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Three quantitative methods are outlined, with suggestions for application to particular problem areas of educational administration: (1) The Leontief input-output analysis, incorporating a "transaction table" for displaying relationships between economic outputs and inputs, mainly applicable to budget analysis and planning; (2) linear programing, permitting the allocation of limited resources to satisfy competing demands and maximize total effectiveness; and (3) queuing or waiting line theory, relating facilities to services and needs within a prescribed period of time. (JK)

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The Use of Quantitative Methods as an Aid to Decision Making in Educational Administration

Marvin C. Alkin

A number of quantitative methods widely used in business and industry have now begun to receive recognition as aids to administrative decision-making in education. The three functions of this paper are:

1. To discuss briefly various quantitative methods for decision-making which might have applicability to education;
2. to provide an overview discussion of some specific kinds of educational decision situations in which certain of these methods might be used; and
3. to discuss the impediments to the utilization of the methodologies in several of these instances.

It can be said that the roots for the emphasis on the application of quantitative techniques to decision-making grew out of the "operations research" group founded by the British during World War II to assist their executive departments. The ideas soon spread to the United States where they were expanded, detailed, and refined. Out of this approach to the scientific solution of complex problems, variously called operations research, system engineering, and system analysis has come a collection of new analytical decision-making tools.

All of these quantitative approaches to decision making have a great deal in common. The following statement of Herbert Simon's is a succinct declaration of the essence of the modern quantitative approach.[1]

> "Whatever the specific mathematical tool, the general recipe for using it in management decision-making is: (1) construct a mathematical model, (2) define the criterion function, (3) obtain empirical estimates of the parameters of the model, and (4) carry through the mathematical process of defining the course of action which, for the specified parameter values, maximizes the criterion function.

In the discussion of this paper we will limit ourselves to the consideration of only three techniques. They are the Leontief input-output model, linear programming, and queuing theory. It is my belief that these three methods, at this time are among the most suited to educational application.

Leontief Input-Output Analysis

The first method to be discussed will be Leontief's input-output analysis. This was first used by Wassilly Leontief, a professor at Harvard University, to show interrelationships among industrial and commercial sectors of the American economic system. The basis of the system is the development of a "transactions table" for conveniently displaying the relationships between economic outputs and inputs of industries and sectors of the national economy. Thus, the table is of

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[1] Herbert A. Simon, The New Science of Management Decision, New York: Harper and Row, 1960, p. 16.

a double entry type, and shows the outputs of each industry, in terms of the inputs necessary for the production of those outputs, as well as the description of intermediate outputs as inputs to other sectors.

Thus, an analysis of this table would allow one to determine the effect of an incremental change in one output on related incremental changes in others. In order to aid in these computations, Leontief has developed a procedure for determing various coefficients or "technical values". Because the analysis represents a relatively simple way of classifying the relationships between interrelated economic data and provides a mechanism for developing a quantitative estimate of incremental changes, it would appear to have value for educational administrators concerned with budget analysis and budget planning.

While I am unaware of any specific completed application which might be cited, it is possible for me to comment for a moment or two on an application that a colleague of mine and I are attempting to make. We became concerned about the percentage of the school budget which is "free" -- that is, available at the discretion of the school administrator for use as he pleased for innovative purposes. In order to get a better understanding of this figure, we have been attempting on an actual accounting basis to allocate certain line item costs (i.e., maintenance) to other budget line items, and on the basis of these allocations to develop a matrix similar

to a Leontief transaction table. Thus, in effect, we are maintaining that because of the interrelationships between budget line items it is possible to think of the outputs of various items as in turn distributed as inputs to other line items. We feel that the computation of coefficients and the performance of an input-output analysis will provide us with information on incremental costs related to various budget decisions.

Linear Programming

Linear programming is a technique for allocating groups of limited resources in order to satisfy competing demands under conditions of known and fixed sets of limitations or restrictions. Allocation problems arise when there are several activities to be performed, but constraints on either the amount of resources or on the way they can be allocated, make it difficult or impossible to perform each separate activity in the most effective way. The problem is in determing how the resources should be allocated to the activities in order to maximize the total effectiveness.

In general, several types of problems have been found amenable to solution by linear programming. One type is where the resources and activities are both specified and the problem is to allocate the resources to the activities in such a way as to maximize some measure of effectiveness (i.e., outputs) or to minimize some

measure of ineffectiveness (i.e., financial costs). An analogous educational example for this type of problem would be one where the student and financial inputs to the system (resources) are fixed, the nature of the activities or programs of the system are determined, and we are seeking to maximize the educational outcomes. Other varieties of allocation models involve only the specification of resources and not activities, or the specification of activities and not resources.

Application to total educational systems might be difficult at this time in light of the lack of adequate research capital. Thus, early applications of linear programming models to education might well concern themselves with relatively finite, easily identifiable sub-systems of the larger educational system which outcome dimensions are readily discernable. The kinds of problems that might be appropriate for solution by this method are easily thought of. For example, linear programming techniques might be applied to the analyses of school transportation system, to consider the number of school buses, garage locations and student pick-up and deliveries, minimizing such things as financial cost and student time enroute. Other allocation problems readily suggest themselves, including assignment of faculty members to their various activities, in terms of their relative strengths or weaknesses, and allocations of classroom and other facilities within an institution.

Perhaps the most valuable applications of this technique to education ultimately will be it's uses in making selections of alternative processes for producing specified educational outcomes. Several impediments have existed which preclude linear programming analyses in this area. These are:

1. The failure to designate precisely the educational programs within educational systems and their attendant financial costs;
2. the lack of sufficient educational research knowledge related to an understanding of the nature of the inter-relationships between inputs-process characteristics-outputs; and
3. the lack of specificity in the designation of educational outcomes.

There are encouraging signs related to the improved technology on each of these dimensions. Various research and development activities of the Center for the Study of Evaluation at U.C.L.A. are contributing in some way to this improved technology.

With respect to the first area, discussions about Planning-Programming-Budgeting-Systems and the development and planned introduction of related accounting systems in some states, is an encouraging first step. These systems, have as part of them the nedessity for specifying programs. The program accounting format

initiated at the Center is presently being considered, with some modifications, as the basis for an accounting system in California, Texas, and other places.

The need for quantitative specification of the problem and the associated necessity for developing mathematical formulations which describe the relationships among variables is being met more easily because of the number of research studies presently taking place. Project talent, the Coleman study and other studies of the Coleman data, certainly form the initial basis of any discussion of attempts to establish a secure data base for optimization studies in education. In addition, there are a vast array of other activities, including the work presently being done at the National Center for Education Statistics of the U. S. Office of Education, several studies being performed under the direction of Scarvia Anderson at the Educational Testing Service, and several systems evaluation studies presently being conducted at U.C.L.A.

It has been widely recognized for some time that school district statements of objectives generally have been stated so ambiguously as to be nearly worthless for the purpose of quantitative optimization studies. The specification of objectives for classrooms or indeed even for specific instructional programs often are not much better. There has been talk for some time about specifying

behavioral objectives for specific instructional programs. However, most attempts at such have been specifically single purpose in construction; in many instances the objectives have lacked clarity and in practically all instances there has been no attempt to disseminate these stated objectives to other segments of the educational community. The Center for the Study of Evaluation, has recently established as one of its major projects a unit which offers promise of providing considerable assistance in this area. The Center has established an Instructional Objectives Exchange, whereby objectives and related test items are being collected from various school districts and other educational agencies. In addition, we are attempting to systematically develop comprehensive pools of objectives and related test items for measuring these objectives in several specific subject area fields. These objectives and items, when completed, will be made available on request to participating agencies.

Hopefully the three kinds of activities discussed above will lead to increased data availability in the short term future and to a greater array of educational decision situations subject to analysis through the use of linear programming techniques.

Queuing Theory

The third quantitative technique to be discussed ~~in~~ is queuing theory. Queuing theory (or waiting line theory) is concerned with problems arising in situations where people or things require some specified service, and the service facilities are present and limited. The time factor is always involved; a waiting line may be created in either these providing the service or the unit being served by the facility. To apply queuing theory one must have information concerning the rate of arrivals at the servicing station or stations, the time required for each operation and the method of selection for service. In general, the problem takes two forms:

1. Either the facilities to meet certain specified needs must be determined, or
2. the facilities are fixed and the problem is to determine the proper scheduling and distribution of arriving units.

Many segments of the educational enterprise seem appropriate for analysis using queuing theory. In addition to school business applications such as scheduling secretarial or telephone answering time, queuing theory could be applied in other areas more closely related to the educational program such as in scheduling of books or counselor time or even student registration.

Needless to say, this discussion has been limited both in the amount of time available to present amplification on the possible applications, as well as in the quantitative techniques which might be discussed. There are a number of other methods which offer considerable promise for educational decision making.