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EFFECTIVE USE OF MODELS IN THE DECISION PROCESS: THEORY GROUNDED IN THREE CASE STUDIES

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Mathematical models have gained wide acceptance in higher education administration over the past decade. These years have seen a shift in emphasis from the large, comprehensive models such as the Resource Requirements Prediction Model (RRPM) to flexible modeling software and smaller problem-oriented models of the sort described by Hopkins and Massey in their recent book, *Planning Models for Colleges and Universities* (1981). The years have also seen a shift in interest from the technological structure and mathematical validity of models to factors which facilitate their utilization.

Instances of failed or ignored modeling efforts have been documented by Plourde (1976), Weathersby (1976), and Dresch (1975). Although the potential utility of models is widely recognized in higher education, many administrators resist using them. This resistance derives from many different sources.

The institutional researcher is often a key link in the chain that connects modeling efforts and the use of their results in decision contexts. As the staff analyst for administrators with line responsibility, the institutional researcher typically possesses both the technical skills that are necessary to develop and operate a model and the knowledge of the decision setting that is needed to ensure utilization of the results. The institutional research staff person can therefore determine the success of a modeling effort by selecting a model structure that is valid and appropriate and by working with decision makers to gain acceptance of the model's results.

The challenges in using modeling as an analytic method are similar to those found by institutional researchers in other contexts. However, there are some problems that derive from the technical nature of this particular type of management tool.

A considerable body of literature exists on various aspects of model utilization. However, a single conceptual framework, that brings together the different strains of research, may help model developers think about the many issues that need to be addressed. The authors propose such a framework. It is the product of experience with the use of a small curriculum costing model in three different health science settings at the University of Michigan and of a review of pertinent literature.

The focus of the framework is on the utilization of models and their results rather than on explicitly technical or mathematical questions. An agenda of items for model developers to analyze at the outset of a project is part of the framework. It is assumed that the model developer is not the line decision maker but serves as an internal staff analyst or consultant to the decision maker. Specific points in the conceptual framework will be illustrated by examples taken from the authors' experiences with the curriculum costing model.

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Factors in the Utilization of Mathematical Models

Model developers know that the process of describing a problem in mathematical terms often results in a different perception of the problem. This, in turn, is reflected in alterations to the model. Model creation is therefore an interactive process in which the model is adapted gradually to fit the reality being described, just as the vision of reality shifts with new insights gained from the model.

Models and model builders must respond to the conditions of the decision setting and the characteristics of the problem to ensure utilization of a model. Adaptation is needed to accommodate technological constraints, the needs and norms of the people who receive the model, and the demands of the decision process for which the model is developed. In these three areas—technology, human factors, and decision process role—there is a mutual impact between the model and its setting. These three areas constitute the main subdivisions of the proposed conceptual framework.

Model Technology

The objective in determining the technology of a model is to achieve an appropriate fit to the constraints of the setting in which the model is being used. Models are flexible tools whose structures can be controlled and adapted by the model builder in several ways. The model builder, after identifying a general model for a decision problem, must ask a number of questions to determine the suitability of this model to the decision needs.

The first question is: Will the model's output fit the information needs of the decision makers? The information needs of decision makers depend on the type of decision to be made. Keen and Morton have suggested an analytic framework for categorizing decisions in their book, *Decision Support Systems* (1978, p. 79).

Borrowing from Anthony (1965) and Simon (1960), these authors propose a two-dimensional matrix which divides problems by organizational level and by problem nature. The organizational-level categories are strategic (i.e., fundamental goals and directions), management control (i.e., specific plans for realizing the goals), and operations (i.e., day-to-day execution of the plans). The problem-nature categories are structured (i.e., problems in which the factors are separable, definable, and predictable), semistructured (i.e., problems only partially definable) and unstructured (i.e., problems with interdependent factors where the governing rules are unclear, unknown, or dependent on the values of decision makers). Table 1 adapts the Keen-Morton matrix, with examples in each decision category drawn from the higher education context.

Table 1
DECISION ANALYSIS FRAMEWORK WITH EXAMPLES FROM HIGHER EDUCATION

Type of Decision \ Organizational Level	Strategic Planning	Management Control	Operational Control
Unstructured	Major resource reallocations	Faculty promotion decisions	Determining graduation requirements
Semistructured	Long-range budget planning	Curriculum cost projections for alternative curricula	Admissions recruiting strategies
Structured	Faculty flow analysis	Annual resource allocation cycle	Schedules for assigning faculty to classes

The strategic/management control/operational categories are found at all levels of an organization. A strategic decision for one level may be a management decision for another. Thus, the strategic decision of a university to shrink in size becomes a management control decision when some colleges are favored and others cut, if seen from the perspective of the central administration. However, when a university's literary college decides to discontinue its geography department, this represents a strategic decision for the college.

Problems at the strategic level are future oriented and broad in scope. They involve the values and judgments of the decision makers, usually the chief officers of the organizational unit. Problems at the operational level typically involve predefined activities which require little judgment. These are usually processed by clerks or administrators.

The information needs at these different levels vary in the degree of accuracy and detail that is required. The nature of the problems also varies, in that some problems yield more easily to modeling than others. How the level of control and the nature of a decision can impact on model characteristics such as accuracy, level of detail, and scope of parameters is illustrated in Table 2 (also an adaptation of the Keen-Morton matrix). Since the boundaries between categories are, in reality, indistinct and often overlapping, the characteristics in Table 2 are intended to be generalizations.

The second question is: Does the model validly represent reality? Models typically consist of a set of parameters which remains constant and a set that changes. The first set of parameters represents the "givens" in a problem setting and the second the "variables," or factors to be examined. When designing a model, the model builder identifies the factors which seem fixed and those which are subject to changes in policy (or reality) and constructs the model accordingly. However, models must be adaptable to changes in the relationship between fixed and variable parameters, since fixed factors may be recognized later as subject to policy.

The percentage of tenured faculty who resign is often treated as a given in a faculty flow model, yet this parameter is subject to changes in policy and needs to remain flexible. This example is obvious. The parameter in a curriculum cost model which relates the ratio of faculty salary to total overhead costs for a department or school is not obvious; the ratio depends on many exogenous factors and should not be treated as a given.

The model's validity must be tested both for the accuracy of predictions under a set of assumptions and for the accuracy of assumptions about the nature of parameters. Testing the model's validity, using data for which the outcome is known, allows both model builder and client to assess the model's parameters and to adjust them where necessary. Even when relationships seem obvious, models sometimes yield surprising results. It is necessary to determine whether these results reflect reality or some peculiarity in the model's structure.

The third question is: Is the model feasible in its data requirements, schedule, and method of operation? The availability and flexibility of computer systems and scheduling considerations will determine whether a model should be computerized or whether a quick pencil and paper product would be more useful. More important than the method of operation is the question of data. The model builder must be sure the chosen model does not require data which are either not available or not collectable within the timeframe of the decision to be made. The difficulties in obtaining data for the large simulations like RRPM have been amply aired (Plourde, 1976), but similar problems can complicate the use of small, problem-centered models such as the faculty flow models using a Markov chain.

Three points have been presented in relation to model technology. The first is the level of detail and scope of the model's parameters in relation to the type of decision to be made. The second is the need to test the validity of the model's parameters against real data with respect to both numerical

Table 2
MODEL CHARACTERISTICS REQUIRED BY VARIOUS DECISION TYPES

Type of Decision \ Organizational Level	Strategic Planning	Management Control	Operational Control
Unstructured	Wide range of variables Aggregation high Low accuracy	decreases → decreases → increases →	Medium range of variables Aggregation medium Medium accuracy
Semistructured			
Structured	Medium accuracy Aggregation medium Medium range of variables	increases → decreases → decreases →	High accuracy Very detailed Narrow range of variables

value and function as a fixed or changeable factor. The third is the feasibility of data collection plans and scheduling. Considerations in all three areas will influence the shape of the ultimate model.

Human Factors

The objective in developing a model is to use in a decision process the information produced. While the validity of the information depends on technical factors based in the model's structure, its utilization depends on the willingness of the participants to accept and consider it.

Modeling is not the usual method of researching decisions in most higher education settings where models are introduced. The model represents an innovation and intervention in a familiar and known pattern of making decisions. The model does not enter a setting as a welcome and sought-after tool; it enters as a competitor to traditional thought structures which rely on existing information and routines for using it. Two kinds of problem may arise as a result. The first has to do with the attitudes and behavior of the individual decision makers who are party to the decision. The second has to do with characteristics of the organizational group.

Ungson, Braunstein, and Hall (1981) have reviewed the considerable research which has been conducted on the influence of individual cognitive styles in the gathering and processing of management information. The research on this subject is still too undefined to provide useful guidelines to the practitioner. Although there are varying conceptual approaches and definitions, two central factors appear to influence most of the measurement instruments which have been developed. These are the manner in which people gather information and the manner in which they process or interpret it (Bariff and Lusk, 1977, p. 822). McKenney and Keen (1974) propose a matrix along these two dimensions, defining the information-gathering categories as "perceptive" and "receptive" and the processing categories as "systematic" and "intuitive." The resulting four-cell matrix identifies distinct cognitive styles which are significant for the modeling consultant. The authors suggest that a systematic manager aims at a model with predictive power and carefully defined constraints while the intuitive manager tends to use models to understand problems better and is less concerned with margins of error and detail.

The consultant is confronted in the academic arena with a broad array of thinking styles which are rooted in disciplinary norms. Explaining a model to a nurse or an English professor is quite different from explaining one to an engineer or an economist. The consultant needs to be sensitive to these differences in clients in order to adjust the presentation of the technique and results as well as the model design itself to the thinking styles of the audience. While there is some disagreement in the literature regarding the degree to which the decision maker must understand a model before utilizing it (Massy, 1981; Schroeder, 1973; McKenney and Keen, 1974), it does appear that there must be a minimum level of understanding prior to acceptance. The consultant must therefore tailor presentations to help the client bridge the gap between understanding the model and trusting in it.

A second consideration which the consultant must address has to do with individual resistance. In their book about organizational change and innovation, Zaltman, Duncan, and Holbek offer an extensive list of the many forms of individual resistance (1973, pp. 94–104). The resistance may derive from anxiety about understanding the model or from fear that the model will take away decision-making power. It may also be based on the perception that, while interesting, the model is not relevant to the problems at hand. This attitude leads to perfunctory participation in the model development and can yield inaccuracies in the model's data and structure.

Decision-making traditions or social climate at the organizational level may interfere with utilization of the information as well. Organizational groups have distinctive styles of decision making which vary from the data oriented and systematic to the political, intuitive, or consultative. Introducing a model to a group of the first type is less difficult than to a group of the second type. Even the data-using organization, however, may distrust the output of a model because the information is in an uncustomary form and no behavioral routines exist for making use of it. A process must exist through which the results can be reviewed, debated, and related to the decisions if the information produced by a model is to be used by a group. The consultant may have to help the group design such a routine.

The social climate of a group may affect the manner in which models are used, in that the results of a modeling effort are subject to manipulation. They can be used to the political advantage of a faction, or they can be discredited and ignored if key people do not endorse the effort. The model may uncover hitherto unknown or unrecognized inequities, or it may identify circumstances which require the negotiation of conflicting and politically charged data sources. The curriculum costing model that was used at the University of Michigan, for example, requires both an average salary figure and a workload parameter. These are often sensitive issues on a campus.

How can the consultant avoid individual or group resistance and motivate the client's interest in the modeling effort? Careful attention to building the client-consultant relationship is recommended by Kolb and Frohman (1970) who describe an organizational development approach to technical consulting. Organizational development consulting typically addresses problems and methods of intervention in the personnel interactions of an organization (French, Bell, and Zawacki, 1978). Kolb and Frohman, for instance, stress the entry phases of the consulting relationship before model development begins. During these phases of scouting, diagnosis, and planning, the consultant must sense how the people will react to the model and how the model will fit into decision routines, in addition to thinking about more technical issues. The consultant must also establish credentials and credibility, since these help build the client's trust in the utility of the model-building exercise. Finally, the consultant must demonstrate and reinforce her/his impartiality if the social climate of the client group is politically charged or distrustful.

Other contributors to the organization development literature stress the importance of establishing a clear and explicit contract before actual work begins (Lippitt and Lippitt, 1978). The contract limits expectations and specifies roles and responsibilities in order to prevent later disagreements on who will gather the data, who will have access to it, and the like. The contract does not require a legal format, but it should be explicit and written.

The modeling consultant is typically an outsider to the client unit. This person may be associated with the central administration in a university or college and, as a result, may be perceived by the client as biased. It is important to be clear about the consultant's role, since abuse of this role is possible on both sides. Because the consultant is an outsider, a certain amount of slow progress must be anticipated during the period when the consultant and the client are developing a communication base and learning to understand each other's way of thinking.

To ensure that the results of a modeling effort are used, the consultant must pay attention to the human factors relating to individual attitudes and organization-level norms and climate.

Guidelines on how to work with these issues are found in the applied consulting literature of organization development. Key elements include building a relationship with the client and careful diagnosis of the setting during the entry phase.

Roles of the Model in the Decision Process

The purpose of using a model is to support the process of making decisions. This support can be supplied in a variety of ways. Hopkins and Massey (1981, p. 18) refer to line and staff roles for a model, paralleling the terminology used for types of delegation to employees. The line role delegates decision responsibility to the model. An example of such delegation is the German system of *Numerus Clausus,* which assigns entering students to disciplines and universities based on grade point average scores in high schools. Strictly applied resource allocation models are another example of line delegation. While the responsibility for the decision remains with the decision maker, the model's function in the staff role is to illuminate the options.

The range of possible roles for models is broader than the two just mentioned. Models can provide a neutral, common language for describing the activities of different organizational units. They can be used to lend credibility to decisions after the fact. They can also be used educationally to bring important issues to the attention of a large constituency. At the University of Michigan, a revenue and expenditure model and an enrollment projection model were used in 1978 to convince deans and faculty of the need to reallocate within the general fund. Both models were simple and highly aggregated in order to show main trends and future possibilities.

Models are often referred to as useful primarily in the context of a single problem and related decision. They can also be used, of course, in an environment with many problems and decisions, all of which affect each other. The interrelation of various decision processes is sometimes ignored, particularly in decentralized settings. To counter this tendency, models can be constructed to connect separate but related decision processes at different levels of the organization.

The role a model assumes depends in part on the point in the decision process where the model is used. Many frameworks have been developed to describe the phases of decision making. A useful one was developed by Mintzberg, Raisinghani, and Theoret (1976, p. 252). This framework renames three phases identified earlier by Simon (1965, p. 54). Mintzberg calls his phases "identification, development, and choice," and identifies several subroutines within each phase. For our purposes, the simple trichotomy is sufficient.

The University of Michigan example just cited illustrates a use of models in the problem identification phase. Before the university's central administrators used the models publicly to raise the awareness of the university community, institutional research staff had used the same models internally to explore the extent of the financial difficulty that the university was facing and to convince the budget officers to take action. A similar use of models, reported from Stanford, motivated Stanford administrators to undertake the Budget Adjustment Program. Models can be used in the development phase to set out various alternative courses of action or to test their implications. Finally, in the choice phase of decision making, models can be used to set bounds for decisions or even to *make* the decisions, as reported in the *Numerous Clausus* example.

Modeling support in decision making can assume a variety of roles, depending on how the information produced is used. The role assumed is influenced in part by the phase at which the model enters the decision process. The contract between the consultant and the client group must consider the expected role of the model in the decision process. In order to avoid confusion later, the various possibilities need to be discussed openly.

Adapting the Model to the Decision Setting: Case Examples

In the late 1970s, the University of Michigan invited an external consultant to develop a curriculum cost construction model for the School of Pharmacy. The authors provided staff assistance to the consultant and then were directly responsible for developing similar models for two other health science units, the School of Nursing and the Program in Physical Therapy. In each case, the conditions surrounding the initiation and development of the model influenced the shape of the final product and its use in the decision.

The model used for these costing efforts is based on the work of Gonyea, Harper, and others who have focused on the problems of describing health professions education programs in terms of resource requirements and cost. A more detailed discussion of some of these problems and suggested approaches for managing them can be found in Gonyea (1978).

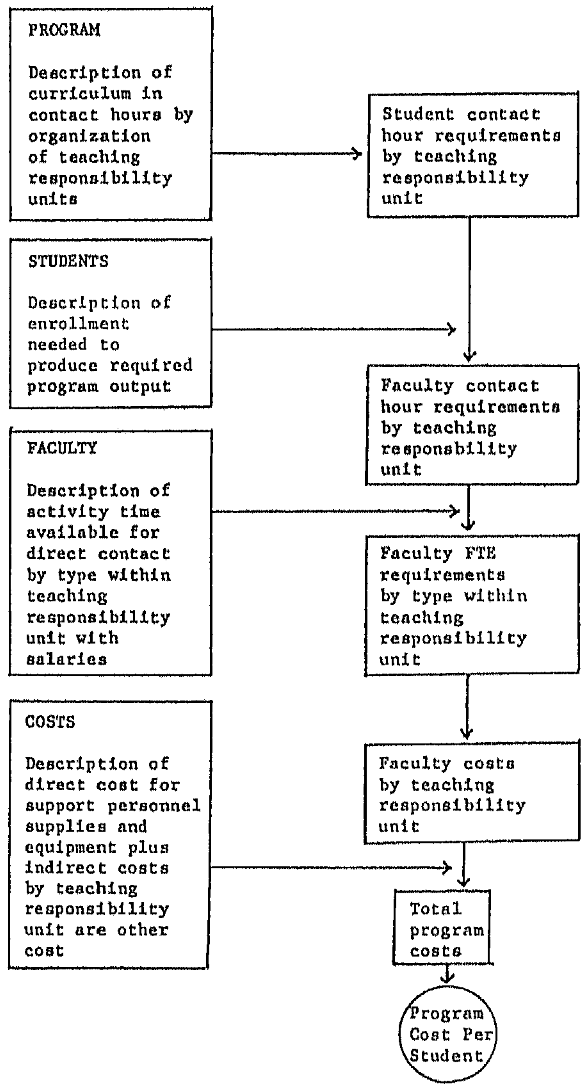

Figure 1. Program cost construction. (From "Program Cost Construction Research in Progress" by M.A. Gonyea and R.I. Harper. In M.A. Gonyea (Ed.), *Analyzing and Constructing Cost. New Directions for Institutional Research* (No. 17). Copyright 1978 by Jossey-Bass Inc., Publishers. Reprinted by permission.)

The basic components of the curriculum costing model are illustrated in Figure 1 and can be summarized as follows: (1) a course-by-course description of the curriculum in terms of the required student contact hours, (2) conversion of student contact hours to required faculty contact hours, based on given enrollment levels and section size constraints, (3) conversion of faculty contact hours to faculty FTE, given workload assumptions, (4) estimation of faculty costs and total program costs, and (5) calculation of the program cost per student.

Some of the advantages of this model are its simplicity and flexibility. Programs can be described uniquely or aggregated to a general pattern, depending on need. The model can be used for predicting faculty staffing requirements, for estimating the impact of various enrollment levels on affected units, or for exploring new instructional modes, in addition to determining per-student curriculum costs. It can properly be described as a curriculum *planning* tool as well as a costing method.

When the curriculum costing model was used in the three health science schools, a number of technical adjustments in the basic model were required to suit the particular information needs of each school. Human issues were also important. In each decision setting, the institutional research staff had to be sensitive to the social climate and thinking of the decision makers who were to use the model.

Model Technology. Fitting the basic cost construction model to the decision settings in Pharmacy, Nursing, and Physical Therapy resulted in three models which differed in parameter definitions, level of detail, and degree of precision. In both Pharmacy and Nursing, the decisions to be made were semistructured management control decisions. The schools needed to determine what configuration of degree programs and enrollments were academically desirable and feasible. They also needed to explore the faculty resource requirements, given constraints on budget and curriculum. These same decisions had strategic implications for the central administration, since major revisions in curriculum and enrollment required additional resources to fund them. These resources had to fit with long-range budget plans and priorities for the institution as a whole. The cost construction model was able to meet both kinds of information needs, and it facilitated the discussion across organizational levels.

Adjustment of the model to the decision began with the negotiation of parameter definitions. While "programs" were defined in the Pharmacy and Physical Therapy cases as "degree programs," this definition was expanded for Nursing to include a set of service courses offered by a research unit within the school. Differing definitions for the length of the academic year and for faculty FTE (e.g., nine-month versus twelve-month FTEs) were also needed. All definitions were questioned in terms of their appropriateness to and consistency with the purpose of the model and its structure.

The Nursing model was the most complex and detailed of the three, due in part to the number of degree programs within the School. Matching the level of detail to the decision setting resulted in a more aggregated approach in Pharmacy and a truncated approach in Physical Therapy where the primary interest was in the direct instructional cost of the program and not in the overhead costs.

The relationship between fixed and variable parameters became important in adjusting the model to fit needs. The workload parameter, for both Pharmacy and Physical Therapy, was fixed after a reasonable figure had been derived from analysis of actual data. In Nursing, the workload parameter became a major policy variable. The School wanted to increase the research efforts of the faculty, but this implied decreasing the average instructional workload. Several alternatives were tested through the model. The policy implications of this were many—including some that were unrelated to the model, such as hiring and promotion practices, and some that were related directly to other model parameters, such as average faculty salaries.

Fitting the model to the practicalities of data availability and time constraints did not pose any serious problems. The simplicity of the model structure meant that computerization was not necessary. However, the time required to develop the model in the three settings varied considerably. Physical therapy required two months and Pharmacy required several weeks. Nursing, on the other hand, took almost a full year to complete because of the complexities of the issues and the need for extensive data-gathering efforts involving several sources. The practicalities forced some compromises to be made along the way. Nursing, for example, desired a greater level of detail about program structure than was feasible, given existing data sources. It was necessary, therefore, to spend several hours with each program investigating, course by course, how much time was spent in each mode of instruction.

The validity of the model in all three cases was verified by describing the year just past and comparing the predicted faculty resource needs and total costs with the actual needs and expenditures. The process of verifying the model and exploring the discrepancies which emerged helped build the confidence of the faculty and the modeling consultants in the model's definitions and structure.

Human Factors. Cognitive style proved an important factor in the shape of the model that was developed for Pharmacy and Nursing. The Pharmacy participants tended to take a perceptive/intuitive approach to the model. That is, they were concerned with looking at the broader relationships of the model components in order to get a better sense of the problem. Specifically, this meant a willingness to use a generalized graduate program description and to tolerate a certain margin of error because the focus was on the relationships of the data, not on the details.

In contrast, to this, the Nursing participants tended to take a receptive/systematic approach which meant a focus on detail and a greater concern with accuracy. As a result, each of the seven graduate nursing programs was described in a very structured and highly detailed manner. The role of the consultant in this setting was to shape the model to reflect the concerns about detail and accuracy and, at the same time, to help the nursing faculty use the model as a tool for broadening their conceptualization of the problem.

The nature of the three organizations proved to be an important factor, especially in the case of the School of Nursing. Data collection took place in a highly charged political climate. The School was attempting to resolve several major issues at one time without a clear sense of overall direction. The result was that among the various internal factions and departments, there was conflict over what the goals of the school ought to be and a sense of competition for scarce school resources. It is not surprising that initially many of the departmental chairpersons viewed the model with suspicion. Fears that the model would be used as a political tool rather than as an information tool were expressed frequently. The faculty also felt that the Office of Academic Affairs was intervening in an area of decision making that was not its domain. The fact that the modeling consultants came from that office did not help.

This difficulty was overcome by emphasizing three points in contacts with the faculty. First, the neutrality of the model was stressed by making it clear that the model's only agenda was to reflect some alternative courses of action as objectively and as accurately as possible. Second, the chairpersons were assured that their full approval was required for the final model description of their respective programs. Finally, the potential benefits of the model for planning purposes at the program level as well as at the school-wide level were emphasized. Making sure that each of the participants understood the model fully was central to building a level of trust and was the basis for the model's main assumptions. This helped to reduce concern about possible political abuse.

This example illustrates that the role of the consultant must be much more than that of a technical expert. The consultant may have to assume the role of persuasive communicator, neutral negotiator, or insightful policy analyst. Activities in the beginning phases, such as scouting and diagnosis as well as model development itself, depend on the consultant's ability to ask the right questions and the client's ability to provide relevant information. Some of the graduate program descriptions in the Nursing case, for example, were revised two or three times before they reached their final form. Throughout the revision process, the politically charged atmosphere and a long-term feeling that the School had been unfairly treated at budget time necessitated more than usual attention to fostering trust and to establishing the credibility of the modelers.

Role in the Decision Process. The utility and effectiveness of a model is very much dependent on whether it is developed as an integral rather than an external part of specific decision processes. The effectiveness of the cost construction model used in the three University of Michigan cases lies in the fact that it was tied directly to one of the most basic and key decision processes within the University—the budget request and allocation process. In terms of its role in finalizing decisions, the model was intended to function in a staff capacity as part of the problem development phase rather than in a line capacity. The cost construction model was not developed to make decisions but, rather, to enhance the judgment of the decision makers (vice president, deans, program chairpersons) by exploring alternatives and expanding their understanding of the problems at hand.

The model provided a common language for negotiating the allocation of resources, internally and externally, in addition to helping the units explore alternative curriculum and enrollment strategies. For both Pharmacy and Nursing, the negotiation process took place between the deans of the schools and the vice president for academic affairs. The model not only helped to frame the negotiating issues but also provided both "hard" evidence that the changes would require increased funding and an estimate of the magnitude of that increase. Both parties in the negotiation process understood the model well enough to be able to challenge and question some of its assumptions and to suggest other alternatives to be tested by the model. For example, the vice president in the Pharmacy negotiations questioned whether an increase in clinical hours, in order to meet accreditation standards, was more than was required. Further analysis showed this to be the case, and the model was revised to reflect a smaller increase. This change resulted in a significant decrease in the resource requirements projected by the model. Because of the effort put into educating participants about the model and involving them in its development, its basic validity was not called into question at any point during the negotation process.

The potential for misuse of a model, either deliberately or inadvertently, always exists. The cost construction model was initiated within the School of Nursing to decide some very specific staff assignments in the undergraduate program. This was an inappropriate use since the structure, components, and accuracy of the model were not designed to replace judgment in these types of decisions. This suggests that once a model is implemented and accepted it can easily take on a validity and life of its own, beyond the original intentions. Obviously, the consultant cannot prevent such misuse once the client has assumed full ownership. Attempts to use the model inappropriately can be diverted during the model development stage through careful consultant-client discussions on the role of the model and its strengths and weaknesses for that role.

Finally, it should be noted that most decisions require more information than the model itself can provide. Supplying supplemental information may be an additional responsibility of the consultant, particularly if he/she is an institutional researcher. In the case studies described here, for example, model results were supplemented by tuition revenue projections for various enrollment alternatives and by an enrollment study which analyzed the feasibility of the proposed alternatives based on historical, demographic, and professional supply/demand trends. The kind of supplemental information required will, of course, depend on a number of factors, including the nature of the decision, the nature of the model, and the unique information needs of the decision maker.

Summary

Analytic models can be integral and effective components of the decision support systems of college and university administrators. To facilitate their use, three areas of concern need to be addressed by persons sharing the responsibility for introducing, developing, and implementing a model in a particular setting.

1. The model's technological aspects must be appropriate to the decision, feasible in terms of practical considerations, and of demonstrated validity.

2. Although various human factors are more difficult to control in the modeling process, there are human factor issues which need to be considered, including the cognitive style of the individuals receiving the model results, the political climate and managerial decision-making traditions of the organization, and the role of the consultant.

3. The role of the model in the decision process must be understood—that is, at what stage it will be used, how it will be used, and by whom.

It is only by viewing models in a broader technological, social, or procedural context that one can hope to achieve more effective use.

Institutional researchers are vital to the effective integration of models into the decision context of higher education because they know both the technical and the policy sides of decisions in their institutions. They are able to make the needed adjustments without compromising the technical structure of the model, but more importantly, they can avoid the numerous pitfalls which have impeded widespread acceptance of models as analytic tools in higher education by carefully analyzing the human setting in which the models are to be used.

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Appendix I
PROGRAM COST CONSTRUCTION EXAMPLE

1. Student contact hours per 15-week term:

Course \ Class Type & Size	Lecture (35)	Laboratory (10)	Tutorial (1)	Faculty Type	Total Hours
100	30		3	Professor	33
		60		GSTA	60
101	45			Professor	45

2. Implied faculty contact per 15-week term—25 students:

Course	Number of Students	Lecture (35)	Laboratory (10)	Tutorial (1)	Faculty Type	Total Hours
100	25	30		75	Professor	105
			180		GSTA	180
101	25	45			Professor	45

3. Conversion of faculty contact hours to FTE:

a. Professors provide 135 hours of class and tutorial contact per term per FTE. To staff the above courses requires the following FTE:

150 ÷ 135 = *1.11* FTE Professor

b. GSTAs provide 60 hours per .25 FTE appointment per term, or 240 hours per FTE, and must supply 180 hours for the above courses.

180 ÷ 240 = *.75* FTE GSTA

4. Calculation of faculty cost:

1.11 FTE professors at $25,000	= $27,750
.75 FTE graduate student teaching assistants at $10,000	= 7,500
Total	= $35,250

5. Calculation of total cost including overhead:

Faculty cost is multiplied by a conversion factor of 2: 2 × $35,250 = *$70,500*

6. Calculation of per-student cost.

$70,500 ÷ 25 students = *$2,820*

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