a common unit of value that faciliates evaluation of the outcome statements in terms of the exchange ratio with other outcome statements.

This study advances the status of optimizing-resource allocation models of public service delivery functions from a fragmented mixture of contributing concepts to an illustrative-operationalized example. The resulting model is not ready for direct application to the multiple features of specific public service functions. One of the values of this study is the identification of specific research to support the utilization of this type of model in public service functions.

Developing an information base

Most of the effort involved in this study was expended in developing the information base to support and structure the model. Optimizing-resource allocation models of public service delivery functions will never be widely used if each operator has to develop an appropriate information base. This function can be carried out by a central agency and the results made available to potential users in the form of a library of two dimensional outcome statements for each specific public service function.

The development of a library of two dimensional outcome statements can be accomplished in three steps. The first step is to identify and classify all relevant result-oriented outcome statements that are needed to establish the scope of the feasible impacts of the specific public service. This can be an accumulative and maturing process that strives to express the multiple facets of organizational results. The second step is to identify and technically express all standard activities for each public service. The technical expression must identify each unique resource and the specific proportion used in each activity. The third step is to derive the most accurate expression of the relationship between each activity and each outcome statement.

Using the library of two dimensional outcome statements, a potential user can structure a model to depict the features of a specific public service that is the subject of analysis. By entering the unique amount of each resource and other constraints involved in the delivery of the public service the model can simulate a number of alternative scenarios.

Strengthening the intuitive logic of the model

The value of the library of two dimensional outcome statements will depend on the accuracy of the technical relationships and the validity of the structure of the model in terms of its ability to portray the actual situation. The level of utilization of the model as an alternative strategy for resource allocation decisions will depend on the simplicity of the intuitive logic of the model. The critical aspect of the intuitive logic is the unit or units of value that are used to express the results of the calculations.

This is the same kind of problem that is being encountered in the conversion from the Fahrenheit to the Celsius scale in temperature measurement and reporting and from the United States system of weights and measures to the metric system of measurement. If research can not identify a numeraire that is easily interpreted to express the value of the technical relationships between the activities and the outcome statements, the valid results will receive little serious consideration by decisionmakers. The same principle applies to the unit of value or reference that is the judgment criteria of outcome statements based on their exchange ratio with other alternative outcomes.

Facilitating mass utilization of the model

A complete library of two dimensional outcome statements for each public service function and an intuitively logical model will not automatically be accepted and utilized by public officials. Considerable applied research will have to demonstrate, discuss and explain the accuracy and validity of the resulting calculations. Simple, practical examples that can be readily understood and checked will have to be developed and made available to public officials. If the simple examples and many of the real problems can be handled by hand-held or desk-top computers (calculators) this will also enhance the utilization of this type of model as an alternative strategy for resource allocation decisions in public service functions.

Summary

Research is needed to develop an information base to support the model. The principal aspects of the information base are; (1) causal linkages between activities and objectives, (2) neutral numeraires and (3) resource-activity productivity factors. Research is also needed to improve the effectiveness of technology transfer so this type of decision-making assistance can be made available to public policy makers.

CHAPTER VI SUMMARY

Objectives of the summary

After reading the summary of the study, you should:

* Be able to determine whether you want to read the entire study.

Summary

The cornerstone of the problem situation is confusion and divided sentiment over the concept of rationality as it relates to public policy decision making. The traditional orientations of political science and public administration, plus individual levels of acceptance of computer technology, appear to be contributing factors to the reluctance of scholars of these disciplines to accept rationality. Economists do not appear to exhibit the same reluctance.

A three-dimensional description of rationality attempts to eliminate the confusion. Mannheim's dichotomy that identifies functional and substantial rationality is supplemented by Diesing's five categories of reason in society: technical, economic, social, legal and political rationality. The third dimension is provided by Simon's six adverbs clarifying the meaning of rationality; objectively, subjectively, consciously, deliberately, organizationally and personally. Technical and economic rationality in a functional organizational setting are specified as the focal concepts in the study.

The distinction between calculation and evaluation is fundamental to the logic of this study. Calculation, where all the information and values are given, is not considered decision making. Evaluation, where judgment is necessary to express preferences (utility) in terms of the exchange value of multiple components, is decision making. A person or a machine can calculate, only a person can evaluate - - make decisions. Diesing's technical rationality, Simon's program decision making and Thompson's situational determination involves calculations that can be performed by a computer. Diesing's economic rationality, Tullock's science of preferences and Starr and Zeleny's multiple criteria decisions involve individual judgment. Public policy makers interpret the calculations of the computer describing the resource allocations associated with the optimal attainment of objectives and strive to maximize total satisfaction.

Management science, public management, operations research and systems analysis are example of supporting subject matter for the development of an optimizing-resource allocation model of a public service delivery function. The Delphi technique and multiple objective linear programming are identified as contributing subjects in the formulation of the model.

Formulation of a specific optimizing model of higher education is identified as the purpose of the study. The implicit hypothesis is that a model will; (1) filter information so the processing demand on the human capacity will not be exceeded and (2) contribute to improved resource allocation in public policy decisions. Formulation of the model can be classified as an exercise in social technology because tentative information, based on expert judgment, is used rather than scientifically proven data. The five objectives are tentative expressions of desired outcomes. The technical relationships between the activities and the objectives are estimates. The internal coefficients are derived from unverified data and the policymakers' interaction is arbitrary.

If a model that can perform the required calculations and present interpretable results can be conceptualized and formulated, the problem of acquiring accurate information can be the subject of future research. The entire logic of the model includes a number of assumptions that are distributed throughout the study. Two of the fundamental assumptions are: (1) the higher education process, which causes (or fails to cause) changes in characteristics of students and pushes (or fails to push) back the frontiers of knowledge, can be optimized; (2) the failure to recognize the difference between schooling and learning, leads to the conclusion that when the demand for learning increases, schooling must expand. Model operation assumes that there is a functional relationship between all phenomena in each public service delivery function and that adequate information is a necessary condition for better institutional decisions. Finally, the study assumes that ends can be separated from means in the mind of the decision maker and that the decision maker's behavior is directed toward pleasure and away from pain.

The supporting literature is a fragmented mixture of concepts that provide the credibility for the study. References to perceived causes for concern, specific educational objectives, multiple criteria decision making and existing resource allocation models in higher education are identified as the foundation for the information content of the study. The Delphi technique, linear programming and multiple objective linear programming are identified as the foundation for the information processing required in the model.

A description of higher education's aristocratic, meritocratic and egalitarian periods concludes that colleges and universities operate in a resource-constrained world and consume resources and provide socially useful outputs. Because they are evaluated in terms of benefits foregone in other alternative uses, higher education must: (1) identify appropriate objectives to pursue, (2) identify sensible levels of attainment of the objectives and (3) calculate the most efficient and effective alternative activity and resource allocation to achieve these levels.

Mission, goal and objective are synonymous for outcome statements in organizational decision making. The concept of these statements has the implicit implication that positive expectation will draw supporting activities. The President's Commission on National Goals and the two restatements, examples of goal statements developed by ten universities, including Iowa State University, and three peripheral applications, are offered as evidence that outcome statements are in present use. Three resource allocation models in higher education are identified as nonoptimizing and unable to respond to what-if questions.

The Delphi technique is described as capable of filling voids in information with the most defensible conclusion derived from expert judgment. This communications process avoids the detrimental effects of the dominant individual, irrevelant and redundant material and the group pressure for a compromise. Controlled research indicates that this process is equally effective with factual information or subjective opinions and is a way to investigate many problems with high social and political content.

Multiple criteria decision making is described as more than a methodology of measurement, a mechanical search or calculation. It involves evaluation in terms of the exchange utility of alternative components and impacts where the final decision unfolds through a process of learning, understanding, information processing, assessment and definition of the problem and its circumstances. Multiple objective linear programming is a computer assisted mathematical technique that includes formulating the problem in MOLP terms, finding the optimal allocation of scarce resources to achieve a desired candidate solution involving multiple criteria and explaining the effect of changes of the value or constraints and the composition of the candidate solution.

The formulation of this optimizing-resource allocation model begins with the identification of five specific objective statements. Two of the objectives are student-centered, two are faculty-centered and one is institution-centered. A group of experts participating in a Delphi exercise derived the technical relationships between these objectives and ten faculty activities. Each expert suggested attributes of faculty, administrators, campus life and students of colleges vigorously pursuing the five objectives. The suggestions are summarized into lists of five attributes representing each objective. Each panel member reviewed and edited the lists and estimated the degree that each attribute is likely to lead to the achievement of each of its representative objectives. They also reported how confident they were of their estimates. These original judgments are summarized and reported back to the panel in terms of the median level judgment with a quartile variance measurement on each side of the median. Knowing the level and the distribution of the group judgment each expert reconsidered his/her initial judgment and then recorded his/her final judgment on these relationships. In this manner the relationships between every attribute and every objective is estimated. The same procedure is repeated to estimate how the performance of each of the faculty activities is likely to contribute to the presence of each attribute.

The final expressions of the experts are adjusted to reflect the significance of extreme estimates. The summaries of the group estimates of the identified linkages are the data for a matrix multiplication that calculates an approximation of the causal linkages between each activity and each objective. Each linkage estimate is titled, defined and standardized. The results represent an education quasi-production function; i.e. for any given levels of specific activities there will be a unique level of achievement of the objective. These are approximately half the linkages needed to formulate the model.

The technical relationships between each resource-constraint and each activity are derived concurrently with the above linkages. This procedure involved identifying, disaggregating, reconstructing and processing data describing expended funds, faculty workloads, course offerings, student enrollments and assigned faculty effort measurements. The data are organized as three academic quarters and is treated as one education effort. This information is used to derive coefficients that express the existing linkages between each resource-constraint and each activity. Each result is titled and defined. These linkages are processed in a modified linear programming program where each class of activity is simulated independently until the results match the reported levels.

Eight independent simulations are formulated into a linear programming structure representing the composite educational function. Because each activity is bounded, the resulting rank ordering of the five objectives of this simulation can be interpreted as an approximation of the institution's present motivation, i.e. revealed preference. Removal of the activity bounds and reaggregation of the resource-constraint values readies the data for optimizing calculations. Attempts to optimize a single objective and identify unique levels of resource allocations reveal that each activity must be partitioned to reflect the rank of the faculty-resource utilized. The logic of the calculation is violated when the formulation of the model allows identical efforts with equal contribution to the objective function to have different dollar cost. Arbitrary assignment of productivity factors to each faculty rank results in the identification of unique levels of resource allocation, shadow prices and reduced cost information in ten single objective simulations representing two student enrollment scenarios.

The same technical relationships and resource-constraint values are reformulated into a multiple objective optimizing calculation. The first calculation is performed with the five objectives rank-ordered with Secure Resources the highest priority and Trained Student the lowest. The second calculation inverted the rank-order. These two calculations identified unique levels of resource allocation to support each professed preference.

The results are not offered as valuable policy insights. The results are evidence that an optimizing calculation of educational data is technically feasible. Before the model can be offered as a viable alternative in public policy making, public policymakers will need to aquire a minimum competency in a number of rational decision-making skills.

The absolute need for two-dimensional outcome statements and identifiable differences in the productivity levels of alternative resources in optimizing-resource allocation models of public service is offered as the major finding. Each objective must be expressed in terms that allow it to be evaluated in terms of its exchange value with alternative objectives. Public policymakers will encounter less difficulty in interpreting the results of the calculations if the different levels of specific objective attainment can be expressed in terms of the probabilities of positive impact. The expression of the objective function as a linear function of the alternative activities may not be as visible to policy makers but it is equally significant. The common unit of value (numeraire) that each objective-linear function is expressed in will also be a big factor in the ease of the policymaker interpreting the calculations. The expression of all five educational objective-linear functions in units of structured graduate instruction is not intuitively clear and may bias the interpretations. If a more valuable resource is allocated to an activity, then more objective achievement must result, may be discovering the obvious. This discovery suggests mixing resources in activities to achieve objectives such that the marginal achievement is always equal to or greater than the cost of the least valuable resource available. If this technical rationality were reflected in educational assignments it is doubtful that all ranks of a college faculty would be equally involved in all the educational activities. Research will need to identify measurement criteria before more productive linkages can be proposed.

Using the tentative linkages of the model as hypothesis of causal relationships to be tested may be the most immediate, practical value of this research. Improving the validity and accuracy of these linkages is necessary before the results of the calculations can serve as the basis for policy decisions. Research identifying, classifying and properly expressing resources, activities and objectives for specific public service functions and estimating the causal linkages can result in a software library package. The software library will allow policy makers interested in that public service to conveniently formulate an optimizing-resource allocation model by selecting the objectives, activities and resource-constraints that resemble the specific service being analyzed. Situations representing up to six objectives appear very feasible at this time.

Community protection and public health situations appear to be viable candidates for optimizing-resource allocation calculations. If simple models of these public services can be described, explained and illustrated on hand-held calculators, eventually optimizing calculations will emerge as an alternative strategy for public policy decision making in these areas.

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APPENDIX 01

INITIAL SURVEY COMMUNICATION

Interoffice Communication | IOWA STATE UNIVERSITY of Science and Technology

DATE February 24, 1978

TO

FROM Jack Whitmer
506 Ross Hall, 4-5263

Subject: Utilizing "The Delphi Technique" to gather expert judgments for use in a public service optimizing study.

Will you please help me again? Using the information I gathered on "educational objectives" about a year ago as a base, I now want to use "The Delphi Technique" to gather and summarize expert judgment that can be used in my study where factual information is not available. "The Delphi Technique" is designed to elicit opinions from a group with the aim of generating a group response. Delphi is a substitute for direct confrontation and debate. It is a carefully planned, anonymous, orderly program of sequential individual interrogations conducted by questionnaire. The series of questionnaires is interspersed with feedback derived from the respondents. The Delphi Technique was originally developed by Olaf Helmer at the Rand Corporation.

I am applying "The Delphi Technique" to higher education because of the convenience of communication here on campus and the willingness of faculty members to try something new. I hope to transfer the process to local government once it is refined.

In this experiment I plan to use five separate questionnaires that will be distributed <u>one at a time</u> during March and April. The time involved to complete each questionnaire is estimated to be about a half hour. I would appreciate it very much if you would agree to be one of the approximately 30 ISU faculty members that I need to help me on this study. If you are willing, please indicate this on the enclosed 3x5 card and return it to me in campus mail by March 3.

Thanks.

CAMPUS MAIL

Jack Whitmer
506 Ross Hall

Date __________

_____ Yes, I will help you.

_____ No, I cannot help you.

Remarks: ________________________________

____

____

____

APPENDIX 02

FIRST DELPHI QUESTIONNAIRE

Interoffice Communication | IOWA STATE UNIVERSITY
of Science and Technology

DATE March 3, 1978

TO

FROM Jack Whitmer
506 Ross Hall, 4-5263

Subject: First Delphi Questionnaire

Thank you for your willingness to help me. I hope that you find the experience interesting.

Please respond intuitively; do not agonize over individual questions. However, I am asking for your judgment, so be as deliberate and specific as possible.

I would like to try to work in about a nine day cycle, so please complete and return the questionnaires as soon as possible -- hopefully before the end of the fifth day after you received it.

Thanks.

Jack

March 3, 1978

Instructions and Reference Information

This is a part of a study that attempts to establish a framework for a pragmatic analysis of public service. In this case, higher education. To do this, it will be necessary to view higher education as a process which causes (or fails to cause) changes in characteristics (attributes) of students and pushes (or fails to push) back the frontiers of knowledge. The five objectives, used as beginning points in this study, if pursued and partially or fully achieved are assumed to be directly or indirectly compatible with the above purposes. There are other objectives that could be considered, but these are chosen as a general cross section representing categories of objectives.

Definition of Objective

Please view an "objective" as a desired outcome of the process of higher education that is specific in nature and measurable by degree of achievement, i.e. an objective is a specific description of a "desired end result" to be achieved.

Definition of Attribute

Please view an "attribute" as an inherent characteristic associated with or belonging to students, faculty, administrators or campus life that are involved in the process of higher education (i.e. if we could observe or feel confident that these attributes were present, we would feel that the process of higher education is achieving a specific objective).

The objective of this aspect of the study is to identify the potential attributes that have a "tendency relationship" with the relevant objective (i.e. those attributes that have a likelihood of occurring with a positive level of attainment of the relevant objective more often than warranted by chance).

What follows is an example from local government which I hope will help you get the idea of how I would like you to express your judgments regarding the attributes of objectives of higher education. Be as specific as you can

Example: Community Protection

Objective: Minimize the annual risk of accidental death occurring in the community.

Attributes:
* widespread knowledge of and adherance to safety regulations
* emphasis on safety is evident in physical facilities
* widespread knowledge and willingness to utilize life-saving techniques by adult population
* emphasis on safety is evident in educational curriculum
* general awareness and pride in an outstanding safety record.
* safety appears to receive top priority consideration in community discussions
* vigorous enforcement of traffic regulations

QUESTIONNAIRE NUMBER

1 2 3 4 5

Name ______________________________________ Date__________

Student, Faculty, Campus Attribute Identification

Assuming that the following educational "objective" is considered very important and is a significant influence on the official policy that is instrumental in guiding the courses of action at an institution of higher education, what attributes would you judge to exist among the students, the faculty, the administrators or campus life and facilities?

Objective #1.: To secure resources from the Iowa Legislature, through the Board of Regents, sufficient to operate this university at a near optimal level.

Attributes:

1. ____

____

____

2. ____

____

____

3. ____

____

____

4. ____

____

____

5. ____

____

____

6. ____

____

____

Time necessary (______ minutes) to complete this aspect of the questionnaire.

QUESTIONNAIRE NUMBER

1 2 3 4 5

Name ______________________________ Date __________

Student, Faculty, Campus Attribute Identification

Assuming that the following educational "objective" is considered very important and is a significant influence on the official policy that is instrumental in guiding the courses of action at an institution of higher education, what attributes would you judge to exist among the students, the faculty, the administrators or campus life and facilities?

Objective #2: To protect the faculty's right to academic freedom.

Attributes:

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

5. ______________________________

6. ______________________________

Time necessary (______ minutes) to complete this aspect of the questionnaire.

QUESTIONNAIRE NUMBER

1 2 3 4 5

Name ______________________________________ Date ___________

Student, Faculty, Campus Attribute Identification

Assuming that the following educational "objective" is considered very important and is a significant influence on the official policy that is instrumental in guiding the courses of action at an institution of higher education, what attributes would you judge to exist among the students, the faculty, the administrators or campus life and facilities?

Objective #3: To develop a student who can think, who can behave intelligently, who can respond creatively and effectively to new situations.

Attributes:

1. ____

____

2. ____

____

3. ____

____

4. ____

____

5. ____

____

6. ____

____

____

Time necessary (_____ minutes) to complete this aspect of the questionnaire.

QUESTIONNAIRE NUMBER

1 2 3 4 5

Name ______________________________ Date __________

Student, Faculty, Campus Attribute Identification

Assuming that the following educational "objective" is considered very important and is a significant influence on the official policy that is instrumental in guiding the courses of action at an institution of higher education, what attributes would you judge to exist among the students, the faculty, the administrators or campus life and facilities?

Objective #4: To translate the talents and capacities of its faculty into significant educational results.

Attributes:

1. ______________________________
____

2. ______________________________
____

3. ______________________________
____

4. ______________________________
____

5. ______________________________
____

6. ______________________________
____
____

Time necessary (_____ minutes) to complete this aspect of the questionnaire.

QUESTIONNAIRE NUMBER

1 2 3 4 5

Name ______________________________ Date __________

Student, Faculty, Campus Attribute Identification

Assuming that the following educational "objective" is considered very important and is a significant influence on the official policy that is instrumental in guiding the courses of action at an institution of higher education, what attributes would you judge to exist among the students, the faculty, the administrators or campus life and facilities?

Objective #5: To train students in methods of scholarship, and/or scientific research, and/or creative endeavor.

Attributes:

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

5. ______________________________

6. ______________________________

Time necessary (_____ minutes) to complete this aspect of the questionnaire.

APPENDIX 03

SECOND DELPHI QUESTIONNAIRE

Interoffice Communication | IOWA STATE UNIVERSITY of Science and Technology

DATE March 27, 1978

TO

FROM
Jack Whitmer
506 Ross Hall
4-5263

Subject: Second Questionnaire of DELPHI Exercise

I received almost all the responses to Questionnaire Number 1 in time to incorporate them into the enclosed "tentative composite attributes." Thank you for the prompt and meaningful responses.

The five (5) "tentative composite attributes" associated with each of the five (5) objectives were composed from your first responses. Your ideas may be combined with others or stated in a little different language, but I made a real effort not to contaminate these "composites" with my ideas. Overall, it was possible to compress most of your ideas into five tentative composite statements. As you might guess, a few ideas fell through the cracks because of my need to limit the size of this exercise. Therefore, the five (5) tentative composite attributes that you are asked to review are those that reflect the most consensus.

The comments on the top of Questionnaire Number 2 note: this exercise builds on the results of the first responses. First it summarizes the input of the previous exercise, offers you an opportunity to critique the summary and then asks you for additional information.

Therefore, will you please:

(1) Edit the "tentative composite attribute" statements and supporting descriptors by crossing out words and phrases you do not think are appropriate to make it the most explicit "composite attribute" statement from your perspective. You may also add additional information that you think will increase its usefulness.

(2) Circle the most important/critical words or phrases in each statement to indicate your emphasis.

(3) Based on the content of each "tentative composite attribute" after you have edited it, judge, using the attribute achievement scale on the enclosed sheet, how the presence of each attribute is likely to lead to the achievement of the objective on that sheet. Record your judgment in the appropriate space on the left-hand margin. (Note: Because of the way these "composites" were developed, you will only use the positive (0 to 5) ratings at this time.) It will be helpful if you avoid giving all the attributes on the same sheet the same rating.

(4) Finally, state your personal confidence, using the "confidence in your judgment scale" on the enclosed sheet, in the attribute achievement judgment you expressed on each tentative composite attribute.

The tentative composite attributes on objective #3 and #5 are quite similar. Please do both separately and completely. I may combine them in the next round, but for now there was enough difference that I would like you to consider them as two separate and distinct objectives.

I would be grateful if you would return your responses by April 5 so I can incorporate that information into Questionnaire Number 3.

QUESTIONNAIRE NUMBER

1 2 3 4 5

Name_______________________________ Date__________

Attribute Description and Relationship to Specific Objectives

This questionnaire is based on the responses to questionnaire #1. First review the content of each "tentative composite attribute." Add or delete applicable terms as you believe necessary. Then "judge" how the presence or absence of each attribute may lead to the achievement of the objective (see scale on attached page). Finally, rate your confidence in your judgment. (see scale on attached page)

Objective #1: To secure resources from the Iowa Legislature, through the Board of Regents, sufficient to operate this university at a near optimal level.

Your Attribute Achievement Judgment	An institution of Higher Education that is pursuing the above objective will possess:	Your Confidence in this Judgment
________	1. An assertive effective external communications/influence effort: i.e. good lobbyist, knowledgeable alumni, outreaching public relations program, all projecting a good image, understandable budget reflecting campus agreement & goals. OTHER:__________	1.________
________	2. Professional & personal behavior on the part of faculty, administrators & students that reflects an awareness that the university instructual, research administration & student life are of significant interest to all Iowans who constantly monitor & evaluate them based on what information they receive. OTHER:__________	2.________
________	3. A widely held and generally accepted reputation that the university provides very good student instruction in a condusive/positive learning environment. OTHER:_____	3.________
________	4. A widely held and generally accepted reputation that the university is continuously producing new and valuable knowledge. OTHER:__________	4.________
________	5. A widely held and generally accepted reputation that the university is continuously providing valuable services to all segments of the state. OTHER:__________	5.________

Time necessary (____minutes) to complete this aspect of the questionnaire.

QUESTIONNAIRE NUMBER

1 ② 3 4 5

Name____ Date__________

Attribute Description and Relationship to Specific Objectives

This questionnaire is based on the responses to questionnaire #1. First review the content of each "tentative composite attribute." Add or delete applicable terms as you believe necessary. Then "judge" how the presence or absence of each attribute may lead to the achievement of the objective (see scale on attached page). Finally, rate your confidence in your judgment. (see scale on attached page)

Objective: To protect the faculty's right to academic freedom.
#2

Your Attribute Achievement Judgment	An institution of Higher Education that is pursuing the above objective will possess:	Your Confidence in this Judgment
________	1. A visible internal communication/assertive effort that emphasizes the significance and rationale of academic freedom (including some consensus on the definition of academic freedom) to faculty, administrators, students and others). ________	1.________
________	2. A visible external communication effort to describe & explain the role of academic freedom in a high quality & productive university. ________	2.________
________	3. Professional behavior on the part of the faculty that reflects an awareness of the value of academic freedom; including the presence of ethical standards.________	3.________
________	4. A visible, vigilant & consistent commitment on the part of the administrators to defend the principles & presence of academic freedom against all challenges at all costs - including a specific policy statement of the university's position; including strong tenure protection, a legal staff against these threats.________	4.________
________	5. An atmosphere that encourages free and open discussion, open-minded democratic faculty and administrators, trust and confidence in peers, acceptance of positive or negative research results. ________	5.________

Time necessary (____minutes) to complete this aspect of the questionnaire.

QUESTIONNAIRE NUMBER

1 (2) 3 4 5

Name________________________ Date__________

Attribute Description and Relationship to Specific Objectives

This questionnaire is based on the responses to questionnaire #1. First review the content of each "tentative composite attribute." Add or delete applicable terms as you believe necessary. Then "judge" how the presence or absence of each attribute may lead to the achievement of the objective (see scale on attached page). Finally, rate your confidence in your judgment. (see scale on attached page)

Objective: To develop a student who can think, who can behave intellignetly, who can respond
#3 creatively and effectively to new situations.

Your Attribute Achievement Judgment	An institution of Higher Education that is pursuing the above objective will possess:	Your Confidence in this Judgment
______	1. A selection, retention, promotion & training effort that results in a diverse, rigorous, demanding faculty that are up-to-date in their field; that enjoy interacting with students to facilitate their learning; that are effective managers of their own time; fewer teaching assistants. ______	1.______
______	2. An admission & grading program that attracts & retains highly qualified, motivated students who have positive personal attitudes about themselves, who have the potential to change & grow, think for themselves & have a tolerance for ambiguity. ______	2.______
______	3. A learning environment that has smaller classes; rewards effective instruction, independent thinking & creativity, encourages adaptation & research, respect for different opinions, that encourages the staff to select their own educational goals, honors programs. ______	3.______
______	4. Course structure, content & presentation that is basic, relevant, practical, useful & student centered (including a comprehensive evaluation procedure that indicates direction & magnitude of personal educational progress). Framework for challenging analysis of broad offerings; emphasize learning skills; & experiencing individual internships. ______	4.______
______	5. Post-graduation evaluation effort of students' quality of life, intellectual growth satisfaction of employers. ______	5.______

Time necessary (____minutes) to complete this aspect of the questionnaire.

QUESTIONNAIRE NUMBER

1 2 3 4 5

Name______________________________ Date________

Attribute Description and Relationship to Specific Objectives

This questionnaire is based on the responses to questionnaire #1. First review the content of each "tentative composite attribute." Add or delete applicable terms as you believe necessary. Then "judge" how the presence or absence of each attribute may lead to the achievement of the objective (see scale on attached page). Finally, rate your confidence in your judgment. (see scale on attached page)

Objective: To translate the talents and capacities of its faculty into significant
#4 educational results.

Your Attribute Achievement Judgment	An institution of Higher Education that is pursuing the above objective will possess:	Your Confidence in this Judgment
________	1. An education environment that includes high expectation of the faculty, abundant opportunities and emphasis on continuing education for faculty to improve professional skills & knowledge, recognizes & rewards outstanding results, less committee work, more release time & resources for producers, not allow tenure to shield inactivity. ________	1.________
________	2. A faculty that is highly motivated to learning, well prepared, innovative, aware of the emphasis on the objectives of education & need to achieve results, committed to excellence, feels positively about peers, has pride in & are dedicated to the concept & value of continuing education & sought by other universities. ________	2.________
________	3. An evaluation effort of educational results that considers the impact of these results beyond the boundaries of the campus, formal & meaningful evaluation of student after graduation -- are they "better" happier people, are they employable, good employees, contributing citizens, is the new knowledge - relevant - practical - useful. ________	3.________
________	4. Well trained administrators who have a high appreciation for high quality education results. Creative management techniques including assertive support for academic process, effective public relations program to draw broad attention to the value & significance of educational results. ________	4.________
________	5. Policies and procedures for adequate distribution of resources & rewards that do not significantly detract from the efforts to achieve educational results. ________	5.________

Time necessary (____minutes) to complete this aspect of the questionnaire.

QUESTIONNAIRE NUMBER

1 2 3 4 5

Name________________________________ Date__________

Attribute Description and Relationship to Specific Objectives

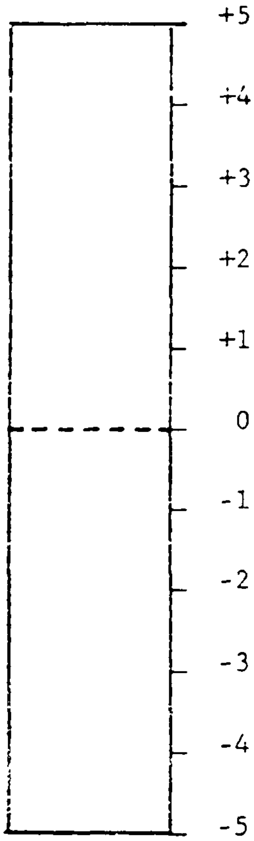
This questionnaire is based on the responses to questionnaire #1. First review the content of each "tentative composite attribute." Add or delete applicable terms as you believe necessary. Then "judge" how the presence or absence of each attribute may lead to the achievement of the objective (see scale on attached page). Finally, rate your confidence in your judgment. (see scale on attached page)

Objective: #5 To train students in methods of scholarship, and/or scientific research, and/or creative endeavor.

Your Attribute Achievement Judgment	An institution of Higher Education that is pursuing the above objective will possess:	Your Confidence in this Judgment
________	1. An admissions, orientation, reward (grading) process that attracts and retains students who are creative, highly motivated, enjoyable, energetic, that have adequate educational/academic capability, positive personal attitudes about themselves and who have tolerance for ambiguity. ________	1.________
________	2. Learning environment that is flexible, has a mixed curriculum, emphasizes intellectual honesty, recognizes the dynamic & tentative nature of new knowledge, has an open expression of new ideas, requires a minimum amount of time to be devoted to activities that do not directly relate to knowledge and learning. ________	2.________
________	3. A selection, retention, promotion & training effort that results in competent, creative, diverse, rigorous, demanding leaders in their field, faculty that are willing to help & enthusiastically pursue discoveries & new knowledge up-to-date in their field, that enjoy interacting with the student & that realize that educating and training are two different academic pursuits, that are effective managers of their own time & efforts.	3.________
________	4. Course structure, content & presentation that is creative, that began early in the undergraduate program to institute creative, individual discover, asks "why" as well as "how" that demands individual honesty, that discusses philosophic framework within which new knowledge is discovered & stresses the problem solving technique (scientific method), communication mediums & other methods & processes. ________	4.________
________	5. The availability & utilization of resources that are adequate for faculty & students that are readily available without excess effort to acquire & that distributes extra resources to high achievers. ________	5.________

Time necessary (_____minutes) to complete this aspect of the questionnaire.

Attribute Achievement Scale



A rating of +5 means that you think the presence of the attribute virtually guarantees the achievement of the objective (the probability of attainment of the objective is practically 100%).

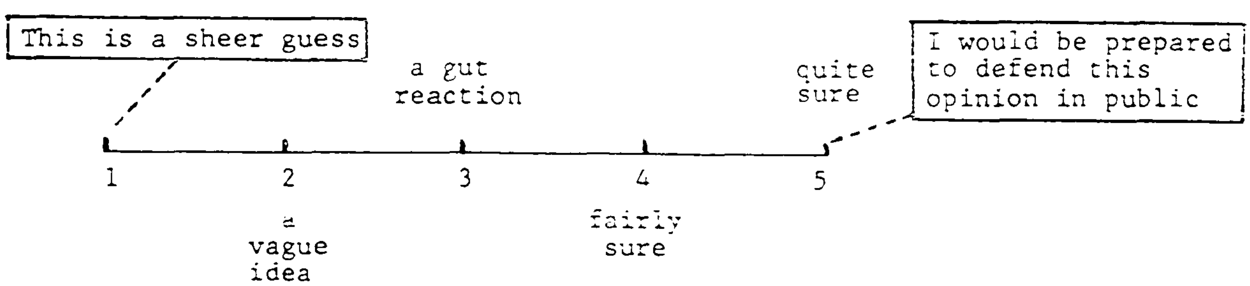
A rating of +3 means that you think the presence of the attribute is likely to lead to the achievement of the objective. (A high probability of the attainment of the objective is associated with the presence of this attribute.)

A rating of 0 means that you think the presence of the attribute is indifferent/of no significance relative to the achievement of the objective (or that you don't know if the presence of the attribute will help or hurt the attainment of the objective).

A rating of -3 means that you think the presence of the attribute is likely to distract from the achievement of the objective. (A high probability that the objective will not be attained is associated with the presence of this attribute.)

A rating of -5 means that you think the presence of the attribute is practically certain to suppress the achievement of the objective (the probability of attainment of the objective is practically zero when the attribute is present).

Confidence of Judgment Scale*



* the degree of confidence you have in your judgment about this relationship

APPENDIX 04

THIRD DELPHI QUESTIONNAIRE

Interoffice Communication | IOWA STATE UNIVERSITY of Science and Technology

DATE May 5, 1978

TO

FROM
Jack Whitmer
506 Ross

Subject: Delphi Questionnaire # 3

Thanks for your persistence. I can see the initial results of your efforts and they look great. Your "editing" on Questionnaire 2 was very helpful. The incorporation of that feedback may have changed the content or emphasis of the "composite attribute statements" some, so be sure to read them carefully before you record your judgment on this questionnaire. Attribute statements are now final and will not change.

The preliminary ratings of the likelihood of attributes leading to the achievement of their initial objective were generally high, i.e. the median of eight attribute achievement ratings were "3"; sixteen were "4" and one was "5." This is about as I expected since the attributes were composed to be in harmony with their initial objective. This relationship may change when you relate the attributes to the other four objectives.

The results of the responses to Questionnaire 2 are incorporated into Questionnaire 3. The results of your judgments are reported in the form x-y-z, where x = the first quartile, y = the weighted median and z = the third quartile. (see the example below) These results were arrived at by recording your Attribute Achievement Rating (AAR) as many times as your Confidence Scale (CS) indicated, i.e. the more confident you were of your judgments, the more weight they were given. By definition, the "Median" of all the (AAR) is the Value with one half of the responses on each side. One half of all responses fall between the first and third quartile values.

The following explanation may help you assign a functional interpretation to these three values.

A. If the reported values are $\boxed{3 - 4 - 4}$; this indicates that one half of the responses were "3" and "4" with most of them "4"

B. If the reported values are $\boxed{2 - (3) - 4}$; this indicates that one half of the responses were "2," "3" and "4" with most of them "3."

Your task on Questionnaire 3 is twofold. First, laying the explanations next to the recording form, read the objective statement and its initial attributes carefully.* Consider the specific wording and the statistics describing the responses of the other participants to this initial relationship and record your Attribute Achievement Ranking (AAR) in the left hand space

x - y - z
(AAR)/ (CS)

and your confidence scale in the right hand space. DO THIS FOR ATTRIBUTES 1.1, 1.2, 1.3, 1.4 and 1.5 relative to Objective #1 and then apply your judgment to the relationship of these same attributes to Objective #2, #3, #4 and #5. See accompanying sheet for scales and descriptors. (Note: Please feel free to use the entrie scale from -5 to +5 on this Questionnaire.)

Then proceed to the next set of five attributes and repeat the sequence doing the refined judgment on the initial relationships first and then proceeding to the other four objectives. Your judgment on the relationship of the attributes to the initial objective may be useful as a reference point for the other judgments.

Keep in mind you are still being asked only for your best judgment based on what you know and accepting the statements at face value. However, if the (AAR) you record on this questionnaire for the initial relationships is above or below the reported quartile boundries of those 25 initial relationships, this may indicate that you know something about that specific relationship that all the rest do not and therefore maybe your judgment should prevail. If this is so, please footnote these specific rankings with an explanation on the back of the sheet. This applies only to the initial relationships.

Would you please try to get this completed questionnaire back to me by May 16. Thanks.

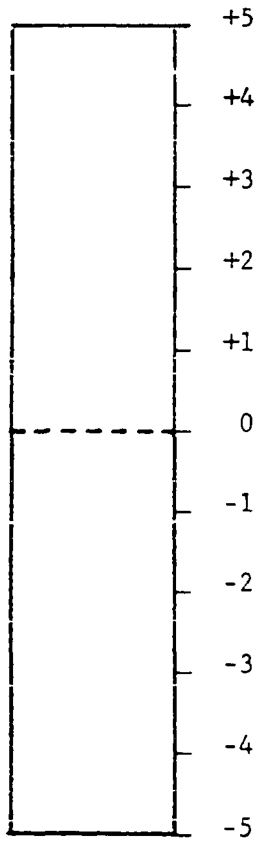
* Attribute 1.1, 1.2, 1.3, 1.4 and 1.5 were initially matched with objective #1 and the judgment of the relationship of these attributes to their INITIAL objective is a refinement of the judgment you gave me on Questionnaire 2, the judgment relative to the other four objectives are original.

QUESTIONNAIRE NUMBER 1 2 (3) 4 5 Date ________

Name: ________

○ weighted median Attribute Number	OBJ#1 Secure Resources	OBJ#2 Academic Freedom	OBJ#3 Thinking Student	OBJ#4 Faculty Development	OBJ#5 Training Students
1.1 Outreach Effort	3 - 4 - 4				
1.2 Professional Behavior	3 - 3 - 4				
1.3 Excellent Instruction	3 - 4 - 4				
1.4 New & Valuable Knowledge	3 - 3 - 4				
1.5 Valuable Service	3 - 4 - 4				
2.1 Internal Communications		2 - 3 - 4			
2.2 Public Awareness Program		2 - 3 - 4			
2.3 Responsible Faculty Behavior		4 - 4 - 5			
2.4 Policy Statement		3 - 4 - 4			
2.5 Trust & Democracy		3 - 4 - 5			
3.1 Competent Faculty			4 - 4 - 5		
3.2 Qualified & Motivated Students			3 - 4 - 5		
3.3 Rewards for Instruction			3 - 4 - 4		
3.4 Student Centered Courses			3 - 3 - 4		
3.5 Post-graduate Evaluation			2 - 3 - 4		
4.1 Expectations				4 - 5 - 5	
4.2 Commitment to Excellence				3 - 4 - 5	
4.3 University Impact				2 - 3 - 3	
4.4 Competent Administrators				3 - 3 - 4	
4.5 Rewards for Productivity				3 - 4 - 4	
5.1 Capable Students					3 - 3 - 4
5.2 Flexible Curriculum					3 - 4 - 4
5.3 Effective Interacting					4 - 4 - 5
5.4 Individual Discovery					3 - 4 - 5
5.5 Resources for High Producers					3 - 4 - 4

Attribute Achievement Scale



A rating of +5 means that you think the presence of the attribute virtually guarantees the achievement of the objective (the probability of attainment of the objective is practically 100%).

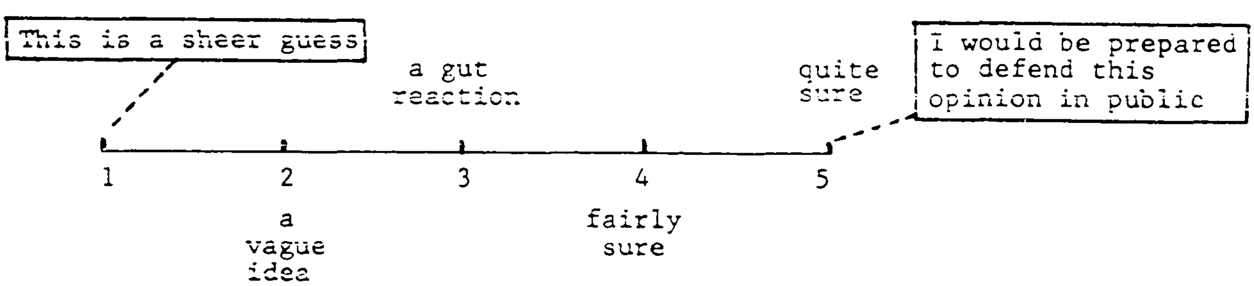
A rating of +3 means that you think the presence of the attribute is likely to lead to the achievement of the objective. (A high probability of the attainment of the objective is associated with the presence of this attribute.)

A rating of 0 means that you think the presence of the attribute is indifferent/of no significance relative to the achievement of the objective (or that you don't know if the presence of the attribute will help or hurt the attainment of the objective).

A rating of -3 means that you think the presence of the attribute is likely to distract from the achievement of the objective. (A high probability that the objective will not be attained is associated with the presence of this attribute.)

A rating of -5 means that you think the presence of the attribute is practically certain to suppress the achievement of the objective (the probability of attainment of the objective is practically zero when the attribute is present).

Confidence of Judgment Scale*



* the degree of confidence you have in your judgment about this relationship

Reference sheet for Delphi Questionnaire Number 3

OBJECTIVES

Objective #1. SECURE RESOURCES: To secure resources from the Iowa Legislature, through the Board of Regents, sufficient to operate this university at a near optimal level.

Objective #2. ACADEMIC FREEDOM: To protect the faculty's right to academic freedom.

Objective #3. THINKING STUDENT: To develop a student who can think, who can behave intelligently, who can respond creatively and effectively to new situations.

Objective #4. FACULTY DEVELOPMENT: To translate the talents and capacities of its faculty into significant educational results.

Objective #5. TRAINED STUDENT: To train students in methods of scholarship and/or scientific research and/or creative endeavor.

ATTRIBUTES

Attribute #1.1 OUTREACH EFFORT: A positive effective external outreach effort projecting a constructive image of the university.

Attribute #1.2 PROFESSIONAL BEHAVIOR: Professional behavior by faculty members, administrators and students that reflects an awareness that university activities are of interest to Iowans who judge the university on the information they receive.

Attribute #1.3 EXCELLENT INSTRUCTION: A widely acknowledged and broadly accepted reputation that the university provides excellent instruction to students in a positive learning environment.

Attribute #1.4 NEW & VALUABLE KNOWLEDGE: A widely acknowledged and broadly accepted reputation that the university is continuously producing new and valuable knowledge.

Attribute #1.5 VALUABLE SERVICE: A widely acknowledged and broadly accepted reputation that the university is willing to and is continuously providing valuable service and extension programs to all segments of the state.

Attribute #2.1 INTERNAL COMMUNICATIONS: A positive effective internal communication process that emphasizes the significance and rationale of academic freedom and pursues some consensus among faculty, administrators and students on a definition of academic freedom.

Attribute #2 2 PUBLIC AWARENESS PROGRAM: A specific and continuous public awareness program that describes and explains the value of academic freedom in a high quality, productive university and in society in general.

Attribute #2.3 RESPONSIBLE FACULTY BEHAVIOR: Responsible faculty behavior that reflects an awareness of the value and limits of academic freedom, including the recognition of ethical standards.

Attribute #2.4 POLICY STATEMENT: A specific policy statement of the university's position on academic freedom that top university administrators rigorously explain and defend.

Attribute #2.5 TRUST & DEMOCRACY: An atmosphere of trust and democracy that encourages objectiveity with a free and open discussion of research results by faculty members, administrators and students who have confidence in their peers.

Attribute #3.1 COMPETENT FACULTY: Competent, diverse and demanding faculty members who are up-to-date in their field; who are effective in interacting with students.

Attribute #3.2 QUALIFIED & MOTIVATED STUDENTS: Qualified and motivated students who have positive attitudes about themselves, think for themselves and demonstrate the potential to change and mature.

Attribute #3.3 REWARDS FOR INSTRUCTION: Rewards for effective instruction, independent thinking, creativity and respect for different opinions.

Attribute #3.4 STUDENT CENTERED COURSES: Student centered course structure that includes comprehensive evaluation of each students' educational process.

Attribute #3.5 POST-GRADUATION EVALUATION: Post-graduation evaluation that indicates the degree of the graduates' intellectual growth and their attainment of self-actualization.

Attribute #4.1 EXPECTATIONS: High expectations of the faculty with encouragement of professional improvement and rewards for outstanding results.

Attribute #4.2 COMMITMENT TO EXCELLENCE: Highely motivated, competent, innovative faculty members who are committed to excellence and achievement of the objectives of higher education.

Attribute #4.3 UNIVERSITY IMPACT: Specific knowledge of the impact of the university beyond campus boundaries.

Attribute #4.4 COMPETENT ADMINISTRATORS: Competent Administrators who have an appreciation for quality educational results and use creative management techniques.

Attribute #4.5 REWARDS FOR PRODUCTIVITY: Distribution of resources and rewards that directly support educational productivity.

Attribute #5.1 CAPABLE STUDENTS: Highly motivated, energetic, capable and creative students.

Attribute #5.2 FLEXIBLE CURRICULUM: A flexible curriculum that promotes a learning environment that emphasizes intellectual opportunities and new knowledge.

Attribute #5.3 EFFECTIVE INTERACTING: Effective interacting by competent, creative faculty and students who together enthusiastically pursue new knowledge with sophisticated techniques.

Attribute #5.4 INDIVIDUAL DISCOVERY: Individual discovery in creative courses that include the philosophic framework within which new knowledge is discovered.

Attribute #5.5 RESOURCES FOR HIGH PRODUCERS: Allocation of resources to protential and proven high producers of instruction and research results.

APPENDIX 05

FOURTH DELPHI QUESTIONNAIRE

Interoffice Communication | IOWA STATE UNIVERSITY
of Science and Technology

DATE May 23, 1978

TO

FROM
Jack Whitmer
506 Ross Hall

Subject: Delphi Questionnaire Number 4

Thank you for tolerating my fuzzy instructions on the last questionnaire. I tried to avoid "blurting out" that you had to make 125 separate decisions because I was afraid it would dampen your enthusiasm.

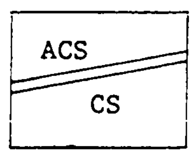
This process is taking longer than I planned, but I hope you will stick with me a couple more weeks. We are approaching the home stretch and the results are looking great.

The mechanics of recording your judgments on this questionnaire are very similar to questionnaire number 3 but THE RELATIONSHIPS ARE COMPLETELY DIFFERENT. In the first three questionnaires, you worked with the relationship between attributes and objectives. In this questionnaire, you will be working with the relationship between activities and attributes. Your judgment on this questionnaire involves how a specific activity contributes to the presence of a specific attribute.

It may help if you understand how all of your judgments will fit together. The purpose of this delphi exercise is to attempt to establish a linkage between activities and objectives. However, that span is too wide, i.e. people have great difficulty determining how an activity contributes to the achievement of an objective. I inserted an intermediate factor: the attribute. This allows me to attempt to link activities to attributes and then attributes to objectives. This information will then be collapsed and expressed in a singular linkage between activities and objectives.

Enclosed are the 25 attributes and their brief descriptions and a NEW scaling instruction sheet. Please read the descriptions of the different levels of the "Activity Contribution Scale" very carefully. The confidence scale is the same. Also enclosed is a worksheet that has 10 activities that are descriptors of how faculty members supposedly spend their time. These are new. Please read each one carefully. Across the top are the headings of the 25 attributes.

The specific task of this questionnaire is to record your judgment expressing how you believe each activity contributes to the presence of each attribute (ACS) using any of the specific ratings of the Activity Contribution Scale from -5 to +5. For example, how does "graduate structured instruction" contribute to the presence of an "outreach effort?" Record that judgment in the top half of the rectangle and your confidence scale in the bottom half.



Mechanically, I believe it will facilitate your providing this information if you do a single activity all the way across the sheet, i.e., how does "graduate structured instruction" contribute to the presence of: an "outreach effort;" this specific "professional behavior;" "excellent instruction;" all the way over to "resources for high producers?"

Please endure. I realize that this involves a lot of specific decisions. However, all of these decisions are implicit in the many gross decisions that involve relating the universities resources to desired outcomes.

Time is slipping away. In fact, I'm afraid that some of you will slip away before I get the last questionnaire out if I can't shorten up my turn-around time. Will you please try to get this back to me by June 2? If you are going to be at a different address the first two weeks in June, would you please write that on the answer sheet so that I can be sure the last questionnaire is delivered to you promptly?

Thanks again.

QUESTIONNAIRE NUMBER
* * 4 5

Name

Date

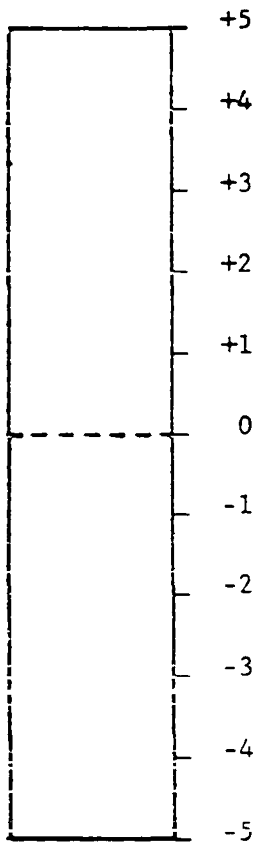
Time Necessary (minutes) to complete this aspect of the Questionnaire

Public service, community involvement, extension presentation, political activities, etc	Professional development, reading professional journals, developing new interests & skills, etc	Research activities, design, administrative presentation of results of research	Professional activities, preparing papers, attending professional meetings, reviewing for journals etc	Administrative activities, supervision of employees, record maintenance, etc	Committee/Councils department, college & university involvement	Undergrad unstructured instruction (on & off campus) individual study, special problems, advising	Grad unstructured instruction (on & off campus) individual study, special problems, advising, thesis dissertation supervision	Undergrad structured instruction on & off campus lecture & lab. classroom setting	Grad structured instruction on & off campus lecture & lab. classroom setting	
										1.1 outreach effort
										1.2 professional behavior
										1.3 excellent instruction
										1.4 new & valuable knowledge
										1.5 valuable service
										2.1 internal communications
										2.2 public awareness program
										2.3 responsible faculty behavior
										2.4 policy statement
										2.5 trust & democracy
										3.1 competent faculty
										3.2 qualified & motivated students
										3.3 rewards for instruction
										3.4 student centered courses
										3.5 post-graduation evaluation
										4.1 expectations
										4.2 commitment to excellence
										4.3 university impact
										4.4 competent administrators
										4.5 rewards for productivity
										5.1 capable students
										5.2 flexible curriculum
										5.3 effective interacting
										5.4 individual discovery
										5.5 resources for high producers

QUESTIONNAIRE NUMBER * * * 4 5 Date______________

Relationships of Activities to Attributes

This is the fourth set of questionnaires. The accompanying worksheets provide you an opportunity to express your judgment on how 10 specific purposeful activities of university faculty contribute to the presence of the 25 attributes that were composed in Questionnaires 1 and 2 . Using the scale on this page, express your judgment as to how each activity contributes to the presence of the attribute. Write in the appropriate number adjacent to each activity in the top half. Next, record your confidence in your judgment in the bottom half.



Activity Contribution Scale

A rating of +5 means that you think the performance of the activity directly contributes to the presence of the attribute. (the probability of the presence of the attribute is practically 100%)

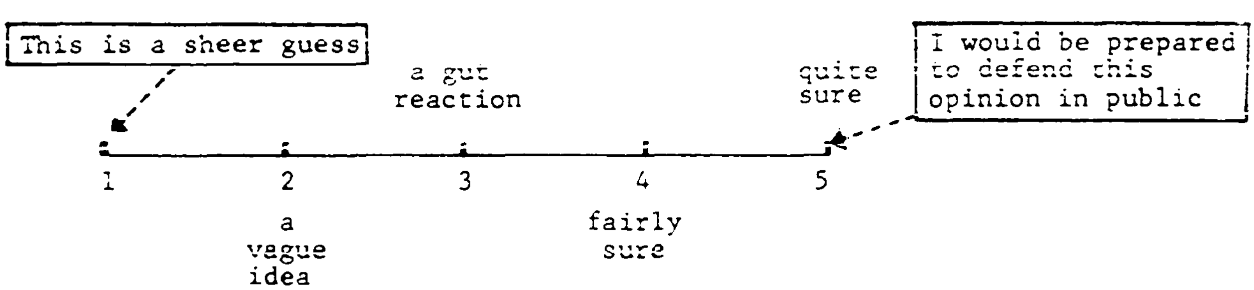
A rating of +3 means that you think the performance of the activity indirectly contributes to the presence of the attribute.

A rating of zero means that you think the performance of the activity is not related to the presence of the attribute, or that you don't know if the performance of the activity has a bearing on the presence of the attribute.

A rating of -3 means that you think the performance of the activity reduces the possibility of the presence of the attribute.

A rating of -5 means that you think the performance of the activity almost guarantees that the attribute will not be present.

Confidence of Judgment Scale*



* the degree of confidence you have in your judgment about this relationship

Reference sheet for Delphi Questionnaire Number 4

ATTRIBUTES

Attribute #1.1 OUTREACH EFFORT: A positive effective external outreach effort projecting a constructive image of the university.

Attribute #1.2 PROFESSIONAL BEHAVIOR: Professional behavior by faculty members, administrators and students that reflects an awareness that university activities are of interest to Iowans who judge the university on the information they receive.

Attribute #1.3 EXCELLENT INSTRUCTION: A widely acknowledged and broadly accepted reputation that the university provides excellent instruction to students in a positive learning environment.

Attribute #1.4 NEW & VALUABLE KNOWLEDGE: A widely acknowledged and broadly accepted reputation that the university is continuously producing new and valuable knowledge.

Attribute #1.5 VALUABLE SERVICE: A widely acknowledged and broadly accepted reputation that the university is willing to and is continuously providing valuable service and extension programs to all segments of the state.

Attribute #2.1 INTERNAL COMMUNICATIONS: A positive effective internal communication process that emphasizes the significance and rationale of academic freedom and pursues some consensus among faculty, administrators and students on a definition of academic freedom.

Attribute #2.2 PUBLIC AWARENESS PROGRAM: A specific and continuous public awareness program that describes and explains the value of academic freedom in a high quality, productive university and in society in general.

Attribute #2.3 RESPONSIBLE FACULTY BEHAVIOR: Responsible faculty behavior that reflects an awareness of the value and limits of academic freedom, including the recognition of ethical standards.

Attribute #2.4 POLICY STATEMENT: A specific policy statement of the university's position on academic freedom that top university administrators rigorously explain and defend.

Attribute #2.5 TRUST & DEMOCRACY: An atmosphere of trust and democracy that encourages objectiveity with a free and open discussion of research results by faculty members, administrators and students who have confidence in their peers.

Attribute #3.1 COMPETENT FACULTY: Competent, diverse and demanding faculty members who are up-to-date in their field; who are effective in interacting with students.

Attribute #3.2 QUALIFIED & MOTIVATED STUDENTS:Qualified and motivated students who have positive attitudes about themselves, think for themselves and demonstrate the potential to change and mature.

Attribute #3.3 REWARDS FOR INSTRUCTION: Rewards for effective instruction, independent thinking, creativity and respect for different opinions.

Attribute #3.4 STUDENT CENTERED COURSES: Student centered course structure that includes comprehensive evaluation of each students' educational process.

Attribute #3.5 POST-GRADUATION EVALUATION: Post-graduation evaluation that indicates the degree of the graduates' intellectual growth and their attainment of self-actualization.

Attribute #4.1 EXPECTATIONS: High expectations of the faculty with encouragement of professional improvement and rewards for outstanding results.

Attribute #4.2 COMMITMENT TO EXCELLENCE: Highely motivated, competent, innovative faculty members who are committed to excellence and achievement of the objectives of higher education.

Attribute #4.3 UNIVERSITY IMPACT: Specific knowledge of the impact of the university beyond campus boundaries.

Attribute #4.4 COMPETENT ADMINISTRATORS: Competent Administrators who have an appreciation for quality educational results and use creative management techniques.

Attribute #4.5 REWARDS FOR PRODUCTIVITY: Distribution of resources and rewards that directly support educational productivity.

Attribute #5.1 CAPABLE STUDENTS: Highly motivated, energetic, capable and creative students.

Attribute #5.2 FLEXIBLE CURRICULUM: A flexible curriculum that promotes a learning environment that emphasizes intellectual opportunities and new knowledge.

Attribute #5.3 EFFECTIVE INTERACTING: Effective interacting by competent, creative faculty and students who together enthusiastically pursue new knowledge with sophisticated techniques.

Attribute #5.4 INDIVIDUAL DISCOVERY: Individual discovery in creative courses that include the philosophic framework within which new knowledge is discovered.

Attribute #5.5 RESOURCES FOR HIGH PRODUCERS: Allocation of resources to protential and proven high producers of instruction and research results.

APPENDIX 06

FIFTH DELPHI QUESTIONNAIRE

Interoffice Communication

IOWA STATE UNIVERSITY
of Science and Technology

DATE June 28, 1978

TO

FROM
Jack Whitmer
506 Ross Hall

Subject: Delphi Questionnaire Number 5 ; The Last One

Wow! That last questionnaire produced a lot of numbers. It is obvious from the fall-off in response and the delay of returning the last questionnaire that five objectives are too many to handle as a block. However, the responses from this last questionnaire are necessary to complete the process for these five objectives which will be used in my research model of resource allocation in a college.

The results of the 12,500 numbers from Questionnaire 4 are summarized on Questionnaire 5 B. You will see as you review the aggregation of your responses that you were very definite and positive about some of the relationships and equally as unsure about others. A preliminary integration of the two sets of relationships, the attribute-objective; expressed on Questionnaire 5 A, and the activity-attribute; expressed on Questionnaire 5 B, indicates some interesting linkages. Your responses indicate that the 10 activities clearly lead to the attainment of "Faculty Development" more than any of the other objectives. On the other extreme, but much more tentative, the 10 activities contribute the least to "Academic Freedom" compared to the other four objectives.

If Questionnaires 5 A and 5 B produce the expected impact on the data, a more definite consensus about each specific relationship should emerge, but in the process about 20% of the relationships will shift one way or the other.

The mechanics of recording your judgments on this Questionnaire are the same as with Questionnaires 3 and 4. Questionnaire 5 is a review and revaluation of your past judgments. I have stapled the Questionnaires and the appropriate descriptors and series into two sets to help you associate the appropriate scale with each set of material.

The results of your responses are reported in the form x - y - z; where x = the upper limit of the first quartile, y = the weighted median, and z = the lower limit of the fourth quartile. The median is the most significant value. One half of the response values are on each side of the median. The quartile limits reflect the degree of consensus around the median value. For example:

1. If the reported values are

4 - 4 - 5
7

; this indicates that one half of the responses were in the range -5 to 4 and the other half were in the range 4 to 5. Also, that at least ½ of all responses were "4's" and "5's"; i.e. there is a strong relationship expressed here and the group is very sure of it.

2. If the reported values are

0 - 1.5 - 3
7

; this indicates that one half of the responses were in the range -5 to 1.5 and the other half were in the range 1.5 to 5. Also, that one half of the responses were between 0 and 3. I.e., there is little or no relationship expressed here and the group is not very confident of its judgment.

Your task on Questionnaire 5 is twofold. First, laying the explanations next to the recording form, read the "objectives" and "attribute" statements carefully. Consider the specific wording and the statistics describing the responses of the participants to each relationship and record your Attribute Achievement Ranking (AAR) in the left hand space and your Confidence Scale (CS) in the right hand space of the 100 relationships that are not blacked out. i.e.

x - y - z
AAR 7 CS

. .

Second, repeat the process by reading the "activity" and "attribute" statements carefully, considering the specific wording and statistics describing the responses of the participants to each relationship and record your Activitiy Contribution Scale (ACS) in the left hand space and your Confidence Scale (CS) in the right hand space of the 250 relationships, i.e.

x - y - z
ACS 7 CS

.

See accompanying sheet for scales and descriptors. Please feel free to use any value on the entire scale from -5 to +5 on Questionnaire 5 .

Keep in mind you are still being asked only for your best judgment based on what you know and accepting the statements at face value. However, if the (AAR) or the (ACS) you record on this Questionnaire for the relationship is above or below the reported "quartile" limits, indicating that you may know something about that specific relationship that all the rest do not, and therefore maybe your judgment should prevail, please footnote those specific rankings with an explanation on the back of the sheet.

I apologize for taking more of your time than I estimated, but the results look very valuable. Please try to get these back to me by the middle of July.

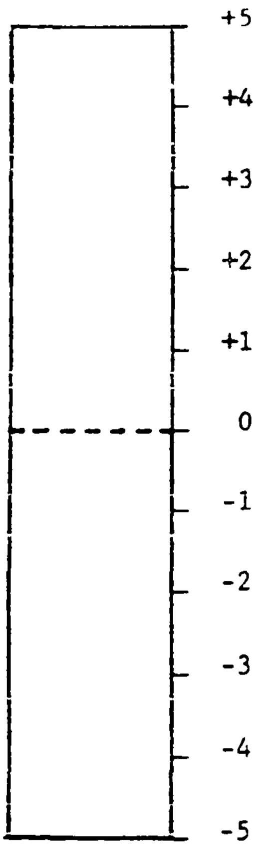
Thanks.

QUESTIONNAIRE NUMBER 1 2 3 4 (5)A Date: ______________

Name: ______________________ Time to complete . ____________

○ weighted median Attribute Number	OBJ#1 Secure Resources	OBJ#2 Academic Freedom	OBJ#3 Thinking Student	OBJ#4 Faculty Development	OBJ#5 Training Students
1.1 Outreach Effort	3 - 4 - 4	0 - 2 - 3	0 - 2 - 3	1 - 2 - 4	0 - 2 - 3
1.2 Professional Behavior	3 - 3.5 - 4	3 - 4 - 4	2 - 3 - 4	2 - 4 - 4	2 - 4 - 4
1.3 Excellent Instruction	4 - 4 - 4	2 - 3 - 4	4 - 4 - 4	2 - 4 - 4	4 - 4 - 4
1.4 New & Valuable Knowledge	3 - 3 - 4	2 - 3 - 4	2 - 4 - 4	3 - 4 - 4	3 - 3 - 4
1.5 Valuable Service	4 - 4 - 4	0 - 2 - 3	0 - 1 - 3	1 - 3 - 4	0 - 1 - 4
2.1 Internal Communications	0 - 1.5 - 3	3 - 4 - 4	0 - 2 - 3	2 - 3 - 4	0 - 2 - 3
2.2 Public Awareness Program	1 - 3 - 4	3 - 3 - 3	0 - 1 - 3	1 - 2 - 3	0 - 1 - 2
2.3 Responsible Faculty Behavior	2 - 3 - 4	4 - 4 - 5	2 - 3 - 4	3 - 4 - 4	2 - 3 - 4
2.4 Policy Statement	0 - 1 - 3	3 - 4 - 4	0 - 1 - 3	2 - 3 - 4	0 - 2 - 3
2.5 Trust & Democracy	0 - 1 - 3	4 - 4 - 5	2 - 3 - 4	2 - 4 - 4	2 - 3 - 4
3.1 Competent Faculty	1 - 4 - 4	2 - 4 - 4	4 - 4 - 5	4 - 4 - 5	4 - 4 - 5
3.2 Qualified & Motivated Students	1 - 3 - 4	0 - 2 - 3	4 - 4 - 5	2 - 3 - 4	3 - 4 - 5
3.3 Rewards for Instruction	0 - 2 - 3	0 - 3 - 4	4 - 4 - 4	3 - 4 - 4	3 - 4 - 4
3.4 Student Centered Courses	0 - 2 - 3	0 - 1.5 - 3	3 - 3 - 4	1 - 2 - 3	2 - 3 - 4
3.5 Post-graduate Evaluation	1 - 2 - 3	0 - 0 - 2	2 - 3 - 3	1 - 2 - 4	2 - 3 - 4
4.1 Expectations	1 - 3 - 3	2 - 3 - 4	3 - 3 - 4	4 - 4 - 5	3 - 3 - 4
4.2 Commitment to Excellence	2 - 3 - 4	3 - 4 - 4	3 - 4 - 5	4 - 4 - 5	3 - 4 - 5
4.3 University Impact	3 - 4 - 4	0 - 1.5 - 4	1 - 2 - 3	3 - 3 - 3	1 - 3 - 4
4.4 Competent Administrators	3 - 4 - 4	2 - 3 - 4	1 - 2 - 3	2 - 3 - 4	1 - 2 - 4
4.5 Rewards for Productivity	2 - 3 - 4	0 - 1 - 3	2 - 3 - 4	4 - 4 - 5	2 - 3 - 4
5.1 Capable Students	1 - 3 - 4	0 - 1 - 3	4 - 4 - 5	3 - 4 - 4	4 - 4 - 5
5.2 Flexible Curriculum	0 - 1.5 - 3	0 - 1 - 3	3 - 4 - 4	2 - 3 - 4	3 - 4 - 4
5.3 Effective Interacting	0 - 2 - 4	1 - 2 - 3	4 - 4 - 5	3 - 4 - 4	4 - 4 - 4
5.4 Individual Discovery	0 - 1 - 3	0 - 2 - 4	4 - 4 - 5	3 - 3 - 4	4 - 4 - 4
5.5 Resources for High Producers	1 - 3 - 4	0 - 2 - 3	3 - 3 - 4	3 - 4 - 5	3 - 4 - 4

Attribute Achievement Scale for 5 A



A rating of +5 means that you think the presence of the attribute virtually guarantees the achievement of the objective (the probability of attainment of the objective is practically 100%).

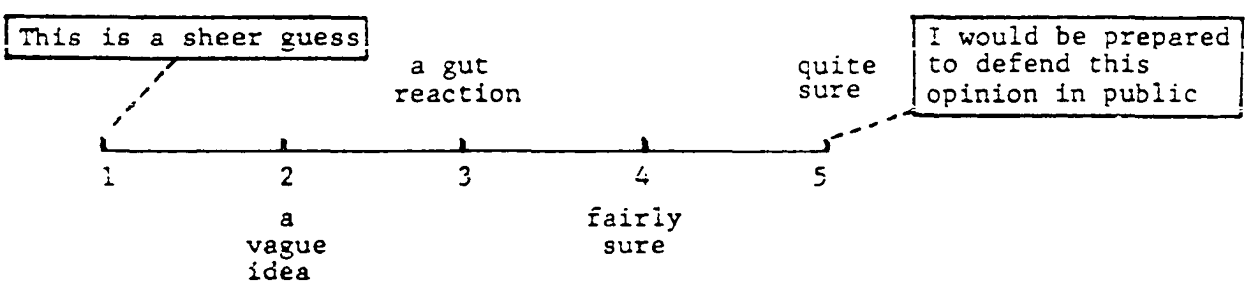
A rating of +3 means that you think the presence of the attribute is likely to lead to the achievement of the objective. (A high probability of the attainment of the objective is associated with the presence of this attribute.)

A rating of 0 means that you think the presence of the attribute is indifferent/of no significance relative to the achievement of the objective (or that you don't know if the presence of the attribute will help or hurt the attainment of the objective).

A rating of -3 means that you think the presence of the attribute is likely to distract from the achievement of the objective. (A high probability that the objective will not be attained is associated with the presence of this attribute.)

A rating of -5 means that you think the presence of the attribute is practically certain to suppress the achievement of the objective (the probability of attainment of the objective is practically zero when the attribute is present).

Confidence of Judgment Scale*



* the degree of confidence you have in your judgment about this relationship

Reference sheet for Delphi Questionnaire Number 5 A

OBJECTIVES

Objective #1. SECURE RESOURCES: To secure resources from the Iowa Legislature, through the Board of Regents, sufficient to operate this university at a near optimal level.

Objective #2. ACADEMIC FREEDOM: To protect the faculty's right to academic freedom.

Objective #3. THINKING STUDENT: To develop a student who can think, who can behave intelligently, who can respond creatively and effectively to new situations.

Objective #4. FACULTY DEVELOPMENT: To translate the talents and capacities of its faculty into significant educational results.

Objective #5. TRAINED STUDENT: To train students in methods of scholarship and/or scientific research and/or creative endeavor.

ATTRIBUTES

Attribute #1.1 OUTREACH EFFORT: A positive effective external outreach effort projecting a constructive image of the university.

Attribute #1.2 PROFESSIONAL BEHAVIOR: Professional behavior by faculty members, administrators and students that reflects an awareness that university activities are of interest to Iowans who judge the university on the information they receive.

Attribute #1.3 EXCELLENT INSTRUCTION: A widely acknowledged and broadly accepted reputation that the university provides excellent instruction to students in a positive learning environment.

Attribute #1.4 NEW & VALUABLE KNOWLEDGE: A widely acknowledged and broadly accepted reputation that the university is continuously producing new and valuable knowledge.

Attribute #1.5 VALUABLE SERVICE: A widely acknowledged and broadly accepted reputation that the university is willing to and is continuously providing valuable service and extension programs to all segments of the state.

Attribute #2.1 INTERNAL COMMUNICATIONS: A positive effective internal communication process that emphasizes the significance and rationale of academic freedom and pursues some consensus among faculty, administrators and students on a definition of academic freedom.

Attribute #2.2 PUBLIC AWARENESS PROGRAM: A specific and continuous public awareness program that describes and explains the value of academic freedom in a high quality, productive university and in society in general.

Attribute #2.3 RESPONSIBLE FACULTY BEHAVIOR: Responsible faculty behavior that reflects an awareness of the value and limits of academic freedom, including the recognition of ethical standards.

Attribute #2.4 POLICY STATEMENT: A specific policy statement of the university's position on academic freedom that top university administrators rigorously explain and defend.

Attribute #2.5 TRUST & DEMOCRACY: An atmosphere of trust and democracy that encourages objectiveity with a free and open discussion of research results by faculty members, administrators and students who have confidence in their peers.

Attribute #3.1 COMPETENT FACULTY: Competent, diverse and demanding faculty members who are up-to-date in their field; who are effective in interacting with students

Attribute #3.2 QUALIFIED & MOTIVATED STUDENTS:Qualified and motivated students who have positive attitudes about themselves, think for themselves and demonstrate the potential to change and mature.

Attribute #3.3 REWARDS FOR INSTRUCTION: Rewards for effective instruction, independent thinking, creativity and respect for different opinions.

Attribute #3.4 STUDENT CENTERED COURSES: Student centered course structure that includes comprehensive evaluation of each students' educational process.

Attribute #3.5 POST-GRADUATION EVALUATION: Post-graduation evaluation that indicates the degree of the graduates' intellectual growth and their attainment of self-actualization.

Attribute #4.1 EXPECTATIONS: High expectations of the faculty with encouragement of professional improvement and rewards for outstanding results.

Attribute #4.2 COMMITMENT TO EXCELLENCE: Highely motivated, competent, innovative faculty members who are committed to excellence and achievement of the objectives of higher education.

Attribute #4.3 UNIVERSITY IMPACT: Specific knowledge of the impact of the university beyond campus boundaries.

Attribute #4.4 COMPETENT ADMINISTRATORS: Competent Administrators who have an appreciation for quality educational results and use creative management techniques.

Attribute #4.5 REWARDS FOR PRODUCTIVITY: Distribution of resources and rewards that directly support educational productivity.

Attribute #5.1 CAPABLE STUDENTS: Highly motivated, energetic, capable and creative students.

Attribute #5.2 FLEXIBLE CURRICULUM: A flexible curriculum that promotes a learning environment that emphasizes intellectual opportunities and new knowledge.

Attribute #5.3 EFFECTIVE INTERACTING: Effective interacting by competent, creative faculty and students who together enthusiastically pursue new knowledge with sophisticated techniques.

Attribute #5.4 INDIVIDUAL DISCOVERY: Individual discovery in creative courses that include the philosophic framework within which new knowledge is discovered.

Attribute #5.5 RESOURCES FOR HIGH PRODUCERS: Allocation of resources to protential and proven high producers of instruction and research results.

QUESTIONNAIRE NUMBER 5B

Name__________

Date__________

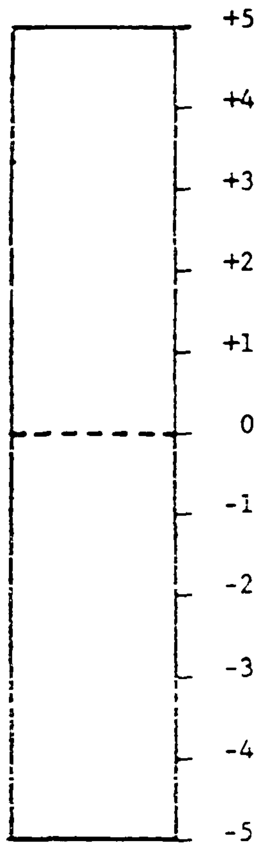
Time necessary (__ min.) to complete this aspect of the Questionnaire.

	1.1 outreach effort	1.2 professional behavior	1.3 excellent instruction	1.4 new & valuable knowledge	1.5 valuable service	2.1 internal communications	2.2 public awareness program	2.3 responsible faculty behavior	2.4 policy statement	2.5 trust & democracy	3.1 competent faculty	3.2 qualified & motivated students	3.3 rewards for instruction	3.4 student centered courses	3.5 post-graduation evaluation	4.1 expectations	4.2 commitment to excellence	4.3 university impact	4.4 competent administrators	4.5 rewards for productivity	5.1 capable students	5.2 flexible curriculum	5.3 effective interacting	5.4 individual discovery	5.5 resources for high producers
Grad structured instruction (on & off campus) Lecture & Lab, classroom setting	1 3 3	2 3 5	3 4 5	1 4 4	2 3	0 2 3	0 1 2	2 3 4	0 3 2	1 2 4	3 4 5	3 4 5	2 4 4	2 3 4	1 3 4	2 3 4	3 4 5	1 3 4	0 2 3	2 3 4	2 4 5	3 4	2 3 4	3 4	3 4
Undergrad structured instruction (on & off campus) Lecture & Lab, classroom setting	1 3 4	2 3 4	3 4 5	1 4 3	1 3 3	0 1 3	0 1 2	3 4	0 0 2	1 2 3	3 3 5	3 4 4	2 3 4	2 3 4	1 3 4	2 4 4	3 4 4	1 3 4	0 1 3	2 3 4	2 3 4	3 4	3 3 4	3	3 4
Grad unstructured instruction (on & off campus) individual study, special problems, advising, thesis, dissertation supervision	1 3 4	2 3 4	3 4 4	3 4 5	1 3 4	0 2 3	0 1 2	1 3 4	0 1 3	1 4 4	3 4 5	4 4 5	4 5	3 4 5	1 3 4	2 4 4	3 4 4	1 3 4	0 0 3	3 4	3 4 5	4 4 5	4 4 5	4 5 5	2 3 4
Undergrad unstructured instruction (on & off campus) individual study, special problems, advising	1 2 4	2 3 4	3 4 4	1 3 3	1 3 4	0 3 3	1 1 3	2 3 4	0 1 2	3 4	3 4 4	4 4 4	3 4	3 4 5	2 3 4	2 3 4	2 [illegible]	3 3	0 1 3	3	3 3 5	[illegible]	[illegible]	[illegible]	[illegible]
Committees/Councils, department, college & university involvement	0 2 3	2 3 4	1 2 3	0 1 2	0 2 3	2 4 5	1 2 3	2 3 4	1 3 4	2 3 4	2 2 3	0 1 1	0 1 2	0 0 2	0 0 3	3 4	1 3 3	1 2 3	2 3 4	2 2 3	1 2	2 3	3	[illegible]	2 3
Administrative activities, supervision of employees, record maintenance, etc	0 3	3 4	0 1 [illegible]	1 2	2 3	2 4 4	2 3	2 3 4	2 3 4	2 4 4	2 3 4	0 1 3	2 4	0 1 3	0 2	3 5	2 4	2 4	3 4 5	2 3	2 3	3	3	2	3
Professional activities, presenting papers, attending professional meetings, reviewing for journals, etc	2 3 4	4 5	2 3 4	3 4 5	2 3 3	1 2 3	3 4	3 4 4	0 2 3	2 3 4	3 4 5	1 3 4	3 4	0 1 3	0 0 2	3 4 4	3 4 5	2 3 4	1 2 3	3 4 5	2 2	2 3	3	3	2 3
Research activities, design, administrative presentation of results of research	2 3 4	4 4	3 3	3 4 5	3 3 4	2 4	2 4	3 4 4	1 3 4	1 3 4	4 4 5	2 3 4	1 2 4	0 0 3	0 1 3	1 4 4	3 4 5	1 3 4	1 2 3	1 4 5	0 2 3	2 3	3 5	3 5	3
Professional development, reading professional journals, developing new interests & skills, etc	4 3	4 4	3 4 5	3 4 5	2 3 4	5 2 3	1 3	2 4 4	0 2 3	1 3 4	3 4 5	2 3 4	2 3 4	3 3	0 1 2	2 4 4	4 4 5	2 3 4	3 4	3 4	2 2	3	3	5	3
Public service, community involvement, extension presentation, political activities, etc	4 4 5	1 3 5	2 3 4	3 4	4 3 5	0 1 2	3 4 4	2 3 4	0 2 3	1 3 4	3 4	0 3 3	0 1 2	0 1 2	0 0 2	1 2 4	2 3 4	3 4 5	1 2 3	0 2 3	3	2 2	2	3	2 3

QUESTIONNAIRE NUMBER * * * 4 5 B   Date ______________

Relationships of Activities to Attributes

This is the fourth set of questionnaires. The accompanying worksheets provide you an opportunity to express your judgment on how 10 specific purposeful activities of university faculty contribute to the presence of the 25 attributes that were composed in Questionnaires 1 and 2 . Using the scale on this page, express your judgment as to how each activity contributes to the presence of the attribute. Write in the appropriate number adjacent to each activity in the top half. Next, record your confidence in your judgment in the bottom half.



Activity Contribution Scale

A rating of +5 means that you think the performance of the activity directly contributes to the presence of the attribute. (the probability of the presence of the attribute is practically 100%)

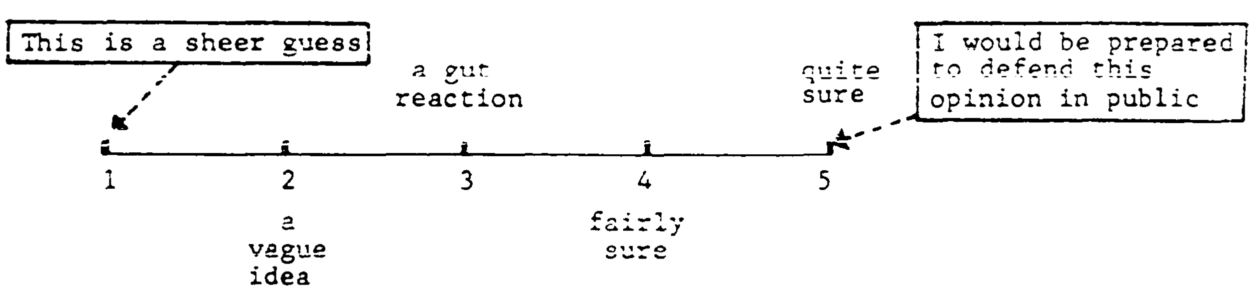
A rating of +3 means that you think the performance of the activity indirectly contributes to the presence of the attribute.

A rating of zero means that you think the performance of the activity is not related to the presence of the attribute, or that you don't know if the performance of the activity has a bearing on the presence of the attribute.

A rating of -3 means that you think the performance of the activity reduces the possibility of the presence of the attribute.

A rating of -5 means that you think the performance of the activity almost guarantees that the attribute will not be present.

Confidence of Judgment Scale*



* the degree of confidence you have in your judgment about this relationship

Reference sheet for Delphi Questionnaire Number 5 B

ATTRIBUTES

Attribute #1.1 OUTREACH EFFORT: A positive effective external outreach effort projecting a constructive image of the university.

Attribute #1.2 PROFESSIONAL BEHAVIOR: Professional behavior by faculty members, administrators and students that reflects an awareness that university activities are of interest to Iowans who judge the university on the information they receive.

Attribute #1.3 EXCELLENT INSTRUCTION: A widely acknowledged and broadly accepted reputation that the university provides excellent instruction to students in a positive learning environment.

Attribute #1.4 NEW & VALUABLE KNOWLEDGE: A widely acknowledged and broadly accepted reputation that the university is continuously producing new and valuable knowledge.

Attribute #1.5 VALUABLE SERVICE: A widely acknowledged and broadly accepted reputation that the university is willing to and is continuously providing valuable service and extension programs to all segments of the state.

ACTIVITIES

1. Grad. structured instruction (on & off campus) Lecture & Lab; classroom setting
2. Undergrad structured instruction (on & off campus) Lecure & Lab; classroom setting
3. Grad. unstructured instruction (on & off campus) individual study, special problems, advising, thesis, dissertation, supervision
4. Undergrad unstructured instruction (on & off campus) individual study, special problems, advising, thesis, dissertation, supervision
5. Committees/Councils; department, college and university involvement
6. Administrative activities; supervision of employees, record maintenance, etc.
7. Professional activities; presenting papers, attending professional meetings, reviewing for journals, etc.
8. Research activities, design, administrative presentation of results of research
9. Professional development; reading professional journals, developing new interests and skills, etc.
10. Public service; community involvement, extension presentation, political activities, etc.

Attribute #2.1 INTERNAL COMMUNICATIONS: A positive effective internal communication process that emphasizes the significance and rationale of academic freedom and pursues some consensus among faculty, administrators and students on a definition of academic freedom.

Attribute #2.2 PUBLIC AWARENESS PROGRAM: A specific and continuous public awareness program that describes and explains the value of academic freedom in a high quality, productive university and in society in general.

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Attribute #3.1 COMPETENT FACULTY: Competent, diverse and demanding faculty members who are up-to-date in their field; who are effective in interacting with students.

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Attribute #3.5 POST-GRADUATION EVALUATION: Post-graduation evaluation that indicates the degree of the graduates' intellectual growth and their attainment of self-actualization.

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