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ABSTRACT

This report provides an extensive discussion of the use of criterion referenced, mathematical modeling procedures to determine which budget reductions minimize reduction in the quality of educational programs. Part I, "Evaluation of Potential Budgeting Roll-backs under Educational Fiscal Crisis," explains the basic design of multiple alternatives analysis and the context for its use. Chapters include (1) philosophical foundation for fiscal modeling, (2) program budgeting for an allocation/deallocation fiscal strategy, (3) traditional modeling via cost analytical design, (4) operations research and the evaluation of feasible alternatives, and (5) simulation modeling within a criterion-impact design. Included also is a background to the field investigation and outline of the technical report. Part II, "Multiple Alternatives Analysis as a Mathematical Decisioning [sic] Model," provides the technical and mathematical details of the analysis, including both construction and validation. Part III, "Field Application of the Rolbak Model," contains an extensive sampling of the use of these procedures in reducing a budget within a local school district, including chapters on (1) construction of the database, (2) initial T-normal transformations, (3) formulation of the rolbak mathematical model, (4) search for regional feasibility as a benchmark, (5) cyclic optimization of the restricted model, (6) cyclic optimization of the relaxed model, and (7) comparison of the restricted and relaxed "decisioning" models. Part IV summarizes the Multiple Alternatives Model and assesses its future. (TE)

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No. 70 MULTIPLE ALTERNATIVES MODELING IN DETERMINING FISCAL ROLL-BACKS DURING EDUCATIONAL FUNDING CRISES

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PREFACE

The Research on Evaluation Program is a Northwest Regional Educational Laboratory project of research, development, testing, and training designed to create new evaluation methodologies for use in education. This document is one of a series of papers and reports produced by program staff, visiting scholars, adjunct scholars, and project collaborators--all members of a cooperative network of colleagues working on the development of new methodologies.

How can one determine the proper mix of educational programs to receive reduced funding when budget cutbacks are necessary? This report provides an extensive discussion of the use of criterion referenced, mathematical modeling procedures to determine which budget reductions minimally reduce the quality of educational programs. Part I of this report explains the basic design of multiple alternatives analysis and the context for its use; Part II provides the technical and mathematical details of the analysis; and Part III contains an extensive example of the use of these procedures in reducing a budget within a local school district. This report describes a highly technical but workable solution to the difficult problem of reducing school budgets.

Nick L. Smith, Editor
Paper and Report Series

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INTRODUCTION TO THE SURVEY

Educational decision-making has evolved into a most complex and demanding process. What was once a realm almost completely associated with experience and 'arm-chair reckoning', administrative perogative now demands a highly informed, structural and often equally complex approach to problem remediation. Educators and educational administrators in particular, have over the past several years chosen to ignore the need to develop more sophisticated decision-making strategies. Now however, the direction is clear. Problems representative of desegregation, declining enrollment, school closures, distinct consolidation, attendance boundary redistricting, P.L. 94-142 compliance and (education's perennial nemesis) reduced funding allocation -- taunt every educational system, from small school districts through state and federal offices.

Many of today's complex educational issues can be translated into what has become known as the "multiple-alternatives problem" (Wholeben, 1980a). For example, in evaluating several elementary school sites for closure, the question is not, "whether site-A versus site-B is closed" but rather <u>how many</u> sites and <u>which</u> ones should be deactivated in order to fulfill: (1) the objectives of the required decision (what we will come to call 'constraints') and, (2) the needs of the district involved (which we will soon learn is the 'conditional vector'). Likewise in developing sophisticated curricular systems, the specialist discovers that many alternative instructional activities exist which could be implemented in fulfillment of the requirements for a priori stated instructional objectives (themselves related to desired concept-learning). Obvious resource factors such as time, cost and the varying expertise of available personnel militate against the otherwise optimal solution of "doing everything". However, the actual problem is much more subtle. For example, how related are activities 'A' and 'B' in regard to satisfying some aspect of objective A? Is A more costly yet more effective, while B is less costly but not as effective? Are both A and B similarly efficient in terms of time required for presentation and/or conclusion of the activity(s) itself? And even more subtle, does the selection of A in terms of some stated objective affect the activities that may be chosen for another objective, related to a different though required concept?

Thus, the multiple alternatives approach to modeling various complex situations in the educational sector is itself a complex milieu; with the purpose of designing a thorough, highly-structural decisioning model to adequately assist the educational decision-maker in understanding, analyzing and decisioning (sic) the multiple alternatives' problems faced today.

The treatise contained within this present paper concerns the expositon and multiple-alternatives interpretation of another complex and highly volati problem in education, to wit:

> Given a situation of reduced funding allocation (and therefore required reduced expenditure) across educational programs, how many programs will be funded and which ones; subject to the budget being balanced and the goals of the school (district) maximized ... while (of course) minimizing any perceivable negative impact upon the system as a whole.

This is the context of fiscal roll-backs; that is, "rolling-back" program execution due to some level of reduced expenditure necessitated by a funding crisis (levy failure, reduced state and/or federal matching support, or the irrational requirement to transfer monies from one account into another (program to program) because one program is P.L.-mandated (public law), while the other is not (though required nonetheless).

This paper addresses (and hopefully satisfies) three main goals. First, the reader will gain an understanding of the budgeting roll-back (alternatives) situation under fiscal crisis. Contained within this intended understanding will be the investigation of "allocation versus de-allocation" as a fiscally-oriented decision-making strategy; and the relevance which traditional cost/benefit modeling provides to the interpretation of a multiple-alternatives framework.

Secondly, the reader will be introduced to a relatively complete (albeit brief but hopefully not cryptic) discussion of multiple alternatives analysis as a decisioning model. Principles from the generation of collectively-exhaustive decisioning alternatives to the development of system-constraints upon that decisioning will be presented and illustrated. Suggestions for validating the constructed model will be provided; and the limitations of the model itself, discussed.

The third and final goal of this treatise is to present the detailed results from a field-application of the fiscal roll-back decisioning model. Identification of the various multiple alternatives (viz., programs) discussed, the development of the constraints (system objectives) defined, and the construction of the modeling framework illustrated. Finally the impact upon the system of the various programs chosen for funding (or defunding) will be investigated via certain statistical procedures; and the role of the modeling constraints demonstrated in terms of the degree (or extent) to which the model "modeled" the simulated decision-making environment.

A final word (of caution) is required at this point for the reader. As discussed in the last section (IV-A-1) of this paper (Complex Approaches to Complex Issues, pp. 138), it is well to understand one of the many (rational as well as realistic) biases of the authors.

Educational decision-making today is a tricky business, full of hidden agenda and unforeseen pitfalls. The responsible decision-maker views a complex issue as (therefore) complex; and does not subscribe to the overused adage, "simple solutions to complex problems should be your objective." Obviously, the problem solver cannot attach issues by "making mountains out of molehills", but must nonetheless recognize each "molehill" as a particulate-source of a "new mountain."

It is not the hidden goal of the authors to convince the reader, that the multiple alternatives approach to certain educational problems is the perfect solution. However, we do very strongly suggest that it is certainly one of a minority of preferred techniques which the emerging educational administrator must be aware of and rudimentarily understand.

Good reading!!

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PART I

EVALUATION OF POTENTIAL BUDGETING ROLL-BACKS UNDER EDUCATIONAL FISCAL CRISES

INTRODUCTION

This section explores the philosophical rationale underlying the modeling of fiscal alternatives in response to budgeting cut-backs, and provides a foundation for viewing the program funding/allocation decision as either an 'allocation' question (i.e. giving to) or a 'deallocation' question (i.e. taking away). To illustrate the rudiments of decision modeling, the basic trends of the traditional cost/benefit model are defined and discussed, especially with regard to applying multiple, competing criterion measures across multiple (potential) alternatives solutions. The four main criterion foci of effectiveness, efficiency, satisfaction and expenditures are discussed relative to multiple decision evaluation; and the ideas of preference and trade-off (compromise) necessitated by the existence of multiple criteria in competition with one another are summarized. Finally, the application of operations research techniques as a tool for evaluating potential alternatives is presented for the reader's understanding.

Part I prepares the reader for the technical discussion (to follow in Part II) regarding the actual construction of the multiple alternatives model (MAM), through the development of a MAM-orientation in a fiscal budgeting (allocation, etc.) situation. Thus this development is situation-specific (to fiscal management) and will hopefully facilitate the understanding of the MAM decisioning context. This parallel theoretical-application discussion will hopefully allow the more discerning reader to view the wide-range of application(s) available to the multiple alternatives design. The reference bibliography at the conclusion of this report will allow the masochistically-inclined reader the ability to read more in the subject of fiscal budgeting and decision-framework for analyzing allocation-strategies.

PHILOSOPHICAL FOUNDATION FOR FISCAL MODELING

Fiscal modeling refers to the studying of an environment in which some decisions are required concerning funding allocations and expenditure control. Practitioners assume that allocation by itself is an automatic interval-control for expenditure. Forgotten (or consciously misplaced) is the notion which goes beyond the question of "how much spent, totally", to the more provocative and accountable inquiry, "how much spent, how (in which ways), and where, totally". The decisions required in order to fund certain programs in lieu of other (equally deserving) programs necessitate that the decision-maker (allocator) understands what monies will be spent where, how and why; and in addition the impact that such expenditure will have upon the total (e.g. district) program in philosophy as a whole. To understand such impact (both validly and reliably) and to be able to make the decision(s) required, certain requirements are mandated.

First, an obvious need exists to define, develop and measure various criterion-variables in order to be able to compare the alternatives; and measure the impact of their funding versus non-funding to the system as a whole. For example, women's athletic programs in higher education have been highly subsidized on some campuses by income from the men's collegiate-varsity sports programs, and from other specially ear-marked funds out of the general student-programs administration budget. As budgeting cutbacks become a fiscal reality in higher education, and increased costs aggravate the existence of less monies, the women's sports program becomes a likely candidate for 'cutback' or complete defunding (cut-off). A sample of the impact-criteria required by this decisioning situation might be noted as:

(1) measures(s) of total savings, delineated into sub-expenditure (object codes), so that the worth of each 'savings' (or 'expenditure') area is known;
(2) measure(s) of total impact to the prevailing campus philosophy of equal opportunity, equity and affirmative action; and
(3) measure(s) of relative worth in retaining or discontinuing this program, compared to other programs (alternatives) which could provide equal revenue savings (eg. campus and grounds maintenance, security, remedial ("bone-head") lower-division courses).

It should be clear that two factors are operating in any MAM-decision. First, the need exists to maximize the positive impact to the system, while minimizing any negative by-products. Second, there must be a near-exhaustive (though empirically impossible) collection of criteria through which to measure both positive as well as negative impact. In reality, it becomes (itself) a goal of the model builder: to utilize the best kind(s) and most type(s) of criteria in order to validate model results.

Maximizing Program Goals Within Budgetary Limitations

Funding cutbacks relate both to the specific form of program (e.g. student activities, gifted education, transportation) and to the more generic definition in which the collection of all programs becomes the 'program' of a higher order (e.g. the same district program). In maximizing the 'good' and minimizing the 'evil', the decision-maker must be alert to which level of program is being referenced. Obviously a criterion related to the co-curricular portion of a student activities program,

> "to maximize the quantity and extent of each student's participation within co-curricular activities,"

may have greater weight to the SBG/ASB advisor than to the principal who needs a higher funding level for a 'back-to-basics' remedial curriculum.

At either level, the focus is identical:

> "to maximize program goals within budgetary limitations",

while minimizing the impact of any budgetary cutback decisions to the system as a whole. Fiscal modeling thus takes on the appearance of a system of compromise -- that which is possible versus that which is desired. By juxtapositioning maximal benefit against minimal harm, each fiscal alternative's "weight" and "importance" become readily apparent, and available for comparative evaluation.

Partial Defunding v. Selective Deallocation

Parallel to the discussion on maximizing program goals (desired outcomes) within established budgetary limitations is the economic notion of a 'break-even point'. Often times, the educational decision-maker announces a cut-back decision on a percent (or percentage) decrease in allocations. The program chairs are advised to "do their best with less", often without reflections upon whether the resulting limits placed upon program goals can be realistically achieved. At some point (the 'break-even point') reduced expenditure (reduced funding) results in program performance occuring below acceptable program goals; and thus opens a forum for discontinuing that program's operation which would then result in the savings of the total potential expenditure. The decision-maker must take into account, however, the potential of negative outcome to the system; and thereby consider an increase of funding to that particular program, with commensurate decrease to another program(s).

Clearly, this decision process is complex. Not only must all combinations and permutations of the programs being compared (multiple alternatives) be analyzed, but the system impact of each combinatorial permutate must also be assessed across all criteria. (Sounds frightening, does it not?) This line of thought is further aggravated by the aforementioned notion of "multiple funding levels" per program. Yet as hopelessly ridiculous as it may appear, the decision must be made -- and is being made in every funding cycle of every district.

Two avenues of approach to the allocation decision may be made. First, reduced funding allocation is permissable <u>if and only if</u> the resulting reduced allocation does not "significantly" (or magnitudinally) lower both <u>specific</u> and <u>generic</u> program goals, below some agreed-upon acceptable level. That is, why fund a program that cannot fulfill its program goals at a reduced expenditure level? The second approach however is a more direct maneuver than the partial defunding approach, and can best be described as selective deallocation.

Consider the various multiple alternatives as specific programs whose collective outcomes form the district's generic program orientation. Further, consider that some of the programs are modeled at "full-funding", some at a "minimally-acceptable level", and others at some discrete point in between. The decision now becomes to fund (allocate) at full or acceptable levels, or not at all. This focus upon selective deallocation is of the utmost importance, in order to provide a control for regulatory accountability to the decisioning framework.

Funding Allocation v. Regulatory Accountability

The virtue, "better to give than to receive" cannot be applied to fiscal allocation cutbacks during budgeting crises. As was said in the preceding sub-topic, some distinguishable point must be defined beyond which a cut-back decision automatically becomes a deallocate ("cut-back") decision. Such decision-making must come from the generic-program administrator; the specific-program chair is not likely to voluntarily offer such suggestions. But since it is true, that "it is easier to give than to account for", the necessity for some form of regulatory accountability is obvious.

The major concern in this regard is of a volatile, political nature. The decision-maker must take initiative in determining the level of acceptable funding, and moreover operationalize the stance that at some "defined" point, the program will be deallocated instead of partially defunded. It is the opinion of the authors that all fiscal roll-back decisions be made under a discrete deallocation philosophy, rather than a progressive partial defunding scheme. Such a structured, disciplined approach is more than offset by the enhanced accountability to the modeled fiscal system.

Full Systems' Orientation To Input

A model of a fiscal system, assisting the decision-making framework for selecting programs to be funded or defunded (rolled-back) is only as reliable as its ability to simulate that system. Reminiscent of the days of systems' planning, organizational development and participative management, a fiscal system's model must so accurately simulate the original environment, that any influence (criterion-related) to the real system is also influential to the fiscal model (i.e. validly modeled). Furthermore, output from the systems' model due to modification of those criterion-variables explaining (constraining) the simulated framework, must also reflect the changes expected to the real system (i.e. reliably modeled). Such a one-to-one correspondence between reality and simulated model requires a full systems' orientation to input.

Input to any model simulation refers generally to the effect imposed upon the model by the criterion-variables used to exemplify the real system; such criterion-referenced measures are known as constraints. The utility of full systems' constraints in accurately and consistently modeling reality is witnessed in three areas. <u>First</u>, the real system is controlled by the main and interactive effects of input from innumerable sources, both internal and external to the system. In the multiple alternatives context, such sources are modeled via the use of multiple competing criteria. Although certain sources may be more influential (i.e. weighted) than others, nevertheless no single input (effect) exists in isolation from the co-related effects (inputs) from other sources.

<u>Secondly</u>, the source of multiple criteria may itself come from multiple sources throughout the system. For example, in

deciding upon a certain curricular program for implementation, a reasonable criterion measure would be the extent of perceived effectiveness in instituting the designed learning change. Such perceived change however might be different for each individual subgroup: teachers, administrators, students and parents. Although a measure of 'learning affectiveness' is desirable, necessary also will be the modeling of a decisioning process where each of four sources are modeled independently (though simultaneously). If the model were to use only a single constraint to input a composite measure of effectiveness, the original variance between the five groups would be lost; and the system inaccurately models the environment surrounding the decision.

Finally, a full system's orientation to input must be modeled so as to allow an ability to compare inputed criterion measures (constraints) across the alternative programs. Only then can an adequate "consensus" model be developed to portray these system sources of impact.

PROGRAM BUDGETING FOR AN ALLOCATION/DEALLOCATION FISCAL STRATEGY

The reader will recall that a decision for allocation or deallocation of funding requires a discrete budgeting-level framework. By discrete, we mean that if a particular program can satisfactorily accomplish an acceptable number of its goals with reduced funding, the specific level of reduced funding must be identified and defined for that program. In this way, a multiple alternatives decisioning model for evaluating programs for fiscal roll-back can also assess a limited number of discrete levels of funding for any particular program. Therefore, program 'A' at full funding exhibits various measures of performance on such pertinent criteria as effectiveness and efficiency, as well as expenditure level. If it is ascertained that a certain part of A could be omitted from program implementation without significantly compromising A's worth, then it is reasonable to evaluate 'AX' along with A as two entirely separate feasible alternatives. That is, 'AX' will also exhibit its own measures of effectiveness and efficiency, with a reduced criterion measure for required expenditure level.

A note of caution and clarification is necessary here. The authors, accepting the discrete level of funding in modeling funding differences, thereby reject the closely related idea of partial funding via percent reduction. It is impossible to ascertain the effect upon a program of an intended 12 percent cut in allocation, unless the dollars associated with the 12 percent are identified specifically within the program. The act of "divoting-up" (sic) the reduction across all shares equally is both unreasonable and irrational (but we choose not to overstate our case).

Building the Fiscal Program System

The decisioning framework surrounding funding levels and revenue allocation has often traditionally been related to the concept of system-building. Under this paradigm, no programs exist a priori, and therefore all potential programs compete (though unequally) for some proration of the total available budget. Education became very enamoured with this concept of budgeting, referred to as zero-base budgeting; and many units used the concept during the early 1970's.

The philosophical elegance of a 'zero-base' model is interesting if not intoxicating: requiring each program to revisit its 'roots' and thus 'stand' the challenge from other competitive programs as they support their claims for even increasing levels of projected expenditure. Others believe that the elegance of the model ends with the statement of its philosophy.

Selecting programs for funding (that is, system building) can also be viewed as an assessment procedure for evaluating certain alternative programs to be added to an already on-going system, and thereby provide some degree of enhancement to the system's mission. Under funding crises however, the question is (normally): what do we cut?; not, what do we add? For this reason, the modeling of a fiscal roll-back decision-making process can easily assume the operational characteristics of the zero-base framework; that is, based upon a certain reduced expenditure budget, what reduced number of programs will continue to be funded?; the balance of the currently operating programs (non-selective) to then be discontinued.

Revising the Fiscal Program System

An alternative to the philosophy of building anew the system in order to indirectly determine cutbacks, is the idea of:

> given the current system of operating programs and their impact/effect upon the system as a whole, what programs can be directly selected for roll-back based upon their modeled performance criteria?

Through the philosophical stance of revision, the overall objective becomes to choose programs for deallocation while minimizing a decreased satisfaction of required/desired system goals, etc. In the case of fiscal roll-backs, a revision approach is the preferred procedure, though in a modified sense.

Since many educational systems are so large as to have hundreds of model-related programs, it would be very time-consuming to require the modeling of entire systems. An alternative is to model only those alternatives (programs potentially available for cut-back); and to choose from this list of 'feasible' expendable programs for solving the fiscal roll-back issue.

From a modeling protocol, the role of constraints in guiding the fiscal roll-back decision may be seen as: minimizing the loss of the contribution to total systems effectiveness and efficiency; while concurrently maximizing the expenditure differential which is destined for roll-back.

Benefits of Itemized Budgeting and Delineated Programming

As discussed earlier, the use of delineated programming in the form of multiple program versions, with different projections of discrete levels of funding, can be very beneficial in modeling fiscal systems for roll-backs. It was also stated that knowledge of the level of required funding (as a composite measure) was not as useful as a differentiation of the required allocation into specific delineated object areas of expenditure.

The typical educational budget is grouped into a series of expenditure areas (called objects) which pertain to such foci as salaries, benefits, supplies and materials, equipment and capital outlay. In a roll-back decision, it is reasonable that the decision-maker may desire to constrain some area (object) of funding greater than another. For example, the reduction in the amount of a floated bond issue may require cut-backs, such that the 'capital expenditure object' must be more severely constrained than other areas of object expenditure. Obviously, the administrator cannot allow programs to be implemented if a capital outlay is mandatory, to the success of these programs, with no capital monies available.

Often times the decision-maker may wish to segregate those programs which exceed the 'average expenditure level' from the remaining programs for more detailed scrutiny. Such an evaluation could easily be a useful strategy immediately preceding a full fiscal study of the current operating system. Finally, the impact upon the system of proposed roll-backs determined by a multiple alternatives modeling technique, can only be viewed via the individual expenditure categories if and only if the individual categories were originally modeled.

Testing for Strengths, Weaknesses and Responsiveness to Stated Needs

Prior to our eminent discussion of the cost/benefit modeling framework as a historical forerunner to the more powerful operations research technique we call the multiple alternatives model, it is advisable that the rationale underlying our preceding comments be reiterated.

Fiscal funding crises require (normally) some degree of expenditure cut-back; it has been the theme of this paper that such decisions should be program-wholistically oriented as compared to leveling a certain "equitable" percentage share across all programs. In other words, it may be more rational to discontinue an entire specific program, as compared to under-funding several of the generic program's specific entries. To operationalize this philosophy, all programs are viewed as multiple alternatives to a fiscal roll-back decision; and measured criteria are used (as contraints) to evaluate all potential combinations and permutations of these alternatives, to determine <u>how many</u> programs must be cut; and <u>which</u> ones. Discrete levels of funding in order to determine various delineated programming alternatives has been discussed as a recommended procedure.

The rationale in the preceding sections has been presented in order to introduce a particular philosophy; and that philosophy reflects the necessity of testing for the comparable strengths <u>and</u> weaknesses between and among program deallocation alternatives; and to specifically determine (understand) each program's (or group of programs) responsiveness to expressed needs of the problem originally intended for remediation. In short, to know <u>what</u> a program is doing and <u>how</u>, and to be able to state <u>why</u> that particular program (selected via evaluation modeling) was 'rolled-back'. Such are the ingredients of a data-based, accountable decision.

TRADITIONAL MODELING VIA COST ANALYTICAL DESIGN

The plethora of cost analytical frameworks has focused mainly upon four specific evaluative or modeling designs: cost-benefit, cost-effectiveness, cost-utility and (though hardly an analytical framework, per se) cost-feasibility analyses. Some of these models support the use of multiple criteria related to a single focus, while other models prefer a singular criterion formed via the composite of multiple foci; but all models agree upon at least one postulate:

> The analysis (and subsequent selection) of an alternative course of action from among multiple alternatives; subject to the evaluation of each of the alternatives across multiple (or singular) criteria, which are purported to measure the alternative's impact upon the system (of decisioning) being modeled;

and such that:

(1) positive effects to the system are maximized;
(2) negative effects (as by-products) are minimized; and
(3) neutral effects (as desirable) are maintained at the central tendency of measured impact.

To accomplish this end-result, cost-analysis modeling has developed into a science of graphic displays, measurement schemes, and statistical overlays. To date, however, the serious shortcoming of many of the cost-analytical designs has been the model's inability to adequately control for interactive effects between (and among) criteria for any particular alternative being evaluated; and an inherent unreliability to systemically evaluate a multiple alternatives solution (where the selection of more than one alternative is necessary to adequately satisfy the required demands/needs of the system being modeled). Before solving this difficult problem of multiple solutions across multiple criteria, the reader must first grasp the more traditional aspects of cost-analysis design and modeling.

Application of a Decisioning Matrix

The choice of a solution from among multiple alternatives, via the evaluation of each alternative across multiple criteria, is easily viewed in a decisioning matrix format (see Figure 1, p. 20). With each column representing the values of stated criteria for a particular alternative, a m X n matrix is formed; consisting of m-criteria (measures) across each of n-alternatives (defined). And as a 5x8 matrix yields (5)(8)=40 cells, so does a m X n matrix yield (m)(n)=mn measures for evaluation. It remains these mn measures which will then be utilized by the decision-maker to judge which alternative action(s) is (are) the 'best' solution(s) to the problem being modeled.

The decisioning matrix provides a useful formulation for the eventual modeling of the fiscal roll-back context. Defining each of the various alternatives (A_j, j=1, ...,8) displayed in Figure 1 as potential programs to be rolled-back in a deallocation decision, the objective becomes: to select that particular alternative (A_j) which best exemplifies the stated criteria being used to make the deallocation decision; and which subsequently balances the budget. In reality of course the experienced practitioner realizes that more than a single alternative program may require roll-back if the criterion objectives are to be met. For the purposes of instruction and illustration of the argument however, only a single-alternative context will be illustrated. The multiple-alternatives context will be discussed in a later section. (Your patience will be rewarded.)

For each alternative A_j, then, there exists a series (column) of criterion measures, a_{ij} (i = 1...,5), reflecting the "nature(s)" of the alternative as measured by each of the i-criteria. In the selection of a single alternative, the

Figure 1. Standard Decision Matrix for Criterion-Referenced Analysis of Multiple Alternatives.

Multiple alternatives being analyzed.

		A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8
Criteria	#01	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}	a_{16}	a_{17}	a_{18}
Criteria	#02	a_{21}	a_{22}	a_{23}	a_{24}	a_{25}	a_{26}	a_{27}	a_{28}
Criteria	#03	a_{31}	a_{32}	a_{33}	a_{34}	a_{35}	a_{36}	a_{37}	a_{38}
Criteria	#04	a_{41}	a_{42}	a_{43}	a_{44}	a_{45}	a_{46}	a_{47}	a_{48}
Criteria	#05	a_{51}	a_{52}	a_{53}	a_{54}	a_{55}	a_{56}	a_{57}	a_{58}

problem involves comparing the valid a_{ij} measures in a reliable fashion, such that the "character" of each of the particular alternatives being modeled is understood; and thus a reasonable, rational and informed decision may be made (or at least "sophisticatedly guessed at"). To accomplish this analysis of the criterion impact via each alternative upon the system, a specific procedure must be devised.

The Composite Variable Ranking (CVR) Procedure

The reliable application of any procedure to the evaluation of alternative action access multiple competing criteria, must satisfy at least four primary requisites:

(1) The comparison (evaluation) of multiple criteria for each alternative, requires a single composite value representing each particular alternative be computed from the available criterion estimates;

(2) The computation of a single composite value requires all of the available criterion estimates be rescaled to a common measurement format, both in terms of units (e.g. dollars, square feet, number of pupils) as well as scaling (nominal, ordinal interval, ratio) -- that is, so that apples can be compared to oranges;

(3) The evaluation of the impact upon the system from the criteria being used, requires a method for analyzing the criterion impact across all alternatives (as well as the value of each alternative across all criteria); and finally,

(4) The realistic modeling of a decisioning context, requires the ability to "weigh" the various criteria being utilized, and thereby vary the relative importance of the criterion effect upon the decision(s) being made (alternative choices).

The Composite Variable Ranking (CVR) model has been designed to specifically address these four requirements. After the initial measurement of the criterion variables has been accomplished (e.g. cost of programs parts in 'dollars'; space requirements in 'square feet' or 'number of rooms'; personnel in total 'FTEs'; etc.), the normalized T-scores of the relative raw measures are computed for each criterion variable (across the range of measured alternatives). That is,

$$a_{ij},\ j = 1,\ldots,n \xrightarrow{(i,j)} T_{ij},\ j = 1,\ldots,n$$

for each criterion i=1,...,m. This conversion replaces all raw measures (square feet, dollars, etc.) with its associated distributional T-normal. T-normals by definition have a mean of 50.0 and a standard deviation of 10.0. Thus, a facility-space measure of 2560 square feet for program alternative C has a T-measure of 50.0 if 2560 square feet is also the distributional mean across all programs for space requirements. Likewise, a personnel requirement of 12 teacher aides has the T-value of 50.0 if 12 (TAs) is the distributional mean across all programs.

The composite variable ranking procedure summates each column's row entries (that is, adds the criterion T-measures for each alternative), producing a single composite measure per each alternative being evaluated. These T-normal sums can then be ranked such that their ordinally-comparative importance to the decision be recognized.

Likewise, the rows can be summed (i.e., adding across each row's column entries), to understand the relative impact of each criterion across all alternatives within the system. Finally, standard weighting practices can be applied to the criterion T-normals (after normalization, of course) before the summation of the column vector entries.

The CVR modeling technique is an excellent field-tested and validated technique for performing most decision analyses involving decison matrixes. Moreover, the CVR approach is well-defined and easily constructed for a fiscal program alternative's setting. The technique is not without its inherent inadequacies, however, centering mostly around its predominant reliance upon both a singular alternative context and main-effects modeling.

Main Effects Modeling

In an earlier section of this report, the issue of multiple alternatives modeling (MAM) was discussed in the context of a solution requiring not just one alternative, but rather a finite group of alternatives (referred to as the "alternatives-mix set" in the first topic of the next section). If a decisioning model purports to truly simulate a real situation, then the model must be able to compare groups of alternatives against other groups of alternatives, utilizing the criterion measures which have been selected to simulate the impact of the alternatives upon the system being modeled. This is the main operational difference between singular and multiple alternatives modeling -- that several alternatives may require operatonalization to satisfactorily remediate the identified problem.

Main effects modeling is a correlated idea to the multiple alternatives context, from the standpoint of the multiple-criterion effect via each evaluated alternative. Consider the following example. Five alternatives have been identified as potential remedial actions for a particular problem being modeled. Each alternative was measured across each of three criteria to permit a criterion-referenced evaluation. (To save time, and wear-and-tear on the authors, the transformation to T-normals is suspended for this discussion). The measurement scale chosen was a 5-point scale with interval of 1 unit, signifying low benefit (=1) to high benefit (=5). The simplified decision matrix is shown in Figure 2.

Note that the column sums indicate Alternative-C as a clear 'winner' in this "identify the most beneficial alternative" contest. However, also note that although C's sum was the highest, the measure of criteria #2 for C (=2) suggests C demonstrates moderately-low performance benefit on this criterion measure. If we approach this simulated example from a 'multiple alternatives' vantage, a likely solution might be the incorporation of both C <u>and</u> B into an <u>alternatives mix-set</u>. Note how B's measure of moderately-high benefit (=4) on criterion #2 counteracts C's moderately-low (=2) value. Also, note how C must then make up for B's apparent disadvantage regarding criteria #1 and #3.

Main-effects modeling would have computed the columnar summations, and selected the alternative 'C', as the most-likely solution. It is just as likely that in a more complicated simulation, the decision-maker might not recognize the criterion #2 influence of alternative C. Clearly, this situation is a potential problem with both singular and multiple alternatives modeling simulations.

Figure 2. Representation of the Composite Variable Ranking (CVR) Formulization for Main-Effects Modeling.

Potential Alternatives

Criteria	A	B	C	D	E	
#1	(1)	(2) →	(5)	(3)	(2)	
#2	(3)	(4) →	(2)	(1)	(2)	
#3	(1)	(2) →	(4)	(3)	(2)	
	5	(8) →	(11)	7	6	(column sums)
	5	2	1	3	4	(ranks)

The solution is to perform what the authors call "interactive effects" modeling -- controlling not only for the presence of multiple solutions, but also controlling for the potential of sub-optimal criterion measures for a given alternative which may be masked by the values of other highly-beneficial criterion measures. The illustration and application of just such a model, the Multiple Alternatives Model, within a fiscal roll-back context is the subject of this report.

Generic Criteria for Competing Alternatives

We have spent a great deal of energy thus far in describing what to do, how and why ... but have gingerly maneuvered around the question of 'with what' viz. criteria. Criteria must be both system-specific as well as alternative(s)-specific. Roughly translated, criterion measures must reflect both the system being modeled as well as the alternative solutions being evaluated, respectively. Otherwise, the impact to the system cannot be measured, since it had not been modeled (i.e. simulated).

The evaluation of potential budgeting roll-backs is no exception. Criteria must be introduced, measured and analyzed across all alternatives, such that: the alternatives can be validly compared within a budgeting context; and the impact to the system of each alternative (or combinatorial premutation of all available alternatives) can be analyzed. Finally, criteria must be collectively exhaustive of the 'foci' required to criterion-model the decisioning context; and allow cross-comparisons between criterion measures, in order to check for collectively unacceptable 'impact' values (interactive effects modeling).

Modeling alternatives within the fiscal domain represent as clear an illustration of criterion considerations as any multiple-alternatives decisioning situation. For traditional cost analytical studies, the generic focus of <u>expenditure</u> has been the province of cost-benefit analysis. Similarly, foci of <u>effectiveness</u> and <u>satisfaction</u> have remained strong criterion entries in cost-effectiveness and cost-utility analyses, respectively. An additional measure focus of <u>efficiency</u> could find itself in either of the three cost-analysis models, depending upon its source of data (as is probably true for all of the initial three criterion foci).

Nevertheless, these four generic criterion foci (effectiveness, efficiency, satisfaction and expenditure) are directly applicable to the fiscal modeling domain:

<u>Effectiveness</u>

1. How effective are each of the various alternative programs in promoting the district's generic program goals?

2. How effective are each of the various alternative programs in optimally reducing the current problems associated with each of the districts' school's specific program goals?

<u>Efficiency</u>

1. How efficient are each of the various alternative programs in conducting the required instructional programs of the district?

2. How efficient are each of the various alternative programs in remediating the current problem(s) to be solved within the district?

Satisfaction

1. How satisfactory are each of the various alternative programs in their execution, based upon the distributional domains of the administrator, teacher, student, parent and school board?

2. How satisfactory are each of the various alternative programs in their remediation of the identified problem(s), based upon the distributional domains of the amdinistrator, teacher, student, parent and school board?

Expenditure

1. What are the specific object costs to the district for each of the various alternatives; and therefore their savings if rolled-back?

2. What are the costs to the district in terms of benefits if the programs continue?

3. What are the costs to the district in terms of 'loss' if the programs are rolled-back?

It is likely (if not strongly suggested) that several criteria (measurement variables) would be identified to adequately model the rather general idea expressed above. For example, the criterion focus of efficiency for a particular set of alternatives curriculum programs might be measured in terms of:

(1) Amount of time in minutes the program requires for instrumentation each week;

(2) Number of students that could be handled per class session (to identify small v. medium v. large group sessions); and/or

(3) Percent of time the program requires use of a particular laboratory or library resource room.

Expenditure is another criterion focus particularly susceptible to the 'delineation' of its content. For example, the total cost of a program is important; but potentially more important is the program's budget-breakdown by object expenditure (e.g. amount for salaries v. amount required for capital improvement). Figure 3 illustrates the impact of differentiated criterion foci upon one traditional decision matrix.

It may now be trivial to state that each of the four sub-matrices within the total decision matrix could be itself a decison sub-matrix. Thus the a x n effectiveness sub-matrix could be executed to determine which alternatives best 'fit' one stated effectiveness criteria. In turn, the bxn efficiency sub-matrix could be executed for its solution; and then each of the remaining c x n satisfaction and d x n expenditure sub-matrices could be evaluated. Such a serial procedure would yield four sets of answers (alternative solutions), which themselves would require comparison for a final solution. The question arises, "Is this really the best, most valid (and reliable) process to follow?"

Hopefully it is also trivial (?) to the reader, that the full decision matrix (a+b+c+d) x n could have been evaluated; the

Figure 3. Representation of a Generic-Criterion Decisioning Model for Analyzing Multiple Competing Alternatives

Criterion	Foci	Multiple Alternatives A_1 A_2 A_3 A_4 . . . A_n
(Effectiveness Criteria)		a x n sub-matrix
$CRIT_1$	EFFEC-1	effectiveness measures across alternatives
$CRIT_2$	EFFEC-2	
. . .	. . .	
$CRIT_a$	EFFEC-a	
(Efficiency Criteria)		b x n sub-matrix
$CRIT_{a+1}$	EFFIC-1	effectiveness measures across alternatives
$CRIT_{a+2}$	EFFIC-2	
. . .	. . .	
$CRIT_{a+b}$	EFFIC-b	
(Satisfaction Criteria)		c x n sub-matrix
$CRIT_{a+b+1}$	SATIS-1	satisfaction measures across alternatives
$CRIT_{a+b+2}$	SATIS-2	
. . .	. . .	
$CRIT_{a+b+c}$	SATIS-C	
(Expenditure Criteria)		d x n sub-matrix
$CRIT_{a+b+c+1}$	EXPEN-1	expenditure increases across alternatives
$CRIT_{a+b+c+2}$	EXPEN-2	
. . .	. . .	
$CRIT_{a+b+c+d}$	EXPEN-d	

solutions determined, reflecting those alternatives which best fit the total effectiveness, efficiency, satisfaction and expenditure criterion sets, simultaneously; and thus, optimally operationalize the preferred interactive effects modeling framework as previously discussed.

A Preference/Trade-Off Analytical Framework

Although previously illustrated with the topic, Main-Effects Modeling (see pp. 23), the importance of variable criterion characteristics for a given alternative must be reiterated. Solutions to real-life problems are found to be "perfect" only in textbooks, professor's lecture notes, and the 1950's cinema. In reality, all potential alternative solutions will be found to have at least one flaw (if not many); and still be the best alternative(s) solution available.

In selecting a final alternative as a solution based upon that same alternative's merits, the decision-maker also (consciously, we hope) accepts that same alternative's lack of merit on other less virtuous criterion measures. Recall the illustration in Figure 2 (page 25). Alternative C was selected based upon the merits of criteria #1 and #3. To fill the gap indicated by criteria #2, a multiple alternatives mix-set solution was sought with the subsequent addition of 'B' to the solution set. However had we not the option to choose a set of solution alternatives, would we have retained alternative 'C'? At this level of macroanalysis, the answer is probably 'yes'.

This is the theory of preference/trade-off in alternatives modeling -- singular or multiple. Alternative C was the final choice due to one preference for high benefit on criteria #1 and

#3; and a concurrent willingness to trade-off (i.e. accept the negative) the low benefit effect associated with criterion #2. This concept is most important in the understanding of the multiple-alternatives/ interactive-effects modeling technique to be illustrated in Part II of this report; and applied to the fiscal roll-back problem in Part III. The main difference between the way the concept of preference/tradeoff has been described, and the way in which it is actually applied will be evident. Basically, the multiple alternatives model (MAM) will define preference/trade-off as a willingess to accept a central-tendency solution mix-set, where the required impact is not alternative-specific, but rather is mix-set generalized. The measures of central tendency and variability (distributional mean and standard deviation) will be applied to a yet-to-be-discussed marvelous vector of values called the conditional vector, in order to assume their preference/trade-off flexibility.

OPERATIONS RESEARCH AND THE EVALUATION OF FEASIBLE ALTERNATIVES

Thus far, this report has devoted much of its content to the exposition of budgeting and funding as a structural allocation-oriented activity. A position has been taken which specifically adheres to the philosophy that fiscal modeling (i.e. the simulation of a fiscal decisioning system) must be criterion-referenced to the actual (real-life) system; and that these criteria should be designed in such a way as to perform three vital functions:

(1) to reliably represent the true system being modeled (simulated);

(2) to validly represent those factors (inputs, outputs, processes) which are required (and desired) to provide the necessary information in order to make decisions);

(3) to totally represent the impact to the system (as a whole) of the potential alternative decisions being evaluated.

Finally, this report has premeditatively focused its energies upon preparing the reader to view the fiscal crisis situation, and its potential demand for fiscal roll-backs, as a decisioning framework of multiple alternatives. In this case the alternatives are defined as either all possible programs (sources of expenditure) or significantly distinct parts of programs which might be discontinued and therefore deallocated from the existing budget; that is, rolled-back in order to balance the budget. To evaluate these many alternative, potential sources of cutbacks, criteria are required which will not only describe the attributes of each alternative in terms of its contributions to system function (or lack of such contributions), but will also demonstrate the costs (object category expenditures) associated with each of the alternatives. The overall goal then is to select those alternative programs (decisions) which may be feasibly and rationally rolled-back without providing major detriment to the system's required functioning, while satisfying the reduced budgetary limits imposed by the fiscal crisis.

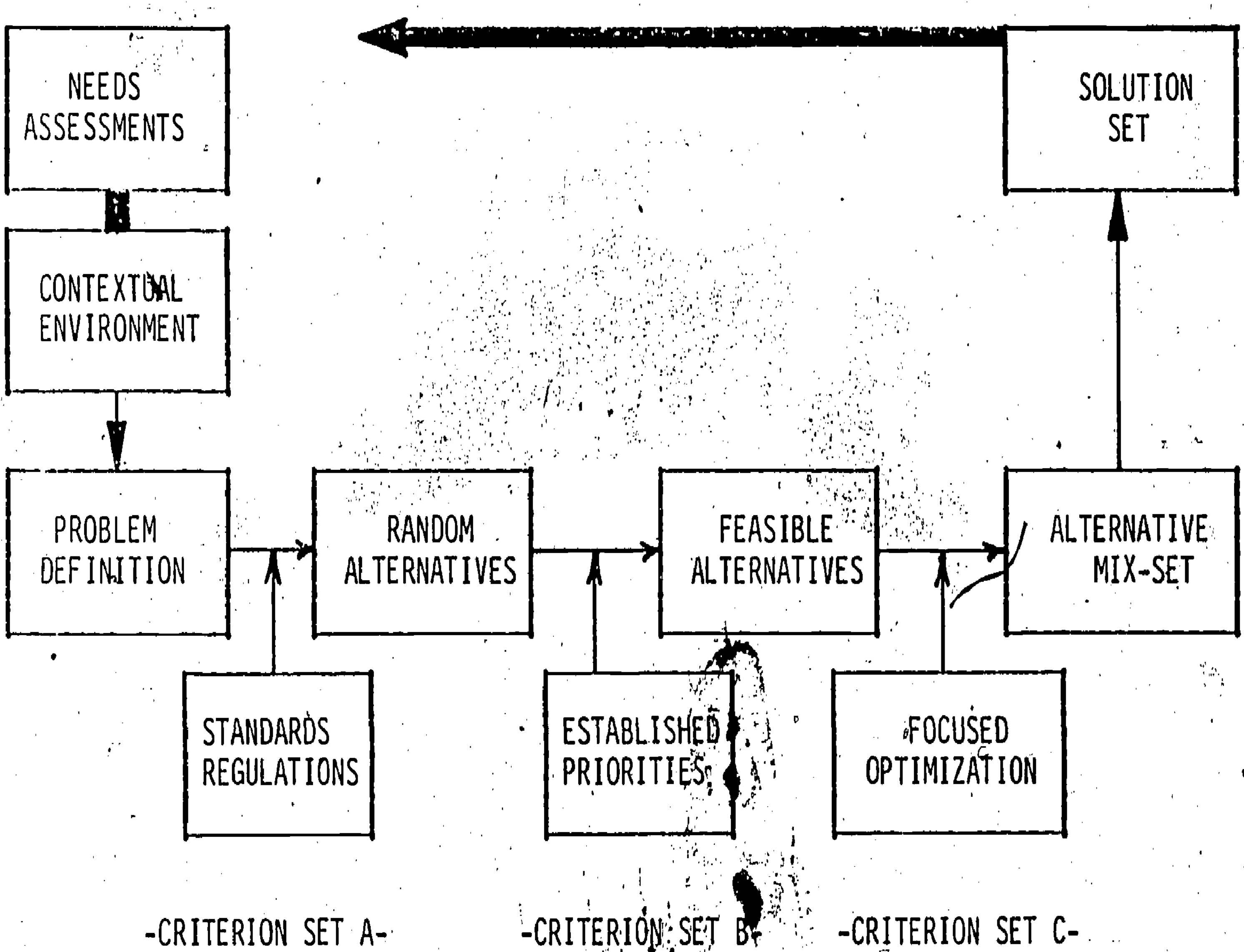
Optimal Decisioning Within a Constrained Feasible Space

Any decision, viewed as the best possible alternative course of action to operationalize, must by definition be optimal; that is, all things considered, this action posits the best interests of the organizations or system being modeled. Simulation of these "things" and "interests" results from the use of criteria to measure the value of each alternative and its impact upon the system as a whole -- that is, how the system is constrained by these criterion measures across all alternatives. Such measures are referred to as criterion constraints. Those alternatives decisions (when evaluated) will display degree of optimality ("best"-ness) in addressing the solution to the problem defined; but first, each particular alternative must itself be a reasonably potential solution to the problem; that is, exhibit the quality of feasibility.

The context of decisioning alternatives is thus a rather interesting flow from a traditional needs assessment (What is the real problem? that is, not the system of the underlying problem) to the determination of a set of solutions to be implemented via a criterion-referenced model of value and worth, versus impact. Figure 4 schematically depicts this (obviously interesting) flow.

After the real problem is determined, dissected and defined (the 3-D's), standards and regulations (operating goals) of the system become the first set of criteria to impact the simulation. Standards provide the necessary data to assist construction of all possible alternative sources of action the decision-maker must consider and evaluate (i.e. the set of random alternatives). Next, established priorities are defined and developed into a set of criteria which allow further scrutiny of the random alternatives, and their measured impact upon the decisioning

Figure 4. Representation of a Sequential, Criterion Referenced Model for Systematically Developing a Multiple Alternatives Solution Set.



system. Often times, an alternative may be "possible" but not "plausible" due to certain established priorities. Alternatives which survive this recent criterion-focused evaluation become known as feasible. Finally, the more important (weighted) criteria are drawn into the evaluation in order to focus the optimization standards for the decisions about to be made (that is, selection of alternatives).

The potential existence of an alternative mix-set focuses once again upon the idea of singular versus multiple alternative(s) frameworks. Recall that a singular framework involves the choice of one and only one (or none, of course) alternative course of action based upon the evaluative criteria used. A multiple alternatives' setting permits the choice of a group of several alternatives that when implemented as a group (not necessarily simultaneously), produce the desired process and attain the required result.

Fiscal Allocation as a Multiple Alternatives Problem

Fiscal crises provide the budget manager and program administrator with a unique experience, "to accomplish more for less". Though tongue-in-cheek, the unfortunate reality of today's economy and our best program prognostications for the future point to a steadily decreasing funding base. Decreased funding will not however be followed by the public's reduced need for educational services, either in quantity or quality. Organizational philosophies, goals and needs will stay relatively constant; yet with a new demand for prioritization and demonstrated accountability. After 25 years of no-holds-barred development and spending, can education 'equally' meet the new demands for austerity and roll-backs, in light of declining enrollments, school closures, a sagging national economy and the ever-increasing demand by teacher for higher salaries?

Whether the problem be one of fiscal allocation or deallocation, the funding framework for program budgeting is a multiple alternative modeling problem. Consider the need to determine which programs are to be funded within established budgetary limitations; and therefore, which programs will not. This is obviously a decisioning situation, whereby the goal is to fund as many programs as possible within the prescribed budget, based upon: (1) each program's merits, (2) the overall system's needs, and (3) the impact of the alternatives -- individually and collectively -- upon system functioning as a whole. Each alternative's merits (type and extent) will be measured via the various criteria which have been a priori identified as demonstrative of the system's definition of 'merit' or 'impact'. Finally, the cost for every aspect of each program is computed; and entered as a measure of impact to the system's budget, in deciding to implement the program (expenditure) or not (savings; with an opportunities cost).

Concisely stated, the fiscal allocation between multiple, competing programs assumes the following direction:

To choose (and therefore also fail-to-choose) some finite number of programs from among the available alternatives -- each alternative associated with measures of merit, worth, impact and cost -- such that:

1. total (collective) positive impact to the system is maximized (meeting needs, goals and interests);
2. total (collective) negative impact is minimized (not meeting needs, etc.); and

3. total (summed program budgetary demand does not exceed the amount of available monies.

Figure 5 provides a simple outline of the above stated goal(s).

While resembling the traditional cost-benefit analytical framework discussed previously, Figure 5 once again affirms the demand for an evaluation tool which is capable of analyzing the role(s) of multiple alternatives across multiple criteria; and selecting those alternatives which best fit the criterion-constrained system (decisioning matrix). Again, we are faced with the issue of interactive-effects modeling.

Interactive Effects Modeling

In a previous section (Main-Effects Modeling, pp. 23), we discussed the need to understand the interactive nature of selecting from among multiple alternatives; that is, the total combined effect of one choice based upon the various values of each alternative's criterion measures; and the desire to choose that set of alternatives which demonstrates a collective composite of acceptable criterion values. This is complicated by the fact that different combinations of alternatives are possible in forming the final solution set. Simply (?) stated, such a decisioning requirement is a nightmare. But can a technical strategy be formulated to address equally the issues of technique as well as the fiscal allocation problem itself? Welcome to the world of operations research!

Figure 5. Fiscal Allocations as a Multiple Alternative Problem, Utilizing the Decision Matrix Framework.

Multiple Alternatives

Criteria		Prog1	Prog2	Prog3	. . .	Progn	
Positive Impact	1.__	+11	+12	+13	. . .	+1n	
	2.__	+21	+22	+23	. . .	+2n	Maximize
	3.__	+31	+32	+33	. . .	+3n	
Negative Impact	1.__	-11	-12	-13	. . .	-1n	
	2.__	-21	-22	-23	. . .	-2n	Minimize
	3.__	-31	-32	-33	. . .	-3n	
Specific Costs	1.__	$11	$12	$13	. . .	$1n	
	2.__	$21	$22	$23	. . .	$2n	Sum ≤ total budget available
	3.__	$31	$32	$33	. . .	$3n	

The Operations Research (OR) Approach

Operations research as a scientific investigation and evaluation tool, views the milieu of decisioning as a criterion-referenced choice between stated alternatives. The term "operations research" is itself a generic label for several actual tools, and states that a decision situation can be modeled (simulated) mathematically. As you will discover in Part II of this report (you've come this far, anyway), the multiple alternatives model employs a particular subset of the OR approach, called binary integer programming, which utilizes systems of simultaneous linear inequalities (roughly equivalent to high school intermediate algebra).

Via an algebraic representation of the specific decisioning framework, where each criterion is represented as a linear inequality (the independent variables as the programs, and the dependent variables as the total system impact), a value of '1' (i.e. to choose) or '0' (i.e. to not choose) can be assigned to each of the independent variables (alternative programs). The best mix of 1's and 0's (across all multiple alternatives) is the most optimal solution set. Thus if Program 1 = '1', Program 2 = '0' and Program 3 = '1' (of only three program alternatives) the decision is to fund programs '1' and '3'; and therefore not fund program '2'. This is the basis for the multiple alternatives modeling of a fiscal roll-back situation.

SIMULATION MODELING WITHIN A CRITERION-IMPACT DESIGN

The theoretical mathematician would say that in the situation of fiscal roll-backs and the use of multiple alternatives modeling in performing such decisioning -- the need to determine roll-backs is the necessary condition and the utility of the MAM technique the sufficient condition -- for the existence of the multiple alternatives modeling technique. However, the total utility of this model extends beyond the ability to provide decision-makers with concrete decisions based upon a criterion-impact design.

Consider the ability (of the decision-maker) to test various hypotheses as to how certain groups of alternatives would impact the system. Consider further the ability to vary the system's parameters (needs, goals, demands, etc.) and observe the differences (if any) of programs selected for funding, based upon the newly modified constraints. Such abilities suggest a setting in which the decision-maker can accurately (validly and reliably) model a system which may not yet exist. It is the tripartite ability to represent a system, experiment with alternatives (programs funded and/or criteria utilized) and predict with some certainty the results of alternatives actions. This is operational modeling in the "crystal ball" setting, or simulation.

The reader may be musing, "True, but so much of the confidence placed in the results of such a simulative model must itself be based upon the assumption that the model indeed 'models' the actual operational setting, both validly and reliably." Obviously, indisputable. Yet, all of educational research was at one time (if not still) held to be non-utilizable due to the inability to control all mitigating and extenuating forces which convoluted curricular learning, management style and teacher attitude findings, ad nauseaum. Recalling that the multiple alternatives modeling technique (as in other simulative frameworks) seeks only to assist the policy analyst's understanding of data to be used in the actual decision-making (regardless of how), we feel confident in saying, "Try it, you'll like it." In today's educational climate, where experimentation with policy is often times both involved and hazardous to one's professional health, the MAM framework can with obvious effort and diligence uncover the projective relationships between program alternatives, criterion impact to the system, and budgeting constraints.

Monitoring System Impact of Selected Alternatives

A final note must be made for fiscal modeling under implementation; that is, what to do when the choices have been made, and all decisions are 'go'. 'Borrowing' as we educational systems' planners did from the electronic engineers during the late 1960's, the issue of systemic cyberneticism once again becomes useful. Cybernetic qualities of any modeling stragegy simply refers to a careful monitorization of the real system under implementation, as you put your fiscal roll-back decisions into effect. Now, and heretofore unforseen consequences, impact, criterion-references and measurement techniques may be discovered, which can be integrated within the original modeling framework; that is, as a new linear constraint equation or inequality.

The utility of fine-tuning a decisioning model for more accurate future use is certainly moot. As in multivariate regression, the model developer may have to try new criteria constraints (variables) to associate their variance patterns with the decisions modeled, and the resulting impact(s) of the decisions made.

BACKGROUND TO THE FIELD INVESTIGATION

We have attempted throughout Part I to prepare the reader for the technical discussion to follow in Part II and the field-research results to be presented in Part III; concerning the development and construction of the multiple alternatives model (technique) and its application as a fiscal roll-back decisioning model, respectively. To date (and possibly more understandably having attempted to translate the discussion in Part I) little has been accomplished in the applicaiton of MAM-type models to educational decision-making. In fact, the first systematic compilation of areas where mathematical modeling had been applied to education was found in one of the author's own works (Wholeben, 1980). For the reader's interest, these surveyed areas of application are listed in Figure 6.

Noteworthy is the fact that no entry in Figure 6 demonstrates work in applying a MAM-approach to the fiscal environment. Certainly, an OR model could have easily assisted educators expend the bountiful monies of the 1960's; as well as today select areas where money will no longer be allocated. This paper makes available such a decision making tool, whose purpose is:

<u>To design, implement and evaluate a mathematically-derived decisioning model, and its utility in determining programs for fiscal roll-back.</u>

In this final section of Part I, early multiple alternatives modeling applications and design will be discussed. Results from an initial trial exercise in fiscal data will also be briefly presented, prior to the in-depth investigation into the recent roll-back analysis and field study found in Part III.

Figure 6. Stratification of Operations Research (OR) Applications Within Educationally-Related Environments.

LIBRARY OPERATIONS

TEACHER ASSIGNMENT
PERSONNEL SELECTION
GRADUATE STUDENT SELECTION
STUDENT ASSIGNMENT

FACILITIES LOCATION
SCHOOL SITE PLANNING/CONSTRUCTION

CAI COMPARISON
EDUCATIONAL ADMINISTRATOR PREPARATION
COUNSELOR TRAINING
CURRICULUM REVISION
TEACHER TRAINING

VOCATIONAL EDUCATION/REHABILITATION
HANDICAPPED/DISADVANTAGED
WORK ENVIRONMENT/PRODUCTIVITY
MANPOWER TRAINING
RELOCATING THE UNEMPLOYED

STUDENT BUSING
URBAN MASS TRANSPORTATION

CORRECTIONS
INCARCERATION v. PROBATION

ENVIRONMENTAL POLLUTION
CHILD DAYCARE
DEPLOYING EMERGENCY SERVICES
STUDENT HEALTH SERVICES
FOOD SERVICES
OUTDOOR RECREATION

DESEGREGATION

AUDIO-VISUAL/MEDIA

INSTRUCTIONAL EFFECTIVENESS
ACCOUNTABILITY
ORGANIZATIONAL COMMUNICATIONS STRUCTURE

ENROLLMENT PROJECTION
CURRICULUM TIME BLOCK ASSIGNMENTS

STUDENT MAJOR v. COURSE SELECTION

Precedent Modeling Application

During 1977-79, extensive work was accomplished in the design and evaluation of a basic main-effects model for comparing elementary school sites across competing criteria, for potential closure due to declining enrollment. In addition, early work commenced on the research and development of a multiple-alternatives, interactive-effects model during 1978, resulting in a sophisticated school site evaluation (closure) model, and a major technical publication concerning its evaluation design and field applicaton.

During 1980, further design studies were formulated which addressed application issues in curricular development (CAP: The Curricular Activity Packaging model); and fiscal roll-backs (ROLBAK-I Model). Through statistical studies of the "school closure" multiple alternatives modeling framework (relationship of criteria to impact and solution; and the relationship of modeling process to solution content), validated the model as a reliable and useful tool. The later CAP-study demonstrated the supplemental utility of the MAM-framework is not only evaluating between-alternatives comparisons, but also within-alternatives comparisons (i.e. sub-program analyses). These analyses led to the 1980 application of the ROLBAK-I, a predecessor to the ROLBAK-II design discussed in Part III.

OUTLINE OF THE TECHNICAL REPORT

A more technical and consolidated discussion now follows in Part II concerning the design and construction of the multiple alternatives model. These sections were added for the more discerning reader who wishes to understand the content and process, as well as the results. We recommend that the readers study Part II (for as long as frustration allows). However, proceeding directly to Part III first (returning to Part II, of course) may help others in their eventual translation.

Part III discussion details the ROLBAK-II formulation; and the analytical results of the execution. We have chosen to include most of the display figures in the text rather than force the reader to constantly "flip-ahead" to an appendix section. Moreover, inserting the figures in the text will also force the reader to at least consciously encounter them.

Part IV concludes the report with a brief discussion of major philosophical issues underlying modeling simulation.

PART II

MULTIPLE ALTERNATIVES ANALYSIS

AS A

MATHEMATICAL DECISIONING MODEL

INTRODUCTION

To include or not to include a more detailed and technical decision of the mathematical design within the MAM -- was a long and arduous decision for the authors. On the one hand, inclusion of a technical section (we reasoned) might sensitize the general reader negatively; and preclude that reader's pursuit of the remaining text. On the other hand, exclusion of that same section (we rationalized) might very well undermine the final acceptance of this report as a valid technique.

Our final decision to include at least some minimal amount of technical development was made, based upon four premises:

(1) though a technical decision may in fact threaten some readers, the Multiple Alternatives Model is (also in fact) a technical design, for which we neither minimize nor apologize;

(2) a technical discussion will add credence to the operating mechanisms of the model, illustrate its interworking parts, and promote a detailed understanding of the "input-process output" relationship -- far above any "Trust us, it really works!" manuever;

(3) the technical formulation can be both informative and documentary, without reading like a biochemist's report on the postpituitary hormone, oxytocin (that is, $C_{43}H_{66}N_{12}O_{12}S_2$, if you are interested); and

(4) a responsible reading of Part I has already acquainted the reader to the general ideas of Part II; that in

fact, Part II should be a 'recall' episode for the material already alluded to in the previous fiscal discussion.

The presentation of Part II consists of four sections which follow a very simple introduction, construction, evaluation (or execution) and validation paradigm. The discussion is void of any particular problematic context (such as the fiscal roll-back milieu of Part I); and thus is generic rather than system-specific in scope. Such an inductive approach, <u>viz</u>. from the specific in Part I to the universal in Part II, will hopefully not only promote better learning and understanding of the MAM technique, but will moreover induce the reader to review the manuscript more closely for its intuitive and generalizable applications to other problem areas of education.

INTRODUCTION TO THE MULTIPLE ALTERNATIVES MODEL

The Multiple Alternatives Modeling (MAM) framework makes <u>four</u> assumptions of the problem (decisioning) areas to which it (model) is to be applied. First, the problem is a multiple alternatives problem, requiring a multiple alternatives solution. That is, the solution to the specified problem situation could reasonably call for the implementation of more than one of the alternative courses of action being evaluated. Whether it be schools to be closed, budgets to be cut, programs to be initiated, or routes over which to transport students --greater than one school, budget, program or route may be selected as the solution.

Secondly, criterion reference points (i.e., variables) can be quantitatively measured for each of the defined alternatives, demonstrating an alterative's impact (if implemented) to the system, according to the criterion's derived focus. Furthermore, this arithmetic summation of all 'selected' alternative's criterion values (across a particular criterion) forms a composite numerical value which illustrates the solution's impact (selected alternatives) to the system as a whole.

Thirdly, the system being modeled can affix some high (or low) limits to these criterion summations, called upper (or lower) bounds. If a criterion measures the total cost of each program being considered for implementation, and a total available budget of some specified amount exists -- then the summed total of all program budgets (for the program to be implemented) must be equal to or less than the total available budget. Obviously, you cannot spend more than you have available (although program administrators do it religiously). In this example, the total budget available is seen as an 'upper bound'. Similarly, a 'lower bound' could be the total amount to be cut from an operating budget, where the criterion is the cost-to-be-saved for each of the potential alternative programs (budgets) available for roll-back.

Finally, some one, individual criterion measure is identified which will be utilized to optimize the selection of the final alternative mix-set solution. Many sets of alternatives (that is, combinational permutations) can usually be identified which will provide a solution to some degree or extent. However, reality normally requires an adherence to some priorities existent within the system being modeled; for example, a desire to maximize the number of students transported (on the average) via each bus; or a desire to minimize the number of stops a bus has to make enroute to the school.

The Multiple Alternatives Model is a complex response to a complex decisioning situation. The model recognizes the need to simultaneously evaluate all available alternatives across all defined criteria, and to therefore simulate the interactive nature of a criterion-inferenced, decision-making environment. Above all else, the MAM framework provides a ready means for evaluating a set of alternatives, collectively -- and based upon the set of criteria which the real-life decision-makers have posited as the desired ingredients of their final decision.

Role of Multiple Alternatives in Decision-Making

In the multiple alternatives context, the potential solution alternatives may be displayed as a serial string; that is, $x_1\ x_2\ x_3\ \ldots\ x_n$ where x_j represents the jth alteratives (of n total), j = 1, 2, ..., n. The MAM decision is to include (or exclude) each alternative as a member of the final solution (mix-set). The only value which x_j may assume is '1' (that is, to include) a '0' (that is, to exclude). Therefore, the decision is to mathematically assign either the value of 1 or 0 to each of the x_j alternatives, j = 1, 2, ..., n; thus the label, binary, integer programming.

In each case of ten alternatives, the serial representation would be illustrated as:

$$[\, x_1 \quad x_2 \quad x_3 \quad \ldots \quad x_{10} \,]$$

If the final solution included alternatives 2, 5, 9 and 10 as members, then the solution vector would be displayed as

$$[0 \ 1 \ 0 \ 0 \ 1 \ 0 \ 0 \ 0 \ 1 \ 1].$$

As we will see in the next section, the function of a binary coding (0,1) extends beyond its use as an easy display mechanism for alternative solution membership.

Decision Criteria as Modeling Constraints

We have seen that an alternative becomes part of the solution by taking on the value of 1 (that is, $x_j = 1$ for some j of n); as opposed to the value of 0 ($x_j = 0$, for all j of n, such that $x_j = 1$, $j = 1, 2, \ldots, n$). The basis for assigning 1's v. 0's, lies in the evaluation of the criteria which were selected and measured to indicate each x_j's impact upon the system being modeled. Furthermore, it was the summation of the criterion values across the selected (solution) alternatives which formulated the multiple alternatives solution (mix-set) impact to the system.

Let us define an 'a' as representing the value of any criterion for any alternative. It is relatively straightforward then to interface a_{ij} as the value of the ith criterion's measure for the jth alternative. For example, recall our previous example of ten alternatives. If there existed only one criterion to assist us in evaluating the set of potential solutions, then the criterion values could be represented as:

$$[\ a_{1,1} \quad a_{1,2} \quad a_{1,3} \quad a_{1,4} \quad \cdots \quad a_{1,10}\ ]$$

In a more complicated example, a set of three criteria used to evaluate ten alternatives would be represented as:

$$\begin{bmatrix} a_{1,1} & a_{1,2} & a_{1,3} & a_{1,4} & \cdots & a_{1,10} \end{bmatrix}$$

$$\begin{bmatrix} a_{2,1} & a_{2,2} & a_{2,3} & a_{2,4} & \cdots & a_{2,10} \end{bmatrix}$$

$$\begin{bmatrix} a_{3,1} & a_{3,2} & a_{3,3} & a_{3,4} & \cdots & a_{3,10} \end{bmatrix}$$

The first case involving only a single criterion, is called a vector of criterion values across the potential alternatives. The second case where three criteria existed, is called a matrix (i.e., a collection of two or more vectors) of criterion values across potential alternatives. Since most MAM problems involve more than a single criterion, and because each criterions' measure will be utilized to constrain the decision to be made (or more appropriately guide the selection of alternatives for inclusion within the solution set), the matrix is known as the constraint matrix.

At this point, we have introduced the variables of $x_j (j = 1,2,\ldots, n)$ and $a_{ij} (i = 1,2, \ldots,m; j = 1,2,\ldots,n)$ to represent the alternatives and criterion values, respectively; that is:

	x_1	x_2	x_3	$\cdots$	x_n
1st criterion:	$a_{1,1}$	$a_{1,2}$	$a_{1,3}$	$\cdots$	$a_{1,n}$
2nd criterion:	$a_{2,1}$	$a_{2,2}$	$a_{2,3}$	$\cdots$	$a_{2,n}$
$\vdots$	$\vdots$				$\vdots$
mth criterion	$a_{m,1}$	$a_{m,2}$	$a_{m,3}$	$\cdots$	$a_{m,n}$

Can you see (?) that a further refinement of the above scheme could be made to appear as follows:

$$[\ a_{1,1}\,x_1 \quad a_{1,2}\,x_2 \quad a_{1,3}\,x_3 \quad \cdots \quad a_{1,n}\,x_n\ ]$$

$$[\ a_{2,1}\,x_1 \quad a_{2,2}\,x_2 \quad a_{2,3}\,x_3 \quad \cdots \quad a_{2,n}\,x_n\ ]$$

$$\vdots \qquad\qquad\qquad\qquad \vdots$$

$$[\ a_{m,1}\,x_1 \quad a_{m,2}\,x_2 \quad a_{m,3}\,x_3 \quad \cdots \quad a_{m,n}\,x_n\ ]$$

This makes sense if you recall that: (1) the value of each x_j will be either a '0' or a '1', depending upon whether it is excluded or included within the solution set; and that (2) the sum of the criterion values measures the total impact of the solution upon the system.

Consider a relatively small example of four alternatives being measured across three criteria. Thus the model would be represented as:

$$a_{1,1}x_1 + a_{1,2}x_2 + a_{1,3}x_3 + a_{1,4}x_4 \quad \text{(system impact if CRIT \#1)}$$

$$a_{2,1}x_1 + a_{2,2}x_2 + a_{2,3}x_3 + a_{2,4}x_4 \quad \text{(system impact if CRIT \#2)}$$

$$a_{3,1}x_1 + a_{3,2}x_2 + a_{3,3}x_3 + a_{3,4}x_4 \quad \text{(system impact if CRIT \#3)}$$

Now if the solution vector $[x_1 \;\; x_2 \;\; x_3 \;\; x_4]$ was represented as $[1 \;\; 0 \;\; 0 \;\; 1]$ where only alternatives #1 and #4 were selected, the model would be shown as:

$$a_{1,1}(1) + a_{1,2}(0) + a_{1,3}(0) + a_{1,4}(1)$$

$$a_{2,1}(1) + a_{2,2}(0) + a_{2,3}(0) + a_{2,4}(1)$$

$$a_{3,1}(1) + a_{3,2}(0) + a_{3,3}(0) + a_{3,4}(1);$$

or in reduced form:

$$a_{1,1} + a_{1,4} \quad \text{(solution impact if criterion \#1)}$$

$$a_{2,1} + a_{2,4} \quad \text{(solution impact if criterion \#2)}$$

$$a_{3,1} + a_{3,4} \quad \text{(solution impact if criterion \#3)}$$

We now see why previous discussions of tradeoff/preference and interactive-effects were germane to the MAM development. Note that if $[1 \;\; 0 \;\; 0 \;\; 1]$ is to be our solution, then the values of $[a_{1,1}, a_{2,1}, a_{3,1}]$ exist for x_1 and $[a_{1,4}, a_{2,4}, a_{3,4}]$ for $x_4 = 1$. Thus the solution x_j, $j = 1,4$ requires that we accept the criterion values of $(a_{1,j}, a_{2,j}, a_{3,j})$, $j = 1,4$ whether they are most desirable or not. What we also know is that the choice of x_1 and x_4 as solutions must coincide with the upper/lower value restriction placed upon the criteria.

System Demand and System Impact

The limits placed upon each of the composite measures formed by summing each criterion's impact across all solution alternatives (i.e., $x_j = 1$ for some j of n), reflect two closely related, system-stimulated components: demand and impact. System demand exemplifies the need(s) of the system by the demand(s) placed upon the value composites of each criterion summation; that is, the upper or lower bounds of the criterion sum across the selected solution alternatives. However, since the bound is established only as a limit (not to be violated), then it is reasonable to assume these sums will seldom be equivalent to the bounded value; that is, the composite may be somewhat less than the established upper bound, or somewhat greater than the established lower bound. The actual value and its distance from the bounded value, is the measure of system impact (for each criterion of the alternatives selected as solutions).

Based upon the already linear relationship between the criterion values and alteratives (defined as coefficients and independent variables, respectively), it is a simple extension to model these criterion limits as a function of inequalities. Thus in a three-alternatives, two-criterion model (requiring a 2 x 3 constraint matrix, right?) -- where the first criterion has an upper-bound required, and the second criterion a lower-bound -- the representation may be stated as:

$$a_{1,1}x_1 + a_{1,2}x_2 + a_{1,3}x_3 \leq b_1$$

$$a_{2,1}x_1 + a_{2,1}x_2 + a_{2,3}x_3 \geq b_2$$

where $b_i (i = 1,2)$ are the upper and lower limits of the first and second criteria, respectively. These values b_i are known as the values of the <u>right-hand side</u> (RHS) of the constraint matrix; the values b_i in vector format (b_1,b_2) are referred to as the entries of the <u>conditional vector</u>. Therefore if the solution vector [1 1 0] is to be analyzed, the following algebraic relationship must be satisfied:

$$a_{1,1}x_1 + a_{1,2}x_2 \leq b_1$$

$$a_{2,1}x_1 + a_{2,2}x_2 \geq b_2$$

If moreover a particular constraint (criterion relationship) exists such that an equality is required, the linear equality:

$$a_{i,1}x_1 + a_{i,2}x_2 + \ldots + a_{i,n}x_n = b_i$$

is useful and valid.

The utility of linear equalities and inequalities in formulating the multiple alteratives model is obvious. However, it is reasonable to expect a situation in which more than one set of alternatives provides a solution to the MAM problem. In these cases, additional system priorities must be set.

System Priorities and the Objective Function

Consider the circumstance where in evaluating the above three-alternative, two-criterion problem, two plausible solution sets became evident: [1 0 1] and [0 1 1]. Since both are plausible, we know that each of the relationships:

$$a_{1,1}x_1 + a_{1,3}x_3 \leq b_1$$

$$a_{2,1}x_1 + a_{2,3}x_3 \geq b_2$$

and

$$a_{1,2}x_2 + a_{1,3}x_3 \leq b_1$$

$$a_{2,3}x_3 + a_{2,3}x_3 \geq b_2$$

are individually, simultaneously satisfied. The question becomes: how to choose between the first ([1 0 1]) and second ([0 1 1]) sets?

The MAM framework provides a solution to this dilemma, via the use of another crierion called the <u>objective function</u> (or <u>cost vector</u>). Unlike the criterion constraint inequalities, the objective function does not have an established upper (or lower) bound assigned. Rather the criterion coefficients for the objective function (labeled c_j, $j = 1,2,\ldots,n$) are summed and the additional demand established that either a <u>maximum</u> or <u>minimum</u> sum be found. Consider the following scheme:

(Alternatives)

	x_1	x_2	x_3		RHS
criterion #1	$a_{1,1}$	$a_{1,2}$	$a_{1,3}$	$\leq$	b_1
criterion #2	$a_{2,1}$	$a_{2,2}$	$a_{2,3}$	$\geq$	b_2
(objective function)	c_1	c_2	c_3		

If the criterion referencing the objective function was of a positive-consequent nature, that is measuring good effects of each of the potential alternatives, then it is reasonable to desire a <u>maximum</u> value from the summation of c_j based upon the alternatives selected as solution.

If the solution {1 0 1} is selected, then the evaluation of:

$$c_1x_1 + c_2x_2 + c_3x_3$$

results in the composite:

$$c_1 + c_3 .$$

Likewise, the solution set {0 1 1} results in the composite:

$$c_2 + c_3 .$$

If c_j are positive (i.e., good and desirable) measures and we therefore wish to maximize the c_j summation -- it is intuitive that the greater of the $((c_1 + c_3)$ and $(c_2 + c_3))$ values will decide the final choice between the [1 0 1] and [0 1 1] sets, respectively. That is, if in fact $(c_2 + c_2) > (c_1 + c_3)$, then the relationship:

$$\text{maximize } c_1x_1 + c_2x_2 + c_3x_3$$

yields the solution set [0 1 1] with a maximized objective function of $(c_2 + c_3)$. The idea of <u>maximizing</u> (the "good") and <u>minimizing</u> (the "bad") the summation of the objective function coefficients, demonstrates the issue of optimal v. feasible solutions. Both [1 0 1] and [0 1 1] were <u>feasible</u> solutions in that both satisfied the limits established via the inequalities and the values of the RHS or conditional vector. However, the [0 1 1] solution was <u>optimal</u> as it alone maximized the objective function summation.

In summary, this example could have been stated completely in the MAM framework as follows:

To <u>maximize</u>: $c_1x_1 + c_2x_2 + c_3x_3$

<u>subject to</u>: $a_{1,1}x_1 + a_{1,2}x_2 + a_{1,3}x_3 \leq b_1$

$a_{2,1}x_1 + a_{2,2}x_2 + a_{2,3}x_3 \geq b_2$

$x_j = (0,1),\ j = 1,2,3.$

The next section will focus in greater detail on the actual quantification of the coefficients; and the development of bounds for the conditional vector.

CONSTRUCTION OF THE MULTIPLE ALTERNATIVE MODEL

Simply stated, the Multiple Alternatives Model is a collection of simultaneous linear equations and inequalities, with an additional string of serial values (the objective function) available to "break any ties" which result when more than one vector of solution values (0,1) exists for the independent variables (the multiple alternatives). Generally speaking, these equations and inequalities which make up the constraint matrix and conditional vector (righthand-side) could be further labelled as the dependent variables (the foci of the particular criterion constraints).

The coefficients of the criterion constraints, the a_{ij} values, reflect measures for each of the x_j alternatives ($j = 1,...,n$) across each of the defined i-criteria ($i = 1,...,n$). The b_i values ($i = 1,...,n$) of the RHS (right-hand-side) represent the limits (upper and lower bounds) placed upon the sums of each criterion, summated across all selected (i.e. solution) alternatives. Since a selection means that the specific x_j value will equal '1', then the criterion value $a_{ij}x_j$ (or a_{ij} times 1) forces a_{ij} to be an added to the sum.

We may now improve tremendously upon our earlier characterization of the decision matrix (see Figure 1, Page 20). By adding the ideas of the conditional vector (to insure flexibility and the potential for tradeoff/preference), we are able to model the interactive-effects premise required of multiple-alternatives decisioning. Supplementing the model further with an objective function, the set of feasible solution alternatives can be further analyzed to choose the singularly best alterative mix-set -- the optimal solution. Figure 7 displays the scheme of the

Figure 7. Representation of the Augmented Decision Matrix Model as the "Multiple Alternatives Model" (MAM).

(Decision Variables)

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8		(RHS)
Constraint #01	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}	a_{16}	a_{17}	a_{18}		b_1
Constraint #02	a_{21}	a_{22}	a_{23}	a_{24}	a_{25}	a_{26}	a_{27}	a_{28}		b_2
Constraint #03	a_{31}	a_{32}	a_{33}	a_{34}	a_{35}	a_{36}	a_{37}	a_{38}	$\leq$ = $\geq$	b_3
Constraint #04	a_{41}	a_{42}	a_{43}	a_{44}	a_{45}	a_{46}	a_{47}	a_{48}		b_4
Constraint #05	a_{51}	a_{52}	a_{53}	a_{54}	a_{55}	a_{56}	a_{57}	a_{58}		b_5

c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8

(Cost Vector Coefficients)

OPTIMIZE: $\sum_{j=1}^{8} c_j x_j$ st $\sum_{j=1}^{8} a_{ij} x_j \; (\leq, =, \geq) \; b_j \quad x \geq 0$

(If MILP, x is integer; if decisional, x=0,1 only.)

augmented model, within the original eight-alternative/five-constraint milieu. We may now proceed to discuss in greater detail the measurement and operational schemes which are possible (and desirable) within the MAM framework.

Generation of Collectively-Exhaustive Alternatives

Valid construction and reliable execution of the MAM system requires the user to recall certain rudimentary facets of basic research and experimental design, and statistical analysis -- the issues of collective-exhaustiveness and mutual-exclusiveness. We will delay the discussion of the mutual exclusivity of selected alternative solutions until a later section. However, the issue of collectively-exhaustive alternatives is germane now.

Recall the two "strong suits" (obviously among many) of the MAM framework: (1) control of interactive effects modeling, and (2) measure of total system impact. Interactive-effects modeling provided a control over the rather complex milieu produced, when decision-making was evaluating multiple alternative solutions across multiple competing criteria. Single alternatives could be measured as "good" or "not-so-good" on various criteria - compared to the correlated criterion measures of other alternatives, and analyzed as to which alterative displayed the best-mix of criterion measures. When compared, however, did some set of alternative solutions produce a better "interactive-mix" than another set? And, were different amounts of alternatives required for either? Thus, interactive-effects modeling assumes highly complex interrelationships not only between sets of multiple alterantives and among (within) those same sets; but also presumes related interactions between the criterion measures of those same alternatives (both singular and multiple) --the necessary foundation for a trade-off/preference potential.

The other 'strong suit' of MAM centers about the issue of measuring total system impact. You will recall, that the RHS-values provide a control upon the summation of each criterion constraint --thus limiting the impact which the selected alternatives will be "allowed" to foster. However, RHS-values establish either an upper-or lower-bound to the summation, not the actual value which the summation must assume. Therefore, the true sum for any criterion constraint might very well be (and usually will be) different than the pronounced limit; that is, somewhat less than the upper-bound, or somewhat greater than the lower bound. In this way, the desired impact to the system is controllable but moreover the actual impact to the system is measureable. By knowing the discrepancy between the desired and actual impact, the MAM model can be used to detect changes to the system (i.e., differential impact) which may occur through the selection of different alternative solutions.

It should be obvious to the reader that neither the control of interactive-effects nor the recognition of system impact via varying alternatives' configurations, is possible without the existence of all possible, feasible, and relevent alternative courses of action for consideration. More succinctly, the set of multiple alternatives being evaluated across the defined criteria constraints must exhibit the characteristics of a collectively-exhaustive population of alternatives. The exclusion of any alternative from the model automatically precludes its impact upon the evaluation of the remaining alternatives, and its impact upon the system as a whole.

Criterion Measurement and Constraint Formation

Since the criterion constraint represents a linear relation (either equality or inequality) of the form:

$$a_{i,j}\, x_j + a_{i,j+1}\, x_{j+1} + \ldots + a_{i,n}\, X_n\ (\leq, =, \geq)\ b_i$$

or more concisely:

$$\sum_{j=1}^{n} a_{i,j}\, x_j\ (\leq, =, \geq)\ b_i, \text{ for each } i = 1, \ldots m,$$

extreme caution must be used in developing the a_{ij} coefficients of the x_j decision variables. Obviously, each a_{ij} must be numeric; and further exhibit such qualities as to allow their arithmetic sum to be a rational and useable quantity for comparison with the associated b_i) RHS-value (discussed in the next section).

Four basic scaling schemes exist for measuring and encoding data: nominal, ordinal, interval and ratio. Progressively inclusive, all can be utilized to formulate the a_{ij} coefficient, dependent upon the definition of the particular criterion constraint (i.e. its focus). The most common scales utilized are the interval and ratio measures, due to their ability to compute measures of central tendency (arithmetic means) and distributive variation (standard deviation). We will limit our discussion to these scaling techniques only.

Data concerning program expenditures (e.g. in dollar-units), number of required personnel (e.g. in FTE-units), or energy consumption (e.g. in BTU-units) are easily ratio-scaled measures. Other data which might be obtained from sample opinionnaires concerning the respondent's perceptions towards each particular alternatives might easily be interval-scaled (e.g. a six-point continuum measure associated with a 'Strongly Disagree, ..., Strongly Agree' response format).

Consider the objective:

"To deallocate such program alternatives as will secure an expenditure savings at least some amount '$SAVE'."

Clearly if we cost-out each program alternative and arrange the constraint as follows:

$$\$_{i,1}\, x_1 + \$_{i,2}\, x_2 + \$_{i,3}\, x_3 + \dots \$_{i,n}\, x_n \geq \$SAVE,$$

then the solution vector $[x, x_2, x_3 \dots x_n]$ must be of such (0,1) configuration as to allow the sum of the $\$_{i,j}$ to be at least the amount $SAVE or greater. This is one of the easier examples of the use for a ratio-scaled criterion.

Consider another objective for use of the interval-scale:

"To deallocate such program alternatives as will coincide with the public's opinion of each program's relative lack of merit."

Suppose that a questionnaire was sent to a random sample of individuals, wherein the question was asked:

"Program x_j fulfills the needs of the community to which it applies."

and the response tallied via the use of the following format:

1	2	3	4	5	6
Strongly Disagree	Disagree	Moderately Disagree	Moderately Agree	Agree	Strongly Agree

where a lesser magnitude (i.e. 1, 2, ...) displayed the respondent's disagreement with the item elicitor, and this measured a negative response to the perceived merit for each of the programs. If 100 people responded to these items (one for each program alternative), the 100 perceptions (1, 2, ..., 6) could be averaged and compiled into the constraint serial:

$$PCP_{i,}\ x_{i,} + PCP_{i,2}\ x_2 + \ldots + PCP_{i,n}\ x_n$$

where PCP_i is the ith constraint, and represents the group's (N=100) perception (PCP) of worth or merit for each program. Of course, a value for the RHS (b$_i$ must be computed; and we will survey this development in the next section.

The importance of each criterion constraint within the constraint matrix lies in its ability to model each alternative singularly (via the individual $a_{i,j}$ values), and collectively (via the summation of the a_{ij}, $j=1,\ldots,n$). Singular modeling allows the individual alternative's contribution to interaction-effects to be input to the decisioning model. Collective modeling then allows the impact to the total system of potential solutions to be comparatively evaluated against the established bounds of the conditional vector.

Computation of the Conditional (RHS) Vector

The need to limit the constraint coefficient summations for a realistic simulation of the system being modeled, as well as the use of these same summations to detect system impact, should now be (hopefully) obvious to the reader. If one wishes to limit the extent of some negative effect to the system via the alternatives selected, then some upper bound is established for the sum of criterion coefficients which represent this negative impact. Similarly, if the modeler wishes to force some level of positive impact, a lower bound would be defined for the sum of 'positive' criterion coefficients, stating that this minimal sum must at least be attained. What may not be so clear yet, is how these limits are arrived at.

One of the authors has performed considerable research in the different ways to develop the RHS-values in the conditional vector. These efforts have produced two basic methods for generating the RHS (the first, static, meaning to be established a priori, and therefore non-varying; the second, dynamic, meaning to be defined algebraically within the model, the value(s) varying as the model varies in its search for a solution). The most common method is the static approach because of its ease in modeling and the acceptability of its assumptions. We will limit our discussion at this time therefore, to the static RHS-value generation technique.

First let us review what we are attempting to accomplish with the linear inequality. Coefficients have been assigned to each of the alternatives-solution independent variables (the multiple alternative decisions being analyzed), based upon the focus and intent of the particular criterion being modeled (as a constraint). Execution of the models will sum various subsets of the set of coefficients defining that criterion; and will repeatedly compare that sum to the RHS limit assigned in the conditional vectors; that is:

$$\sum_{j=1}^{n} a_{ij} x_j \leq b_i \quad \text{(\underline{negative} impact)}$$

on,

$$\sum_{J=1}^{n} a_{ij} x_j \geq b_i \quad \text{(\underline{positive} impact).}$$

Recall also that the b_i value is to denote impact to the system as a whole; that is, the collective impact of the subset of decision alternatives being evaluated as a potential solution. If we think of "as a whole" and "collective impact" in the arithmetic sense, a useful analogy is the arithmetic average or mean. That is, the system will average the coefficients' value being analyzed; and compare this average value with the sum of the coefficients.

To accomplish this, the modeler first needs to predict <u>how many</u> decision alternatives (x_j) are likely to be selected for the final solution; let us say 'k'. Then the modeler computes the mean of the coefficients for a particular criterion,

$$\overline{A}_i = \frac{\sum_{j=1}^{n} a_{ij}}{m}$$

and multiplies the mean value A_i by the expected number (amount) of multiple solutions,

$$b_i = k \cdot \overline{A}_i =$$

where b_i is the RHS-value to be compared with the constraint coefficient (subset) sum. Thus,

$$\sum_{j=1}^{n} a_{ij}x_j \leq k \cdot \overline{A}_i$$

where the number of j's approximate the value of k.

Unfortunately, experience shows the use of the mean (alone) to be substantial in establishing a workable b_i value, this problem is easily rectified by introducing the standard deviation of the criterion coefficients to the b_i formula. Remembering that the standard deviation SD_A is obtained from:

$$SD_A^i = \left[\frac{\sum_{j=1}^{n} (\overline{A}_i - a_{ij})^2}{n-1} \right]^{\frac{1}{2}}$$

we can now modify the b_i generation formula as follows:

UPPER BOUND $\quad b_i = k \cdot (\overline{A}_i + SD_A^i)$

such that,

$$\sum_{j=1}^{n} a_{ij}x_j \leq k \cdot (\bar{A}_i + SD_A^i)$$

<u>LOWER BOUND</u> $b_i = k \cdot (\bar{A}_i - SD_A^i)$

such that,

$$\sum_{j=1}^{n} a_{ij}x_j \geq k \cdot (\bar{A}_i - SD_A^i).$$

Use of the mean and standard deviation provides a consistent format for constraining the decisioning matrix; and each constraint, therein. Not only is systematic flexibility afforded to the model as it searches for a unique (optimal) subset of solution alternatives, but the problems associated with <u>initial system infeasibility</u> are minimized. The notion of infeasibility will be covered in greater detail in a later section of this paper.

<u>Cyclical Optimatization Via Iterative Objective Functions</u>

In our earlier discussion of the role of the objective function (or cost vector) in gaining the <u>most optimal</u> solution (decisioning alternatives subset) from the <u>available feasible</u> solution subsets (acceptable to established constraints), the reader may have become aware of the subtle bias the OF-coefficients place upon the final solution. Often, this bias is intended. As often, however, it provides "fuel" for model critics to attack the MAM procedure as another "computerized, mathematically gerrymandering" technique. A satisfactory solution to this 'potential' problem is available, and relatively easy to implement.

The idea of cyclical optimization involves the cycling of each constraint entry (i.e. the coefficients a_{ij} of the constraint matrix) through the objective function. Generally speaking, this involves re-executing the model i-times, once for each of the defined constraints where:

$$c_{ij} = a_{ij},$$

each i-th iteration.

Since we either maximize or minimize the sum of the c_j values, depending upon their positive or negative focus respectively, cyclical optimization must be structured to then maximize the objective function when the constraint values being cycled are of a 'positive impact' nature. And of course, the reverse being true for the negative-impact constraint focus.

The MAM structure thus involves an optimization strategy, which may be depicted as:

$$\begin{matrix}\text{MAX} \\ \text{MIN}\end{matrix} \sum_{j=1}^{n} c_{ij}x_j \quad \text{for each ith iteration}$$

$$\text{subject to: } \sum_{j=1}^{n} a_{ij}x_j \ (\leq, =, \geq)\ b_i$$

$$c_{ij} = a_{ij} \text{ for all i of m;}$$

$$x_j = 1,0 \text{ for some j of m.}$$

Cyclical optimization does not eliminate the bias of the objective function; but rather allows each constraint focus to similarly bias the result of the solution subset selection. As we will see in a later section on "solution teaching," the cycling of each constraint through the objective function provides a most useful technique for studying total system impact.

Evaluation of the Multiple Alternatives Model

After rather detailed treatments of the design and construction of the MAM framework, additional discussion concerning the model's evaluation (that is, implementation and execution) may seem redundant to the reader. Obviously, the model is designed in full acknowledgement of the way in which it will 'work' to select alternative solutions. And the authors have gone to considerable length to indicate how the model will react to the various changes in its design and development.

But execution of the Multiple Alternatives Model is not in itself a "static" process. As a system of simultaneous linear inequalities, varying configurations of the solution vector $[x_1 \; x_2 \; x_3 \; \ldots \; x_n]$ will produce different interaction effects among the criterion constraint coefficients, effecting directly their sums and thus their ultimate comparison to the established RHS-bounds. It is conceivable (and unfortunately occurs often), that the initial relationship between the constraint matrix and conditional vector produces what is known as an <u>infeasible region</u>. The model must then be revised by <u>relaxing</u> one or more of the constraint summation limits, in order to determine (locate) an initial <u>feasible space</u>, and its associated parameters (b values). Since the relationship between criteria across alternatives (<u>viz</u>., interactive effects modeling) is not immediately evident in an infeasible situation, considerable time can often be expended in locating the "problem" RHS-value (or values).

Execution also refers to a previously discussed notion of cyclical optimization; and the differing solution vector subsets which usually result when the objective function is replaced by different values. The modeler must keep track of the different solution vectors (thus the term, solution teaching), and observe the nature of each cyclical-OF impat upon the system's final solution.

If the above few paragraph's still sound like "Cicero's oration to the pretorium," then we have not errored by including this section.

Total System Impact Via Multiple Competing Constraints

As each potential solution alternative competes with other alternatives for inclusion within a solution set, so also does any particular permutated solution subset compete with other feasible solution vector alternatives. The formation of the optimal solution vector occurs as the system asks itself these questions during execution:

(1) how many alternatives will occupy the solution vector?

(2) which alternatives will be selected?

(3) will these (e.g.) three alternatives better fit the constrained system optimally, versus these other five?

(4) will in fact any combinational permutation of the alternatives being modeled satisfy the constraints?

(5) which constraints "constrain" more than others? which less?

(6) if the conditional vector is comprised of desired impact, how close can the model select an optimal solution vector, and minimize the desired v. actual

$$(b_i - \sum_{j=1}^{n} a_{ij}x_j) \text{ values?}$$

(7) what tradeoffs/preferences have been made based upon the criteria as a whole, in the selection of one feasible solution subset over another.

Thus, impact to the system being modeled is based upon the selection of the solution vector subset <u>and</u> the related criterion constraints. It is this complicated interrelationship between alternatives and criteria (<u>viz</u>., interactive effects modeling) which makes the MAM an outstanding criterion-referenced, decision-making tool.

<u>Initial System Feasibility and Constraint Relaxation</u>

The MAM framework cannot systematically evaluate solution subsets for an optimal configuration until <u>system feasibility</u> has been initially established. Feasibility simply means, that at least one solution vector configuration exists which will satisfy the modeled criterion constraints (linear inequalities). If no such configuration exists (that is, the solution vector is a zero vector [0 0 0 ... 0], then the system is declared infeasible. Although subtle, the occurrence of a zero-vector is a most important (albeit, frustrating) result.

If the system has been carefully simulated and modeled via valid criterion constraints, with the RHS-values accurately reflecting system needs and/or demands -- then the result of a zero-vector simply means that no alternative is acceptable to the system as a solution. In most cases, the modeler would then "relax" one or more of the modeled constraints by increasing an upper-bound and/or decreasing a lower-bound. Such alteration makes the selection of some solution vector easier without violating a constraint coefficient summation. However, if the system modeled (in reality) can neither reasonably nor rationally accept the relaxation of its "standards and priorities," the modeled region is declared infeasible. The modeler must then seek new potential solution alternatives to be included in the MAM framework. But if the earlier issue of the collective-exhaustiveness of the alternatives has been addressed, the system is declared insoluable.

Cyclical Optimization and Solution Tracking

Cyclical optimization is accomplished by utilizing the a_{ij} coefficients of each constraint as the c_{ij} coefficients of the objective function. For a model with m-constraints, a maximum of m-executions, each with m-different sets of objective function coefficients, is possible. During any particular optimization cycle, the constraint whose coefficients form the objective function is still retained as a constraint for the determination of initial system feasibility.

Quite obviously (we hope) the reader now ponders the fact, that m-executions (or more appropriately, m-optimizations) will produce m-sets of optimal solution alternatives. That is, given a five-alternative model, with three-constraints, the resulting three cyclical optimizations could result in the solution sets:

	x_1	x_2	x_3	x_4	x_5	TOTAL
Cycle 1:	0	0	1	0	1	2
Cycle 2:	1	0	0	1	0	2
Cycle 3:	0	1	0	0	0	1
TOTAL	1	1	1	1	1	

As you can see, the first two cycles produced a solution set with two 'solutions' each; the third selecting a single alternative only. What is more interesting (though suicide-provoking in real-life) is the fact, that each alternative was chosen once (and only once) throughout the three cycles executed. Which alternative(s) should then constitute the solution set?

Suppose now that a different example (and more realistic) is posited, as follows:

	x_1	x_2	x_3	x_4	x_5	TOTAL
Cycle 1:	1	0	0	1	1	3
Cycle 2:	1	1	0	0	1	3
Cycle 3:	0	0	1	1	1	3
Cycle 4:	1	0	0	0	1	2
Cycle 5:	0	0	1	1	1	3
TOTAL:	3	1	2	3	5	

This five-alternative, 5-constraint problem has produced a series of '3-3-3-2-3' solutions throughout the five optimization cycles.

More important (for now, anyway) is the total frequency with which each alternative was selected as a member of the solution set. This framework is very close to a vote casting situation, where each of five voters can vote for a maximum of three candidates. (We guess voter #4 is as frustrated as many of us are at election time.) Candidate #5 "picked-up" a total of five votes, followd by candidates 1 and 4. Candidates 3 and 2 acquired two and one vote(s), respectively.

Such a tallying of solution choice by constraint cycle is known as solution tracking. Each set of constraint values takes a turn at influencing the development of a solution set; at the end of which, a simple tally displays the proportion of total choice across all possible alternative choices. The novice at this point may declare that option 5 is a clear choice; and that 1 and 4 should follow suit, forming the solution set:

[1 0 0 1 1].

Depending upon the mutual exclusivity of selected alternative solutions, we chose to agree amicably or disagree violently!

Mutual Exclusivity of Selected Alternative Solutions

We have devoted an earlier section to the importance of formulating collectively-exhaustive alternatives (see P. 62) for evaluation via the MAM framework. It was also expressed that the alternatives should overlap as little as possible (if at all); that is, the alternatives should represent clear, distinct actions -- no portion of which are included within the domain of another alternative solution being evaluated. Such distinction is known as the mutual exclusivity of defined alternatives.

It remains ironic then, to now state that some multiple alternatives problems by their very nature and substance, preclude such mutually-exclusive solutions. At this point of ambiguity, the best teacher is an example.

Consider our earlier cyclical optimization illustration in which the final composite solution vector was:

$$[x_1 \quad x_2 \quad x_3 \quad x_4 \quad x_5] = [3 \quad 1 \quad 2 \quad 3 \quad 5]$$

Now let us place this solution into context. As a policy alternative to the management of enrollment decline, you have chose to evaluate five elementary school sites for closure, based upon five a priori stated criteria. Being the intelligent and far-sighted person you are (you're welcome!), you decide to invoke the MAM framework to analyze these sites. The resulting five-cycle optimization produced the above composite vector. What is your decision?

Those of us experienced in school closures (you can tell by the scars) know, that the closing of one site may preclude a neighboring 'jeopardized' site from immediate closure, due to the transfer of students form the former to the latter school. Thus the choice of one alternative (e.g. site) may preclude the rational selection of another alterntiave. This more situation-specific illustration of a generic nonmutual-exclusiveness inherent in the problem itself, demonstrates the need for the modeler to beware.

A solution to this problem is evident, however. Choosing the 5th site for closure, the RHS-values

$$k \cdot (\bar{A}_i + SD_A^i)$$

can be recomputed with $i = 1,\ldots,4$ (5 missing) and the problem re-executed. Of course, the enrollments of the schools neighboring the closed site would be increased via transferred students; and criteria where enrollment was a factor, recomputed. Also, site #5 would no longer be a part of the model.

Thus it is not enough, that multiple decisioning alternatives be generated distinct from one another (mutual exclusiveness, input). Moreover, the individual entries of the derived solution set must demonstrate such distinction (mutual exclusiveness, output).

VALIDATION OF THE MULTIPLE ALTERNATIVES MODEL

As the final section of Part II and prior to commencing the development and implementation of the sample RØLBAK I and ROLBAK II models, we would be remiss in ignoring a most critical issue of the MAM framework; that is, "Does MAM do what it purports to do -- the manner in which it is supposed to?" Such a demand for accountability can only be responded to with a most humble (though gratifying) 'yes.'

Model Validity and Reliability Testing

Validation of the Multiple Alternatives Model can occur only through its ability to predict performances other than performance in itself (viz. validity), and the degree to which modeling results (the solution vector) are consistent with purported performance (viz. reliability). Validating the execution and results of a mathematical decisioning model thus extends beyond the simple notion of measurement. In effect, the modeling process must demonstrate at a minimum:

(1) that the decision arrived at is indicative of the criteria used in the rendering of that decision; and

(2) that the criteria as a collective whole are "predictive" of the resulting decision.

For validity testing of the MAM system, the distributional characteristics of each criterion variable must be analyzed, to determine if a significant difference exists between the distribution of the criterion measuring the "selected" alternatives and the distribution representing the "non-selected" alternatives. If the criterion measures are interval or ratio scaled, the analysis technique is simply a oneway analysis of variance procedure, where the independent variable represents whether the alternative was selected (=1) or not (=0). The results of this ANOVA procedure would determine if the partitioned criterion distribution representing the selected solution alternatives actually reflected the initial intent of the criterion constraint focus. If the criterion measures are nominal or ordinal scaled, the use of the Chi-Squared procedure (with a (0,1) independent variable) is recommended.

Reliability testing offers a new dimension to the validation of decisioning models; that is, the test of the modeled criteria's ability to predict future "choices" between multiple alternatives based upon established criteria inter-relationships. Thus in the results of a five criteria model, we ask the question:

"To what extent do relationships between the criterion variables (constraints) exist, in order to permit a prediction of future solution decisions based solely upon these same inter-relationships?"

Instead of a single dependent (criterion) and independent (decision) variable(s), we are now (in one example) confronted with a dichotomous dependent variable (0,1; to choose or not) and five independent variables attempting simultaneously to explain a correspondence between selection and criterion alues. This is (obviously?) the protocol for employing discriminant functions analysis. Applying discriminant analysis, prediction equations (linear combinations) are developed to allow future decisions based upon the model's use of the current constraint criteria.

Validity testing thus reflects the extent to which the MAM solution vector reflects an appropriate partitioning of each of the vector's formulation. Secondly, reliability analysis illustrates the degree to which the criteria relationships are so well defined as to be predictive (collectively) of solution vector inclusion versus exclusion.

Individual vs. Collective Criterion Impact

We have reiterated many times the superior quality of the MAM system in controlling for the impact (and influence) of interactive effects. In the previous section, analysis of variance procedures were recommended to test the validity of decision modeling per individual criterion. However, the MAM framework does not exist in a criterion-vacuum, but rather supports a collective criterion influence upon decisionmaking. The use of discriminant functions to illustrate this collective influence as a measure of reliability, is consistent with the focus and importance of interactive-effects modeling.

A more detailed investigation is required of the interactive effects by the multiple competing criteria because of the additional reliance upon cyclical optimization and the resulting composite-generated solution vector. Only through the use of predictive linear combinations, can the true "predictable" criterion impact be understood.

Comparative Effects from Main-Effects Modeling

An earlier discussion of the use of the composite variable ranking (CVR) technique (see page 21) in analyzing potential solution alternatives, introduced the main-effects modeling approach to multiple alternatives. The results from the CVR procedure can be directly compared to the MAM results for overlap. Indirectly, the CVR solution vector can be utilized as the independent variable to an ANOVA procedure, or as the dependent variable to discriminant functions. The resulting statistics can then be matched against the same statistics resulting from an analysis of MAM results; and the "differential impact" per criterion, and collectively across all criteria compared.

The reader is cautioned however to remember that the CVR approach does not control for interactive effects. Thus any particular choice (solution) takes into account only the measures of the criterion analyzed individuallly. It is reasonable to expect then, that CVR results may produce more agreeable ANOVA comparisons. The "proof of the pudding" however will lie in the matching of the results from the use of discriminant functions, when all criteria are taken into account simultaneously (which is also reality's demand).

Non-Negotiable Solution Alternatives

A final comment before displaying the actual results of two MAM applications in a fiscal roll-back context. You might ask, why go to all this trouble in order to analyze a multiple alternatives situation? Clearly, a great deal of effort is required to define the criteria, measure and input them to the model. Is it all worth it? And if so, why?

An organization's vague, ambiguous (and otherwise 'wishy-washy') approach to decisioning might lead the casual observer to believe that the resulting decision can likewise be non-specific. While this may often occur, the actions derived from the decisions will not themselves be vague (although they may be incoherent). And the results of these actions will not be ambiguous (though they may provide worthless or even disastrous). Decision making, especially in the multiple alternatives arena, is neither as easy nor as simple (non-complex) as some people lead others to believe.

Multiple alternatives decision-making can only be rationally accomplished via the use of defined criteria; and the conscious control of the criteria's competitive interaction. If you as a decision maker can accomplish this successfully while discounting the MAM framework, we are most humble impressed. However, if having read the previous pages you can now recognize the complexity of multiple alternatives decisioning, and the requirement for a structured framework in which to evaluate these alternatives -- we rest our case!

PART III

FIELD APPLICATION OF THE ROLBAK MODEL

INTRODUCTION TO THE FIELD APPLICATION

Part III now prepares to address the issue of actually operationalizing the claims of the first and second parts. That is, can a structured decisioning system be formulated to evaluate the specific criterion-referenced alternatives of various program units for fiscal roll-back in a budgetary crisis; and can such a criterion-referenced, multiple-alternatives model be utilized confidently in a funding deallocation situation?

The authors have had the distinct (though unfortunate) advantage of residing in a state which now finds itself in the midst of a severe, financial emergency. In all sectors of education, from the state policy level to the realm of the classroom teacher, alternatives are now being studied to brace for a cut to state-support for both K-12 and post-secondary education. To present the design and utility of the ROLBAK formalization, a single school district has been selected for the required piloting activities to demonstrate the ROLBAK formulization.

Need for the Research

In an age of expanding technology, the role of sophisticated approaches to decision-making has become more accessible to the field administrator. Nothing supports this view more strongly than the recent advance of computer technology in particular. Yet, those individuals who could best afford the advantages of such sophistication remain the greatest obstacles to the acceptance of sophisticated tools as a beneficial tool for data analysis and evaluation. The situation surrounding the funding deallocation of specific programs is a clear example.

Scant resources require a revision of expanding service activities. Compounding the problem of forced decline is the fact that many years of affluence in the availability of wide, diverse service delivery now clouds the issue of which services are essential and which are a luxury -- that is, the difference between entitlement on the one hand, and enrichment on the other. Therefore, the evaluation of current operating programs for possible elimination (or reduction) will not only require assessment of performance, but also a measure of the program's demand and need. As the decision-maker adds the criteria of need and demand to the already generic criterion list of effectiveness, efficiency, satisfaction and expenditure, the role of a multiple alternatives formulation to determine programs for retention vs. reduction via an analysis of multiple, competing criteria becomes paramount.

Finally, the need for a demonstration of a criterion-referenced, multiple-alternatives decisioning model is dictated by the parallel need of due-process. Not only does the decision maker need to be convinced of the efficacy of a carefully formulated MAM framework, but the program participants themselves need a firm understanding of the modeling perspective. People affected by the model-generated solutions (in this case, programs to be terminated) must accept that their personal interests were part of the decision, and that the relevant criteria were taken into account in the preparation of the final decision.

Purpose of the Research

The mission of this undertaking is two-fold; first, to demonstrate the development and design of the multiple-alternatives analysis framework for the area of fiscal roll-backs; and second, to assess the relevant issues of decision validity and model reliability for the reader and potential user. We as scientists fully realize, that acceptance of our technique can reasonably come only after maximal critique and scrutiny. We have endeavored to step-by-step annotate the development of the ROLBAK model for this particular study. And, we have employed the use of parametric statistical procedures in order to assess the model's impact upon the task at hand.

That task is this. Given an existing district program of 31 individual and distinct units, and the costs involved -- prepare, execute and evaluate the results of a mathematical modeling procedure which utilizes a criterion-referenced base for determining which program units remain operational, and which program units must be discontinued.

The criteria involved represent the identified expenditure requirements of each program unit, delineated across the eight "object" categories of a program budget; and a single measure of subjective opinion on the part of central office administrators as to which units are more important than others. We limit the inclusion of criterion references to only nine indicators <u>for convenience only</u>. Many other measures must be included in the final determination of units to be deallocated. However, the demonstration of the model's utility will not require the loading of all relevant criteria into this piloting-formulated model.

Overview of the Research

The outline for the contents of Part III have been constructed to accommodate a chronological discussion of the ROLBAK model's design, data construction, execution, and post-hoc evaluation.

The following section deals with the construction of the database for subsequent MAM-analysis. The next two sections will then present the rationale and methodology for utilizing the T-normal transformation of the new-scaled measures (dollars of expenditure). In addition, a brief discussion of special considerations in dealing with scant matrices will be presented.

The fifth section deals entirely with the search for initial model feasibility -- that is, the identification of the correct mix of constraint values (RHS) to permit an initial solution to the model.

The next two sections present the results (solutions) developed through the use of "restricted" and "relaxed" models, respectively. These two sections have been developed separately to highlight the differential impact of weighting.

The final two sections provide both a comparison of the restricted versus relaxed solutions, and a generalized discussion of the total ROLBAK performance under analysis.

CONSTRUCTION OF THE DATABASE

Although an actual field application (i.e. "for real") of ROLBAK to a fiscal emergency would necessarily include many criterion references to effectiveness, efficiency, need, demand, satisfaction and expenditure; the authors have limited the pilot of ROLBAK to a small aggregate of measures. Under the broad title of 'database' will exist the numerical values required to operationalize the functions of the constraint matrix, conditional vector (RHS), and the objective function. Finally, three distinctly different scales will be used to demonstrate the versatility of the model's data-input requirements.

Source of Data

Data for the model's execution represents two generalized measures: (1) a measure of expenditure requirement(s), in thousands of dollars; and (2) a measure of subjective bias, ordinally-scaled in units of rank (i.e., 1,2,3,...).

The expenditure data is input to the model in two separate fashions. The first, segregated by object-category, provide eight (8) separate expenditure amounts for each of the program units under consideration. These object categories are defined as projected allocations for:

1. CERT - certificated salaries
2. CLAS - classified salaries
3. BENE - employee benefits
4. SUPL - supplies and materials
5. INST - instructional supplies

6. CONT - contractual services
7. TRAV - travel expenditures
8. CAPI - capital outlay

These measures (originally in $1000's) will be later transformed into T-normal scores. Secondly, a category of 'total expenditures' required will be input to the model. This particular constraint will be utilized to efficiently control the 'cutting bias' of the model execution.

The second, general input manner will be an ordinal "rank of perceived expendability" attributed to each of the individual program units. Central office administrators were directed to rank the programs under consideration as to their degree of relative expendability, with 1 = most expendable.

For this particular ROLBAK pilot, a total of 31 programs were evaluated to determine the membership of the target set for deallocation. The criterion indicators to perform the MAM analysis included eight measures of <u>object expenditure</u> and a measure of <u>perceived expendability</u>, as well as a measure of composite expenditure.

<u>Method of Data Generation</u>

Total projected expenditures for each of the 31 identified program units were delineated into 8 object categories, as available from district office budgeting records. The rank-measures of perceived expendability portray composites from the aggregated ranks of four staff members: superintendent, assistant superintendent, and two administrative assistants.

In addition, the eight objects were summed to provide a measure of projected total expenditure by unit. The utility of this composite measure will be discussed in a later section. Where no expenditures were noted for a particular program under a specific object, the value of 0 (zero) was assumed. Such zero-cells form a scant (or sparse) matrix. Necessary controls for the analysis of scant matrices are discussed in the succeeding two sections.

Matrix Formating for MAM Utilization

Figure 8 displays the raw database to be transformed to T-normals (see next section) and subsequently evaluated by the MAM procedure. Note that the model will incorporate 10 criterion measures for analysis: expenditure by object (8), total expenditure by unit (1), and perceived expandability (1). As will be discussed in a later section, the total unit expenditure criteria will be utilized twice under actual model execution: once to establish a level of minimal cuts, and the second to provide an upper bound on the model's 'cutting' (we did not want the procedure to go "wild").

Recall the reason for the database described in Figure A. These measures will guide the RØLBAK analysis in determining which units will be allocated vs. deallocated funding -- based not only upon their expected expenditure by object but also upon their degree of perceived expendability. In addition, the measure of total unit expenditure (across all 8 objects) will be utilized to control for determining when "enough cuts" have been made to balance the new budget limitations.

Figure 8. Initial Raw Data Base for T-Normal Transformation and Entry into ROLBAK Procedure.

PRG	Budgeted Expenditures in $1000 by Object								TOTAL	PCP
	OBJ-1 [CERT]	OBJ-2 [CLAS]	OBJ-3 [BEDE]	OBJ-4 [SUPL]	OBJ-5 [INST]	OBJ-6 [CONT]	OBJ-7 [TRAV]	OBJ-8 [CAPI]		
01	55.0			5.5	20.0			7.0	87.5	19
02	19.0	5.0	.5	3.5	3.0	1.0		12.5	44.5	18
03	19.0	5.0	.5					10.0	34.5	23
04	54.0			1.0	9.0	.5	.5	6.5	71.5	13
05	53.0			5.5	10.0	1.5		.5	70.5	14
06	20.0			1.0	7.5			4.0	32.5	15
07	40.0			3.0	5.0	.5		3.0	51.5	16
08								1.5	1.5	25
09		3.0		19.0	3.5			17.5	43.0	4
10						3.0		1.0	4.0	17
11		13.0	1.0	16.0		16.0		8.0	54.0	21
12		1.0							1.0	2
13					5.0		.5		5.5	24
14	3.0					.5		.5	4.0	20
15		39.0	3.5	3.5		36.0		34.0	116.0	11
16						1.0		22.0	23.0	7
17								107.0	107.0	10
18				13.0					13.0	1
19		2.0							2.0	9
20				1.0					1.0	8
21	14.0		1.5					.5	16.0	30
22						.5		10.0	10.5	28
23		34.0	9.5		11.5				55.0	26
24	1.0		.5		2.0	1.0			4.5	29
25					2.0	.5			2.5	31
26	10.0	3.0						6.0	19.0	12
27				1.0					1.0	3
28				1.0					1.0	5
29	1.0	.5	.5						2.0	22
30				2.0		10.0			12.0	27
31						2.5			2.5	6

INITIAL T-NORMAL TRANSFORMATIONS

One of the original directions to this paper was to present the versatility of the MAM framework to accept a wide array of measurement scales as indicators for the values of the criteria. Although not discussed at length, all scales (i.e. nominal, ordinal, interval and ratio) can be accommodated by the MAM model.

In addition, the MAM framework in general and ROLBAK in particular, can be structured to model one of two situations (or both) concerning measured impact: impact of the system modeled specific to the individual effect for each alternative's value; and impact to the system modeled generalized to the collective effect for all alternatives' values. Briefly, the need for control of specific, individual effect (the former) addresses the need to measure the utility of each program alternative, and its absolute ability to coexist with other alternatives as part of the solution set. The use of a control for generalized, collective effect (the latter) however, addresses a less rigorous need to measure the utility of a program alternative, and its relative ability to become a member of the solution set.

Extensive research has been accomplished over the past five years by this author to understand the implications of a generalized, collective measurement system for criterion evaluation and control. Specifically, this research has centered about the usefulness of standardized (normalized) measures to accomplish this collective control need. Early work with z-scores was satisfactory, but required vigilance for the arithmetic impact of weights beneath the mean, that is, the negative values of z-score. Conversion to T-normals precluded such concern, and forms the primary measurement scale for the object expenditures in the ROLBAK model.

The use of standardized measures allows the decision-maker to measure the relative impact of each criterion's weight (for each unit alternative) without being concerned about the specific dollar amount. Reliance upon relative impact via the "object" criteria is valid within the ROLBAK system, since an additional criterion of total expenditure for each program unit is present.

Transformation Considerations for a Scant Matrix

Before proceeding with a specific illustration of normalized transformation, we add a cautionary note concerning data matrices with a high number of empty cells. Empty cells normally mean one of two things: either the measure was 'zero', and therefore a zero was entered; or the criterion was inappropriate to that particular alternative, and therefore no measure is possible. As we said much earlier, the choice of relevant criteria which are applicable across all alternatives will preclude the model builder from the need to control for sophisticated confounded effects from irrelevant criterion variables.

For ROLBAK, the amount of zero-cells demonstrating zero-cost in particular objects for certain alternatives is very large -- large enough to call the data matrix a "scant" or "sparse" matrix (more zeros than not). To control for this situation, and to provide a better environment for the use of the RHS control values, we chose to exclude the empty cells from calculation of the normalized measures.

This is to say (please read very carefully now), that:

> the normalized values associated with a particular criterion demonstrate the relative weight of that criterion for the individual unit, relative to the other unit weights where such criterion expenditure actually exists.

(You can stop reading carefully now!)

In effect, the zero weights denoting no expenditure are not part of the original distribution that will compute the standardized measures; and thus the calculated weights will be more conversant with the other unit values where criterion expenditure actually exists.

First Stage Transformation to Z-Scores

The following subsections are presented in brief to help those readers who have misplaced their statistics knowledge (who has not?).

A z-score is a normalized measure, standardized to reflect the relative weights of each of the 'raw data' values which form a specific distribution of scores (in our specific case, the distribution of expected expenditures, by object category). A z-score represents the mean of the raw distribution as a '0.00', and the standard deviation as a '±1.00'. That is, a raw score which represents a single standard deviation above the mean of the distribution is computed as a +1.00. If a score is one and one-half times the standard deviation below the mean, it is represented as -1.50; and so forth.

This is to say (please read very carefully now), that:

> the normalized values associated with a particular criterion demonstrate the relative weight of that criterion for the individual unit, relative to the other unit weights where such criterion expenditure actually exists.

(You can stop reading carefully now!)

In effect, the zero weights denoting no expenditure are not part of the original distribution that will compute the standardized measures; and thus the calculated weights will be more conversant with the other unit values where criterion expenditure actually exists.

First Stage Transformation to Z-Scores

The following subsections are presented in brief to help those readers who have misplaced their statistics knowledge (who has not?).

A z-score is a normalized measure, standardized to reflect the relative weights of each of the 'raw data' values which form a specific distribution of scores (in our specific case, the distribution of expected expenditures, by object category). A z-score represents the mean of the raw distribution as a '0.00', and the standard deviation as a '±1.00'. That is, a raw score which represents a single standard deviation above the mean of the distribution is computed as a +1.00. If a score is one and one-half times the standard deviation below the mean, it is represented as -1.50; and so forth.

For the zealots among you, the transformation formula for computing a z-score from a raw distribution is follows:

$$z_i = \frac{X_i - \overline{X}}{s}$$

where,

$$\overline{X} = \frac{\Sigma X_i}{N} \qquad \text{(mean)}$$

and,

$$s = \left[\frac{\Sigma(X_i - \overline{X})^2}{N - 1}\right]^{\frac{1}{2}} \qquad \text{(standard deviation)}$$

subject to,

$i, = 1,2,\ldots,N$ values.

Second Stage Transformation to T-Normals

The use of T-normals is simply suggested as a useful technique for circumventing the negative values of z-scores (or z-normals, if you wish). T-normals are standardized measures, with a mean of 50.00 and a standard deviation of 10.00. Thus, a negative T-normal would result only from a raw measure, whose value resides greater than 5 standard deviations below the mean of the distribution (somewhat unlikely, in the usual case).

T-normals are computed directly from z-scores, as follows:

$$T_i = 10.0(z_i) + 50.0,$$

such that a z = -1.0 becomes a T = 40.0, a z = +2.5 becomes a T = 75.0, and so forth.

FORMULATION OF THE ROLBAK MATHEMATICAL MODEL

The reader is directed to Figure 7 (see page 61) to review the format of the generalized MAM framework. Recall that the model utilizes three distinct though obviously interrelated segments. The first, the constraint matrix, contains the coefficients for the system of simultaneous linear inequalities (and equalities), whose independent variables are the alternative program units. Therefore, these coefficient values are really the criterion measures associated with each independent variable's "performance" or "need".

The second distinct segment, the conditional vector (or "right-hand-side"), contains the composite measures which restrict the summations of the coefficients of the independent variables, as those independent variables are evaluated for inclusion within the final solution set. These RHS-values are the upper (or lower) bounds associated with the linear inequalities, and the exact standard associated with any linear equation.

The last segment, the objective function, provides the guiding force behind the selection of alternatives for membership within the solution set. Remember that objective function (sometimes referred to as cost vectors, whether measuring cost or not) must be either maximized or minimized, depending upon the objective of the problem modeled. Maximizing (or minimizing) the summation of the objective function is referred to (in fashionable circles, of course) as optimization.

Under optimality then, the goal of the model is as follows:

> to formulate the "best" solution mix of alternatives based upon the values of the objective function; given the constraints defined by the simultaneous system of inequalities (and equalities) as modeled by the constraint matrix, and the limits provided by the conditional vector.

The Constraint Matrix

To formulate the ROLBAK problem, a total of 31 individually funded programs were defined for evaluation. Each program's budget was delineated into it's individual 'object expenditure' requirements (certificated salaries, instructional supplies, etc.). These initial eight expenditure breakdowns form the first 8 constraints of the constraint matrix; and are entered as T-normal transformations. The next two constraints are identical vectors containing the total, composite expenditure requirements for each program unit. Expressed in thousands of dollars, these two vectors will provide the basis for controlling the model's final, total amount of final deallocation. The last constraint vector, in the matrix, contains the ranked values for the "perceived expendability" of each unit; where 1 = most expendable and 31 = least expendable.

Thus the criterion coefficients of the constraint matrix represent three distinct measurement features: T-normals measured in standard units, total expenditure measured in thousands of dollars, and expendability measured in ordinal ranks.

Conditional Vector for a Scant Matrix

The RHS-values of the conditional vector served to operationalize the simultaneous system of the constraint matrix; that is, they establish the limits which the vector-coefficients summations must comply with.

For the initial 8 object-expenditure constraints, the RHS-values are computed to effect a generalized impact upon the system as a whole treating all objects equally. Thus, expenditures projected in any one category do not place their associated programs in weighted jeopardy. Although in some modeling cases such weighting will be desirable, the current example weights all equally for demonstration purposes. These specific values will be discussed at length in the next section.

The next two constraint vectors are identical in that their coefficients represent composite object expenditures for each program. The district's current operating budget comprised 893.5 (thousands) dollars. The goal of the model was to develop a plan for effecting a revised operating level of not less than 675.0 dollars (1000's) nor greater than 700.0 dollars (1000's). To model this objective (constraint), the sum of the first vector was limited to 675.0 (greater than or equal, and the sum of the second vector to 700.0 (less than or equal). In effect, this "bracketing" allows a 25.0 dollars (1000's) flexibility factor for model evaluation.

The final constraint, the measure of perceived expendability, was modeled to effect a smaller sum (minimized). This was necessitated due to the fact that a smaller rank represented greater expendability -- and thus, the sum of smaller values produces a "preferred" smaller amount.

The considerations required for a scant matrix involve only the first 8 inequality vectors. However, the sum of zeros will not deter from the utility of the conditional vector in successfully controlling the sum of the remaining sums. Since the empty cells represent no expenditure for that particular object, the choice of the associated program unit will not contribute to the RHS-requirement (limit). (Again, please refer to the next section for a more detailed discussion.)

Cyclical Objective Function

Since the construction of the objective function, and the subsequent maximization or minimization of its sum, defines what we call 'optimality', the content to the O.F. is a biasing factor to the model's evaluation of alternatives. It is reasonable to expect a different mix of solution alternatives, if the model utilizes a different objective function <u>or</u> changes from maximization to minimization of the same objective vector.

ROLBAK examines the effect such manipulation has upon solution results by cycling each individual constraint vector through a separate execution as the objective function. Moreover, the focus is altered to investigate both optimality directions, maximization and minimization.

The Problem

Given the structure of the MAM framework discussed above, the resulting ROLBAK model will select ($X_j = 1$) those program units to be retained, that are to receive funding.

SEARCH FOR REGIONAL FEASIBLITY AS BENCHMARK

The initial attempts in executing a MAM-designed solution, requires the establishment of first, initial region feasiblity of the decision space, and second, a benchmark from which the manipulation of RHS-weighting and cyclical optimization can both be measured. Decision space (regional) feasibility simply means that at least one solution exists which satisfies the requirements of the constraint matrix and conditional vector. If no solution exists, under any circumstance allowed by the linear inequalities and equalities, then the decisioning (constraint) region is declared to be "infeasible"; and the model either altered or abandoned.

Once feasibility is determined, a benchmark is established to begin the cyclical evaluation of the various agreed-upon criterion values. The benchmark may in fact be the initial point at which feasibility is determined. However, serious practitioners of the art (obviously us!) will search for two separate modeling configurations from which to observe the effect of the varying optimality criteria. These separate configurations can best be addressed as states of restriction and relaxation.

The restricted model contains RHS-values which force the execution to choose its solution set most carefully; that is, the limits imposed are very restrictive as to what is allowable to constitute a solution. On the other hand, the relaxed model utilizes such RHS-values as will invite solution set membership patterns which widely differ. The authors have chosen both so as to please even the most skeptical of our readers.

'N' of the Scant Matrix

The normal procedure in attempting to establish feasibility is to arbitrarily project the number (N) of solution which is likely to result from the successful implementation of the model. With the use of T-normals, and the given T(mean) = 50.0 and T(standard deviation) = 10.0, the arbitrary N can be used to establish a beginning RHS-value:

$$N(50.0 + 10.0) = N(60.0)$$

for a perceived upper bound; and:

$$N(50.0 - 10.0) = N(40.0)$$

for a perceived lower bound. (The rationale for such considerations has been discussed at length in a previous chapter of this report.)

The existence of a scant matrix however provides a rather unique situation concerning such 'N' formulation. That is, the N's concerning each criterion across all alternatives will differ, based upon the number of empty (i.e. zero) cells. And in fact for this particular ROLBAK formulation, this is exactly the case. Referring to Figure 8 (on page 91), you will see that the number of non-zero cells are as follows:

CERT = 12
CLAS = 10
BENE = 8
SUPL = 14
INST = 10
CONT = 14
TRAV = 2
CAPI = 18.

Under these circumstances, the useful relationship of

$$N(T(Mn) + T(S.D.))$$

must be changed to

$$N_k(T(Mn) + T(S.D.))$$

for <u>each</u> separate k = 1,2,...,8 of the object expenditure categories.

Expected Solution Index

The expected solution index (ESI) controls for <u>both</u> the existence of a scant matrix of zero-cells, and the necessity to investigate varying levels of solution N's -- that is, the number of units which may be members of the final solution set. Although inextricably related, we will develop each separately for the sake of understanding their unique contribution.

The existence of a scant matrix will provide a varying number of non-zero cells. To operationalize the utility of the N(T(Mn) + T(S.D.)) idea, we must vary the N for each computation of the particular RHS-value. Furthermore, the region of feasible solution(s) will likewise require the search for a suitable (expected) solution set size; that is, to allocate (for example) funds to 10 programs; or 12; or 14; etc.

The EIS is calculated to take into account both scant matrices and varying solution set membership by utilizing the postulate:

$$\frac{(N > 0)(E)}{N(\text{total})}$$

where,

(N > 0) = number of non-zero cells for the given criterion constraint;

(E) = number of expected solution set alternatives; and

N(total) = number of total possible alternatives.

In our ROLBAK example, this expression can be reduced to

$$\frac{(N > 0)\ (E)}{31}.$$

For example, if we were to examine the ESI for the "certificated salaries" constraint (12 non-zero cells) and an expected solution membership of 10, the index based upon the (N > 0) would be calculated as:

$$\frac{N>0}{31} = \frac{12}{31} = .387 ,$$

and with the expected membership (E) of 10,

$$\frac{N>0}{31}(E) = .387(E) = .387(10) = 3.87$$

This index and its relationship to the T-normal values will be described in the next subsection.

RHS-Values by Index

Figure 9 summarizes the calculation of RHS-values utilizing the idea of an expected solution index (ESI) for a scant matrix. for example, given the constraint of certificated salaries (CERT), with 12 non-zero entries and an expected solution membership of 10 units, the RHS-value would be computed as:

$$\frac{12(10)}{31}(50.0 - 10.0) = 3.87\ (40.0) = 155.0,$$

assuming that a "linear bound" is the desired RHS intention.

The RHS-values for PERC and COMP are arrived at arbitrarily as well, but without resorting to the above scheme for T-normals.

Search for Feasibility

Use of the ESI system discussed in the preceding subsection established immediate feasibility, with concurrent values for

Figure 9. Computation of Conditional Vector (RHS) Values for Constraint Matrix with Zero Sub-Matrices and Cell-Entries Based Upon T-Normal Scores

Criterion Constraint	Code	N>0	INDEX*	E=10	E=12	E=14	E=16
				RHS-Values by Expected Index**			
Certificated Salaries	CERT	12	.389	155	186	217	248
Classified Salaries	CLAS	10	.323	129	155	181	206
Employee Benefits	BENE	08	.258	103	124	145	165
Supplies & Materials	SUPL	14	.452	181	217	253	289
Instructional Supplies	INST	10	.323	129	155	181	206
Contractural Services	CONT	14	.452	181	217	253	289
Travel Expenditures	TRAV	02	.065	026	031	036	041
Capital Outlay	CAPI	18	.581	232	279	325	372
Administrative Perception	PERC	31	(Restricted = 500 / Relaxed = 600)				
Composite Budget	COMP	31	(Lower Limit = 675.0 / Upper Limit = 700.0)				

* Index = $\frac{N>0}{31}$

** RHS (EXP) = [N>0] [T(Mn) ± T(SD)] / 31 = (Index) (Tm ± 10), where: 1. Index (40) for Lower Bound (≥)
2. Index (60) for Upper Bound (≤)

PERC and COMP as shown. Any value for PERC less than 500, however, lost the feasible region.

Search for Benchmark

The range of expected membership values was varied from E = 10 to E = 16, and the definition(s) of <u>relaxed</u> benchmark attached to:

$$E = 16; \; PERC = 500,$$

and <u>restricted</u> benchmark attached to:

$$E = 10; \; PERC = 600.$$

Since the object categories were constrained to force summations <u>greater than or equal to</u> the RHS-values established by the ESI, the larger the RHS-value, the more difficult to find an acceptable solution -- therefore, the more restricted. Likewise, for the relaxed system and smaller values of the RHS.

For the purposes of the remainder of this chapter, the restricted and relaxed benchmarks will be utilized to observe the effects of cyclical optimization upon solution set membership.

CYCLIC OPTIMIZATION OF THE RESTRICTED MODEL

The first of two major quantitative assessments, the cyclic optimization of each of ten (10) criterion linear (convex) combinations as the objective function, produced analyzable results under both maximization and minimization. This section will study these results, and address their relationship to both the model's execution and the criteria utilized, for the restricted model.

Maximized/Restricted Solutions

Figure 10 displays the results of the various cyclical maximizations within the restricted setting. Of the possible combinations of the available 31 units for solution membership, only two distinct solution sets were formed. The mix set of 10 entries

[01,02,03,04,05,07,09,11,15,17]

produced a new budget of 680.0 dollars (1000's) for a savings of 213.5 dollars (1000's), in five cases. Similarly, another five instances formed the mix set of 10 entries

[01,02,04,05,07,11,15,16,17,23]

producing a new budget of 680.5 dollars for a savings of 213.0 dollars.

Additional technical data has been included within the figure for the more technically knowledgeable.

Figure 10. Effect Upon Budget Deallocation Decisions Based Upon the Variable Flows of a Cyclic Objective Function, and the Interaction of a "Maximized, Restricted" Constraint Iterative Problem.

Objective = Maximization Constraints: Restricted (EXP=16; PERC = 500)

Budget Alternatives	01 CERT	02 CLAS	03 BENE	04 SUPL	05 INST	06 CONT	07 TRAV	08 CAPI	09 PERC	10 COMP	SELECTION TALLY	BUDGET AMOUNT
01	X	X	X	X	X	X	X	X	X	X	10	87.5
02	X	X	X	X	X	X	X	X	X	X	10	44.5
03	X	X		X			X	X			5	34.5
04	X	X	X	X	X	X	X	X	X	X	10	71.5
05	X	X	X	X	X	X	X	X	X	X	10	70.5
06											--	32.5
07	X	X	X	X	X	X	X	X	X	X	10	51.5
08											--	1.5
09	X	X		X			X	X			5	43.0
10											--	4.0
11	X	X	X	X	X	X	X	X	X	X	10	54.0
12											--	1.0
13											--	5.5
14											--	4.0
15	X	X	X	X	X	X	X	X	X	X	10	116.0
16			X		X	X			X	X	5	23.0
17	X	X	X	X	X	X	X	X	X	X	10	107.0
18											--	13.0
19											--	2.0
20											--	1.0
21											--	16.0
22											--	10.5
23			X		X	X			X	X	5	55.0
24											--	4.5
25											--	2.5
26											--	19.0
27											--	1.0
28											--	1.0
29											--	2.0
30											--	12.0
31											--	2.5

	01	02	03	04	05	06	07	08	09	10
	10	10	10	10	10	10	10	10	10	10
O.F. Value:	340.7	274.5	217.9	433.9	330.0	362.1	50.0	534.6	496.2	680.5
Iteration at Optimality:	36	69	76	115	228	27	114	51	5000+	369
Time (secs):	.266	.298	.288	.325	.384	.264	.383	.274	4.498	.850
Roll-Back Savings:	680.0	680.0	680.5	680.0	680.5	680.5	680.0	680.0	680.5	680.5
(- Cut)	(-213.5)	(-213.5)	(-213.0)	(-213.5)	(-213.0)	(-213.0)	(-213.5)	(-213.5)	(-213.0)	(-213.0)

Note: Total Initial Budget = 893.5 ($1000's)

Figure 10. Effect Upon Budget Deallocation Decisions Based Upon the Variable Flows of a Cyclic Objective Function, and the Interaction of a "Maximized, Restricted" Constraint Iterative Problem.

Objective = Maximization   Constraints = Restricted (EXP=16; PERC = 500)

Budget Alternatives	01 CERT	02 CLAS	03 BENE	04 SUPL	05 INST	06 CONT	07 TRAV	08 CAPI	09 PERC	10 COMP	SELECTION TALLY	BUDGET AMOUNT
01	X	X	X	X	X	X	X	X	X	X	10	87.5
02	X	X	X	X	X	X	X	X	X	X	10	44.5
03	X	X		X			X	X			5	34.5
04	X	X	X	X	X	X	X	X	X	X	10	71.5
05	X	X	X	X	X	X	X	X	X	X	10	70.5
06											--	32.5
07	X	X	X	X	X	X	X	X	X	X	10	51.5
08											--	1.5
09	X	X		X			X	X			5	43.0
10											--	4.0
11	X	X	X	X	X	X	X	X	X	X	10	54.0
12											--	1.0
13											--	5.5
14											--	4.0
15	X	X	X	X	X	X	X	X	X	X	10	116.0
16			X		X	X			X	X	5	23.0
17	X	X	X	X	X	X	X	X	X	X	10	107.0
18											--	13.0
19											--	2.0
20											--	1.0
21											--	16.0
22											--	10.5
23			X		X	X			X	X	5	55.0
24											--	4.5
25											--	2.5
26											--	19.0
27											--	1.0
28											--	1.0
29											--	2.0
30											--	12.0
31											--	2.5
	10	10	10	10	10	10	10	10	10	10		
O.F. Value:	340.7	274.5	217.9	433.9	330.0	362.1	50.0	534.6	496.2	680.5		
Iteration at Optimality:	36	69	76	115	228	27	114	51	5000+	369		
Time (secs):	.266	.298	.288	.325	.384	.264	.383	.274	4.498	.850		
Roll-Back Savings:	680.0	680.0	680.5	680.0	680.5	680.5	680.0	680.0	680.5	680.5		
(- Cut)	(-213.5)	(-213.5)	(-213.0)	(-213.5)	(-213.0)	(-213.0)	(-213.5)	(-213.5)	(-213.0)	(-213.0)		

Note: Total Initial Budget = 893.5 ($1000's)

Minimized/Restricted Solutions

Minimizing the various objective functions within the restrictive setting produced similar results (Figure 11). Four occurrences of the solution vector

[01,02,03,04,05,07,09,11,15,17]

and three occurrences of the solution vector

[01,02,04,05,07,11,15,16,17,23]

resulted in the minimized, restricted setting. Unlike maximized optimality however, the use of minimized objective functions failed to produce a solution in three separate instances.

Validity Evaluation of the Restricted Model

Analysis of variance procedures were utilized to detect the extent of criterion difference between membership in the solution vs. non-solution sets. Since optimality within the restricted setting produced only two different combinations of solutions, these post hoc assessments were easy to execute. Results are presented in Figure 12.

A review of the ANOVA results show that in all cases except one, the mean values of the "included" criterion indicators were greater than the non-solutional weights; and were therefore consistent with model expectations and formulated constraints. The one exception occurs in both optimality settings when the perception of expendability was used as the O.F.

Figure 11. Effect Upon Budget Deallocation Decisions Based Upon the Variable Forms of a Cyclic Objective Function, and the Interaction of a "Minimized, Restricted" Constraint Interative Problem.

Objective = Minimization Constraints = Restricted (8xP=16; PERC=500)

Budget Alternatives	01 CERT	02 CLAS	03 BENE	04 SUPL	05 INST	06 CONT	07 TRAV	08 CAPI	09 PERC	10 COMP	SELECTION TALLY	BUDGET AMOUNT
01		X	X	X	X	X		X	X		7	87.5
02		X	X	X	X	X		X	X		7	44.5
03			X		X	X			X		4	34.5
04		X	X	X	X	X		X	X		7	71.5
05		X	X	X	X	X		X	X		7	70.5
06											--	32.5
07		X	X	X	X	X		X	X		7	51.5
08											--	1.5
09			X		X	X		X	X		4	43.0
10											--	4.0
11		X	X	X	X	X		X	X		7	54.0
12											--	1.0
13											--	5.5
14											--	4.0
15		X	X	X	X	X		X	X		7	116.0
16		X		X				X			3	23.0
17		X	X	X	X	X		X	X		7	107.0
18											--	13.0
19											--	2.0
20											--	1.0
21											--	16.0
22											--	10.5
23		X		X				X			3	55.0
24											--	4.5
25											--	2.5
26											--	19.0
27											--	1.0
28											--	1.0
29											--	2.0
30											--	12.0
31											--	2.5
	10	10	10	10	10	10	10	10	10	10		
O.F. Value:	--	234.5	197.0	366.8	314.8	313.0	--	482.6	489.0	--		
Iteration at Optimality:	--	5000+	686	200	85	902	--	203	53	--		
Time (sec):	--	4.581	.933	.563	.304	1.193	--	.407	.256	--		
Roll-Back Savings:	--	680.5	680.0	680.5	680.0	680.0	--	680.5	680.0	--		
(-Cut)	--	(-213.0)	(-213.5)	(-213.0)	(-213.5)	(-213.5)	--	(-213.0)	(-213.5)	--		

Note: Total Initial Budget = 893.5 ($1000's)

Figure 12. Summary of Cyclic Optimality Directions (of Criterion Objective Functions) Utilized in Guiding the Fully Restricted (EXP=16; PERC=500) Problem to Two Distinct Solutions; and Resulting Object Expenditure Impact.

Fully Restricted (EXP=16; PERC=500)

Direction	Solution = (1,2,3,4,5,7,9,11,15,17)	Object	Solution = (1,2,3,5,7,11,15,16,17,23)	Direction
MAX	P= .02 I=34.1 X=12.4	Certificated Salaried	P= .15 I=29.1 X=14.8	---
MAX	P= .07 I=27.4 X=10.7	Classified Salaries	P= .25 I=23.4 X=12.6	MIN
MIN	P= .27 I=19.7 X= 9.8	Employee Benefits	P= .14 I=21.8 X= 8.8	MAX
MAX	P= .00 I=43.4 X=12.9	Supplies & Materials	P= .04 I=36.7 X=16.1	MIN
MIN	P= .03 I=31.5 X=11.2	Instructional Supplies	P= .02 I=33.0 X=10.5	MAX
MIN	P= .21 I=31.3 X=18.6	Contractural Services	P= .05 I=36.2 X=16.3	MAX
MAX	P= .59 I= 5.0 X= 2.4	Travel Expenditures	P= .59 I= 5.0 X= 2.4	---
MAX	P= .00 I=53.5 X=17.5	Capital Outlay	P= .00 I=48.3 X=20.0	MIN
MIN	P= .67 I=48.9 X=50.5	Administrative Perception	P= .88 I=49.6 X=50.2	MAX
---	P= .00 I=68.0 X=10.2	Budgetary Composites	P= .00 I=68.1 X=10.1	MAX

Cell Entries:

(P=) ... statistical significance of mean difference, include v. exclude.
(I=) ... mean budget amount for included object of budget revision.
(X=) ... mean budget amount for excluded object of budget revision.

It is also interesting to note, that the

[01,02,03,04,05,07,09,11,15,17]

pattern resulted in six (6) statistically significant differences while the other pattern resulted in only five (5). Though barely different in number, the criterion producing such differences (as O.F.) varied in both cases. The reader should recall that significant differences in criterion mean weights portray the ability of the model to utilize such criterion constraints within the decisioning and solution set building process.

Reliability Evaluation of the Restricted Model

Discriminant function analysis was employed to study the consistency and predictability of the model's function in producing reliable solution sets.

Figure 13 displays the discriminant results for solution set

[01,02,03,04,05,07,09,11,15,17].

The major criterion values predictive of the established solution is shown in the order of their importance. Re-prediction was established with 96.77 percent accuracy.

The results for the solution set

[01,02,04,05,07,11,15,16,17,23]

are found in Figure 14. In this case, only three criterion distributions were required to re-predict membership at an equivalent 96.77 percent accuracy.

Figure 13. Use of Discriminant Analysis in Predicting Program Inclusion for Budgetary Revision, Solution #1, Based Upon the Cyclic Optimization of the Restricted Problem.

Budget	Incl	Budget	Incl	Budget	Incl	Budget	Incl
01	1	09	1	19	1	25	--
02	1	10	--	18	--	26	--
03	1	11	1	19	--	27	--
04	1	12	--	20	--	28	--
05	1	13	--	21	--	29	--
06	--	14	--	22	--	30	--
07	1	15	1	23	--	31	--
08	--	16	--	24	--		

Summary of Criterion Value in Discriminating Inclusion Decisions:

Step	Entered	Removed	Not Used
1	Budgetary Composites		Employee Benefits
2	Supplies & Materials		Instructional Supplies
3	Capital Outlay		Contractural Services
4	Certificated Salaries		Travel Expenditures
5	Classified Salaries		Administrative Perception

Classification Results From Predictive Validation:

(Percents in Parenthesis)

Actual Group	(N)	Predicted Group Membership 0	1
0	21	20(95.2)	1(4.8)
1	10	---	10(100.0)

Percent of Grouped Cases Correctly Classified: 96.77

Figure 14. Use of Discriminant Analysis in Predicting Program Inclusion for Budgetary Revision, Solution #2, Based Upon the Cyclic Optimization of the Restricted Problem.

BUDGET	INCL	BUDGET	INCL	BUDGET	INCL	BUDGET	INCL
01	1	09	--	17	1	25	--
02	1	10	--	18	--	26	--
03	--	11	1	19	--	27	--
04	1	12	--	20	--	28	--
05	1	13	--	21	--	29	--
06	--	14	--	22	--	30	--
07	1	15	1	28	1	31	--
08	--	16	1	24	--		

Summary of Criterion Value in Discriminating Inclusion Decisions:

STEP	ENTERED	REMOVED	NOT USED
1	Budgetary Composites		Certificated Salaries
2	Contractual Services		Classified Salaries
3	Instructional Supplies		Employee Benefits
			Supplies and Materials
			Travel Expenditures
			Capital Outlay
			Administrative-Perception

Classification Results from Predictive Validation:

(Percent in Parenthesis)

Actual Group	(N)	Predictive Group Membership 0	1
0	21	21(100.00)	--
1	10	1 (10.0)	9 (90.0)

Percent of Grouped Cases Correctly Classified: 96.77

CYCLIC OPTIMIZATION OF THE RELAXED MODEL

The second of the two major quantitative assessments, the relaxed setting produced a wide diversity of solution sets. In fact, out of twenty executions and seventeen successful feasibilities, all seventeen solution sets were unique.

Maximized/Relaxed Solutions

Figure 15 displays ten unique solutions, one for each of the cyclic optimizations under maximization. All solutions were successful in rebudgeting between the 675.0 and 700.0 limits. It is perhaps more interesting to study the column of numbers labelled 'selection tally', on the right side of the figure. The repetition with which particular units were chosen for continued funding resembles closely the two solution sets constructed with the restricted model formulation.

Minimized/Relaxed Solutions

Minimizing in the relaxed setting produced three failures at set building. Of the seven solution sets constructed, all are distinct; and different from the maximization sequence. Figure 16 presents these data results.

The alert reader will also note that the relaxed setting produces varying numbers of units within the solution set (low of 10 to a high of 13 units selected).

Figure 15. Effect Upon Budget Deallocation Decisions Based Upon the Variable Flows of a Cyclic Objective Function, and the Interaction of a "Maximized, Relaxed" Constraint Iterative Problem.

Objective = Maximization Constraints: Relaxed (EXP=10; PERC = 600)

Budget Alternatives	01 CERT	02 CLAS	03 BENE	04 SUPL	05 INST	06 CONT	07 TRAV	08 CAPI	09 PERC	10 COMP	SELECTION TALLY	BUDGET AMOUNT
01	X	X	X	X	X	X	X	X	X	X	10	87.5
02	X	X	X	X	X	X		X			7	44.5
03	X	X	X				X	X			5	34.5
04	X	X	X	X	X	X	X	X	X	X	10	71.5
05	X		X	X	X	X	X		X	X	8	70.5
06	X			X	X		X	X	X		6	32.5
07	X	X		X	X	X	X	X	X	X	9	51.5
08											--	1.5
09	X	X	X	X	X	X	X	X	X	X	10	43.0
10						X					1	4.0
11		X	X	X		X		X		X	6	54.0
12											--	1.0
13					X		X				2	5.5
14									X		1	4.0
15	X	X	X	X	X	X	X	X	X	X	10	116.0
16						X		X	X	X	4	23.0
17	X	X	X	X	X	X	X	X	X	X	10	107.0
18				X					X		2	13.0
19		X									1	2.0
20											--	1.0
21	X		X								2	16.0
22								X			1	10.5
23		X	X		X		X		X	X	6	55.0
24											2	4.5
25											--	2.5
26	X	X					X			X	4	19.0
27				X							1	1.0
28				X					X		2	1.0
29										X	1	2.0
30						X					1	12.0
31											--	2.5

	01	02	03	04	05	06	07	08	09	10
	12	12	11	13	11	12	12	12	13	12
O.F. Value	485.4	425.5	316.1	615.9	476.6	477.7	100.0	459.04	600.0	700.0
Starting at Optimality:	20	60	202	16	43	52	163	65	5000+	457
Time (sec):	.246	.359	.416	.227	.297	.337	.589	.310	6.022	1.166
Roll-Back Savings:	685.5	685.5	699.5	693.0	684.5	684.5	693.5	675.5	675.5	700.0
	(-208.0)	(-208.0)	(-194.0)	(-200.5)	(-209.0)	(-209.0)	(-200.0)	(-218.0)	(-218.0)	(-193.5)

Note: Total Initial Budget = 893.5 ($1000's)

Figure 16. Effect Upon Budget Deallocation Decisions Based Upon the Variable Flows of a Cyclic Objective. Function, and the Interaction of a "Minimized, Relaxed" Constraint Iterative Problem.

Objective = Minimization Constraints: Relaxed (EXP=10; PERC = 600)

Budget Alternatives	01 CERT	02 CLAS	03 BENE	04 SUPL	05 INST	06 CONT	07 TRAV	08 CAPI	09 PERC	10 COMP	SELECTION TALLY	BUDGET AMOUNT
01	X		X	X	X	X	X		X		7	87.5
02	X			X	X	X			X		5	44.5
03				X	X	X					3	34.5
04	X		X	X	X	X	X		X		7	71.5
05			X	X	X		X		X		5	70.5
06			X			X	X		X		4	32.5
07	X		X	X		X	X		X		6	51.5
08											--	1.5
09	X		X		X	X	X		X		5	43.0
10											--	4.0
11	X		X		X		X		X		5	54.0
12											--	1.0
13			X								1	5.5
14											--	4.0
15	X		X	X	X	X	X		X		7	116.0
16	X		X	X	X		X				5	23.0
17	X		X	X	X	X	X		X		7	107.0
18	X		X		X	X					4	13.0
19											--	2.0
20											--	1.0
21							X				1	16.0
22	X										1	10.5
23	X			X		X					3	55.0
24											--	4.5
25											--	2.5
26				X	X	X	X				4	19.0
27											--	1.0
28			X								1	1.0
29											--	2.0
30											--	12.0
31				X	X						2	2.5
	12	--	13	12	13	12	12	--	10	--		
Optimal Value	2[illegible].8	--	110.0	304.7	265.9	198.3	50.0	--	482.3	--		
Iteration at Optimality:	669	--	5000+	197	625	1030	5000+	--	34	--		
Time (sec):	1.665	--	4.143	.548	.731	1.823	4.010	--	.249	--		
Roll-Back Savings:	676.5	--	676.0	682.5	686.0	675.0	691.5	--	678.0	--		
(% Cut)	(-217.0)	--	(217.5)	(-211.0)	(-207.5)	(-218.5)	(-202.0)	--	(-215.5)	--		

Note: Total Initial Budget = 893.5 ($1000's)

Validity Evaluation of the Relaxed Model

Figures 17 and 18 contains the analysis of variance results concerning the mean values for criterion weight membership. As might be expected due to the diverse membership of the many solution sets formed under relaxation, statistical significance is not as controlled and patterned as the restricted modeling outcomes.

Reliability Evaluation of the Relaxed Model

Because of the seventeen different solution sets formed by optimization within the relaxed setting, post hoc assessments of consistency were undertaken in a different fashion than those under restricted optimality. As Figures 19 and 20 demonstrate for maximization and minimization respectively, the frequency of a unit's selection as a solution was utilized for discriminant analysis. Such a choice to utilize frequency obviously increased the interval variance of the dependent variable; and it is thus expected to diminish the extent of re-predictive accuracy.

Maximization discriminants required five of the available ten criteria to predict membership at 70.97 percent accuracy. Correspondingly, the minimization discriminants required six criterion indicators to re-predict at 83.87 accuracy.

Figure 17. Tests for Level of Satisfactory Significant Differences Between Objects of Budget Revision (Included) and Oellocated Budgets (Excluded); Relaxed Maximization.

(Objective = Maximization)

Criterion Constraint	CERT	CLAS	BENE	SUPL	INST	CONT	TRAV	CAPI	PERC	COMP	[N_C ($p \leq .10$)]
	Varying Focus of Cyclical Objective Function										
Certificated Salaries	P= .00 I=40.4 X= 6.1	P= .17 I=27.3 X=14.4	P= .08 I=30.2 X=13.4	P= .19 I=26.4 X=14.3	P= .05 I=31.3 X=12.9	P= .14 I=24.2 X=16.3	P= .02 I=32.4 X=11.2	P= .14 I=28.0 X=13.9	P= .24 I=25.8 X=14.7	P= .20 I=26.8 X=14.7	[4]
Classified Salaries	P= .28 I=22.1 X=12.3	P= .00 I=35.5 X= 3.9	P= .01 I=30.4 X= 8.3	P= .86 I=17.1 X=15.4	P= .47 I=20.5 X=13.7	P= .67 I=18.5 X=14.6	P= .23 I=22.8 X=11.9	P= .23 I=22.9 X=11.9	P= .59 I=13.3 X=18.2	P=.07 I=26.0 X= 9.9	[3]
Employee Benefits	P= .48 I=16.7 X=10.7	P= .09 I=21.7 X= 7.5	P= .00 I=28.7 X= 4.4	P= .81 I=11.8 X=13.9	P= .71 I=15.1 X=11.8	P= .97 I=12.8 X=13.1	P= .87 I=13.9 X=12.5	P= .52 I=16.4 X=10.8	P= .47 I= 9.5 X=15.6	P= .32 I=18.2 X= 9.7	[2]
Supplies & Materials	P= .05 I=34.4 X=15.3	P= .14 I=31.5 X=17.2	P= .05 I=35.0 X=16.0	P= .00 I=47.4 X= 4.9	P= .02 I=37.5 X=14.6	P= .00 I=40.1 X=11.7	P= .22 I=30.1 X=18.1	P= .04 I=34.9 X=15.0	P= .02 I=35.5 X=13.5	P= .12 I=31.8 X=17.0	[7]
Instructional Supplies	P= .02 I=30.6 X= 9.7	P= .12 I=26.5 X=12.3	P= .05 I=29.7 X=11.2	P= .05 I=28.2 X=10.2	P= .00 I=43.3 X= 3.7	P= .16 I=26.2 X=12.4	P= .00 I=36.2 X= 6.2	P= .16 I=25.8 X=12.7	P= .02 I=29.6 X= 9.2	P= .08 I=27.7 X=11.5	[7]
Contractural Services	P= .76 I=20.9 X=23.9	P= .86 I=21.7 X=23.4	P= .76 I=24.7 X=21.6	P= .81 I=24.1 X=21.7	P= .99 I=22.8 X=22.7	P= .00 I=39.8 X=11.9	P= .32 I=16.8 X=26.5	P= .28 I=29.2 X=18.6	P= .96 I=22.5 X=22.9	P= .58 I=26.1 X=20.6	[1]
Travel Expenditures	P= .75 I= 4.2 X= 2.6	P= .75 I= 4.2 X= 2.6	P= .67 I= 4.5 X= 2.5	P= .82 I= 3.8 X= 2.8	P= .05 I= 9.1 X= 0.0	P= .75 I= 4.2 X= 2.6	P= .07 I= 8.3 X= 0.0	P= .75 I= 4.2 X= 2.6	P= .82 I= 3.8 X= 2.8	P= .75 I= 4.2 X= 2.6	[2]
Capital Outlay	P= .00 I=51.0 X=15.2	P= .00 I= 45.5 X=18.7	P= .00 I=47.8 X=18.8	P= .04 I=40.5 X=20.8	P= .02 I=43.2 X=21.4	P= .00 I=48.5 X=16.8	P= .01 I=43.4 X=20.1	P= .00 I=55.0 X=12.8	P= .05 I=39.6 X=21.5	P= .01 I=44.4 X=19.5	[10]
Administrative Perception	P= .91 I=49.8 X=50.2	P= .73 I=49.2 X=50.5	P= .59 I=51.3 X=49.3	P= .02 I=45.2 X=53.5	P= .83 I=49.5 X=50.3	P= .61 I=48.9 X=50.7	P= .86 I=49.6 X=50.2	P= .82 I=49.5 X=50.3	P= .06 I=46.2 X=52.8	P= .56 I=48.7 X=50.8	[2]
Budgetary Composites	P= .00 I=57.8 X=10.5	P= .00 I=57.1 X=10.9	P= .00 I=63.6 X= 9.7	P= .00 I=53.3 X=11.1	P= .00 I=62.2 X=13.7	P= .00 I=57.0 X=11.0	P= .00 I=57.8 X=10.5	P= .00 I=56.3 X=11.5	P= .00 I=52.0 X=12.1	P= .00 I=58.3 X=10.2	[10]
[N_R ($p \leq .10$)]	[5]	[4]	[7]	[5]	[6]	[4]	[5]	[3]	[5]	[4]	

Cell Entries: (P=) = Statistical significance of mean differences, include vs. exclude.
(I=) = Mean budget amount for included object of budget revision.
(X=) = Mean budget amount for excluded object of budget revision.

N_C($p \leq .10$) N of $p \leq .10$ occurrences, where criterion constraint values reflect desireable mean-value weights across the cyclic objective functions.

N_R($p \leq .10$) N of $p \leq .10$ occurrences, where each defined objective function produced desireable mean-value weights across the criterion constraints.

Figure 18. Tests for Level of Satisfactory Significant Differences Between Objects of Budget Revision (Included) and Deallocated Budgets (Excluded); Relaxed Maximization.

(Objective = Maximization)

Criterion Constraint	CERT	CLAS	BENE	SUPL	INST	CONT	TRAV	CAPI	PERC	COMP	[N_C ($p \leq .10$)]
Certificated Salaries	P= .99 I=19.4 X=19.4	-- -- --	P= .38 I=24.5 X=16.2	P= .02 I=32.1 X=11.3	P= .27 I=25.4 X=15.0	P= .03 I=31.7 X=11.6	P= .02 I=32.1 X=11.3	-- -- --	P= .02 I=34.4 X=12.2	-- -- --	[4]
Classified Salaries	P= .13 I=23.5 X=11.5	-- -- --	P= .29 I=10.2 X=19.9	P= .21 I=23.2 X=11.7	P= .09 I=24.8 X= 9.9	P= .04 I=27.1 X= 9.2	P= .73 I=18.1 X=14.9	-- -- --	P= .05 I=22.2 X=13.2	-- -- --	[2]
Employee Benefits	P= .32 I=18.2 X= 9.7	-- -- --	P= .47 I= 9.2 X=15.4	P= .39 I=17.5 X=10.2	P= .66 I=15.2 X=11.4	P= .39 I=17.5 X=10.2	P= .89 I=13.7 X=12.5	-- -- --	P= .70 I=15.4 X=11.9	-- -- --	--
Supplies & Materials	P= .02 I=36.4 X=14.1	-- -- --	P= .01 I=38.0 X=13.1	P= .66 I=25.4 X=21.0	P= .04 I=34.1 X=14.5	P= .04 I=34.7 X=15.2	P= .03 I=35.3 X=14.8	-- -- --	P=.00 I=47.5 X=10.9	-- -- --	[6]
Instructional Supplies	P= .12 I=26.5 X=12.3	-- -- --	P= .09 I=27.3 X=11.7	P= .08 I=27.5 X=11.6	P= .62 I=20.5 X=15.8	P= .02 I=30.9 X= 9.5	P= .10 I=27.0 X=11.9	-- -- --	P= .00 I=36.7 X= 8.8	-- -- --	[5]
Contractural Services	P= .28 I=29.2 X=18.6	-- -- --	P= .58 I=26.1 X=20.6	P= .25 I=29.5 X=18.4	P= .22 I=28.9 X=18.3	P= .30 I=16.5 X=26.6	P= .58 I=26.1 X=20.6	-- -- --	P= .21 I=31.3 X=18.6	-- -- --	--
Travel Expenditures	P= .75 I= 4.2 X= 2.6	-- -- --	P= .07 I= 8.3 X= 0.0	P= .75 I= 4.2 X= 2.6	P= .82 I= 3.8 X= 2.8	P= .75 I= 4.2 X= 2.6	P= .75 I= 4.2 X= 2.6	-- -- --	P= .59 I= 5.0 X= 2.4	-- -- --	[1]
Capital Outlay	P= .00 I=46.6 X=18.1	-- -- --	P= .08 I=39.4 X=22.6	P= .01 I=44.4 X=19.4	P= .00 I=46.0 X=16.9	P= .00 I=45.0 X=19.0	P= .00 I=51.3 X=15.1	-- -- --	P= .00 I=52.7 X=17.9	-- -- --	[7]
Administrative Perception	P= .40 I=48.1 X=51.2	-- -- --	P= .14 I=46.7 X=52.1	P= .59 I=48.8 X=50.8	P= .05 I=46.0 X=52.9	P= .28 I=47.6 X=51.5	P= .60 I=48.8 X=50.8	-- -- --	P= .49 I=48.2 X=50.8	-- -- --	[1]
Budgetary Composites	P= .00 I=56.4 X=11.4	-- -- --	P= .00 I=52.8 X=13.7	P= .00 I=56.9 X=11.1	P= .00 I=52.8 X=11.5	P= .00 I=56.3 X=11.5	P= .00 I=57.6 X=10.6	-- -- --	P= .00 I=67.8 X=10.3	-- -- --	[7]
[N_R ($p \leq .10$)]	[3]	--	[5]	[4]	[5]	[6]	[5]	--	[5]	--	

Cell Entries: (P=) = Statistical significance of mean differences, include vs. exclude.
(I=) = Mean budget amount for included object of budget revision.
(X=) = Mean budget amount for excluded object of budget revision.

N_C ($p \leq .10$) N of $p \leq .10$ occurrences, where criterion constraint values reflect desireable mean-value weights across the cyclic objective functions.

N_R ($p \leq .10$) N of $p \leq .10$ occurrences, where each defined objective function produced desireable mean-value weights across the criterion constraints.

Figure 19. Use of Discriminant Analysis for Predicting the Frequency of Budget Selection Resulting from a Cyclic Maximization of the Relaxed Problem.

BUDGET	FREQ	BUDGET	FREQ	BUDGET	FREQ	BUDGET	FREQ
01	10	09	10	17	10	25	--
02	7	10	1	18	2	26	4
03	5	11	6	19	1	27	1
04	10	12	--	20	--	28	2
05	8	13	2	21	2	29	1
06	6	14	1	22	1	30	1
07	9	15	10	23	6	31	1
08	--	16	4	24	--		

Summary of Criterion Value in Discriminating Selection Frequencies:

STEP	ENTERED	REMOVED	NOT USED
1	Budgetary Composites		Certificated Salaries
2	Instructional Supplies		Employee Benefits
3	Employee Benefits		Supplies and Materials
4	Capital Outlay		Contractual Services
5	Administrative Perception		Travel Expenditures
6	Classified Salaries		
7		Employee Benefits	

Classification Results from Predictive Validation:

Actual Group	(N)	0	1	2	4	5	6	7	8	9	10
0	(6)	4 (66.7)	1 (16.7)	1 (16.7)	--	--	--	--	--	--	--
1	(7)	1 (14.3)	5 (71.4)	1 (14.3)	--	--	--	--	--	--	--
2	(4)	1 (25.0)	1 (25.0)	2 (50.0)	--	--	--	--	--	--	--
4	(2)	--	--	--	2 (100.0)	--	--	--	--	--	--
5	(1)	--	--	--	--	1 (100.0)	--	--	--	--	--
6	(3)	--	--	--	--	--	1 (66.7)	--	--	1 (33.3)	--
7	(1)	--	--	--	--	--	--	1 (100.0)	--	--	--
8	(1)	--	--	--	--	--	--	--	1 (100.0)	--	--
9	(1)	--	--	--	--	--	--	--	--	1 (100.0)	--
10	(5)	--	--	--	--	--	--	1 (20.0)	1 (20.0)	--	3 (60.0)

Percent of grouped cases currently classified: 70.97

Figure 20. Use of Discriminant Analysis for Predicting the Frequency of Budget Selection Resulting from a Cyclic Minimization of the Relaxed Problem.

BUDGET	FREQ	BUDGET	FREQ	BUDGET	FREQ	BUDGET	FREQ
01	7	09	5	17	7	25	--
02	5	10	--	18	4	26	4
03	3	11	5	19	--	27	--
04	7	12	--	20	--	28	1
05	5	13	1	21	1	29	--
06	4	14	--	22	1	30	--
07	6	15	7	23	3	31	2
08	--	16	5	24	--		

Summary of Criterion Value in Discriminating Selection Frequencies:

STEP	ENTERED	REMOVED	NOT USED
1	Budgetary Composites		Certificated Salaries
2	Employee Benefits		Classified Salaries
3	Contractual Services		Instructional Supplies
4	Travel Expenditures		Administrative Perception
5	Capital Outlay		
6	Supplies and Materials		

Classification Results from Predictive Validation:

Actual Group	(N)	0	1	2	3	4	5	6	7
0	(11)	9 (81.8)	1 (9.1)	1 (9.1)	--	--	--	--	--
1	(4)	1 (25.0)	3 (75.9)	--	--	--	--	--	--
2	(1)	--	--	1 (100.0)	--	--	--	--	--
3	(2)	--	--	--	2 (100.0)	--	--	--	--
4	(3)	--	--	--	--	3 (100.0)	--	--	--
5	(5)	--	--	--	--	1 (20.0)	3 (60.0)	1 (20.0)	--
6	(1)	--	--	--	--	--	--	1 (100.0)	--
7	(4)	--	--	--	--	--	--	--	4 (100.0)

Percent of grouped cases currently classified: 83.87

COMPARISON OF THE RESTRICTED VS. RELAXED DECISIONING FRAMEWORK

Modeling within the restricted setting produced the most 're-predictable' and criterion-significant results. Less criterion measures were required to explain the solution set membership. And, restricted optimizations tended to require no greater modeling effort than the relaxed setting (measured via iterations and computation seconds).

Results of the relaxed setting, however, provide a strong preview of the flexibility of the model for determining a wide array of solution memberships based upon varying standards (objective function values). In addition, the relaxed setting also presents a hint of the diversity in model building based upon the weighting of particular criterion indicators by relaxing certain RHS-values while retaining others in a restrictive fashion.

Finally, both optimality sequences demonstrate the utility of the MAM system in general (and the ROLBAK system in particular) for evaluating multiple criteria, and selecting a distinct solution set from among multiple competing alternatives.

Effect of the Restricted Environment Upon Optimality

The restricted environment which constrained the ROLBAK decision-making was constructed using an expected solution index (ESI) of value 16; and a perceived expendability value of 500. That is, the design of the solution set (program units to be funded, for a total new budget between 675.0 and 700.0 (1000's dollars); and reflecting an administrative perception of priority for expendability -- was required to exhibit the qualities of potential solution with 16 possible "average" member units for each of the 8 object expenditure categories modeling the individual programmatic budgets. Sequentially, each constraint was cycled through the model as the objective function (first for maximization, then for minimization) in order to differentially direct the construction of the solution sets under optimality; that is, those solution sets which best represented the constrained environment design by the restricted, linear inequality constraints, and furthermore provided the most maximal (or minimal) summation of the objective function vector.

Optimality under maximization. Utilizing restricted RHS-value(s) vectors to construct a feasiblity region for ROLBAK decision-making, 2 distinct solution sets were formulated by separate sets of 5 of the available 10 cyclic objective functions. Solution #1:

[1 2 3 4 5 7 9 11 15 17]

presented 10 program unit budgets for funding under the reduced budgetary levels, out of the existing 31 potential multiple alternatives. The 5 object expenditure (budgeting) vectors which produced these solutions under maximization were:

1. CERT (certificated salaries);
2. CLAS (classified salaries);
3. SUPL (supplies and materials);
4. TRAV (travel expnditures); and
5. CAPI (capital outlay).

A total of 213.5 (1000's dollars) was cut from the original budget of 893.5 (1000's dollars), deallocating 21 program units, resulting in a new, system operating level of 680.0 (1000's dollars). The other distinct solution set constructed under maximization, solution #2:

[1 2 4 5 7 11 15 16 17 23]

also presented 10 program unit budgets for continued funding, out of the potential 31 alternatives available. The remaining 5 object expenditure vectors which produced these solutions under maximization, were:

1. BENE (employee benefits);
2. INST (instructional materials);
3. CONT (contractual services):
4. PERC (administrative perception); and
5. COMP (budgetary composites).

A total of 213.0 (1000's dollars) was cut from the original budget of 893.5 (1000's dollars), deallocating 21 program units, resulting in a new, system operating level of 680.5 (1000's dollars). Thus the difference between the two solution sets was approximately .5 (1000's dollars) and 4 varying unit member slips.

Optimality under minimization. Utilizing restricted RHS-value(s) vectors to construct the feasibility region for ROLBAK decision-making, the same 2 distinct solution set were found under minimization, as were developed under maximization. Differences were observed however, both in the number of occurrences of the solution set, and in the objective function(s) which guided the solutional design. Solution #1:

[1 2 3 4 5 7 9 11 15 17]

resulted from the following 4 objective function vectors:

1. BENE (employee benefits);
2. INST (instructional materials);
3. CONT (contractual services); and
4. PERC (administrative perception).

The reader will note, that under maximization, these same four vectors collaborated on a different solution set. The resulting expenditure reduction of 213.5 (1000's dollars) remains the same, of course. Solution #2 under minimization:

[1 2 4 5 7 11 15 16 17 23]

occurred in 3 instances; under the use of the cyclic objective functions:

1. CLAS (classified salaries);
2. SUPL (supplies and materials); and
3. CAPI (capital outlay).

The reader will also note, that previously under maximization, these same three vectors collaborated on a different solution set. As before, the resulting expenditure reduction of 213.0 (1000's dollars) remains the same.

Validity analysis of restricted results. For the purposes of this study, validity tests represented the administration of post hoc analysis to determine if the resulting solutions reflected the original objectives of the ROLBAK model. The original ROLBAK objectives were formulated via the construction of the linear 'object category' vectors. Validation under these circumstances proceeds in two stages. Stage 1 validation is moot, since the executed ROLBAK model produced at least one solution vector (in our case, two distinct alternative solution sets), in conformance with pre-defined RHS-vector values. Stage 2 validation proceeds to analyze the values of the various constraint vectors; and to test their mean-differences determined by their solution versus the non-solution membership. Parametric, oneway analysis of variance procedures were utilized to test these criterion, mean-value differences. Solution #1:

[1 2 3 4 5 7 9 11 15 17]

demonstrated 6 of the 10 criterion vectors to produce statistically significant ($p \leq .10$) greater criterion mean-weights for the solution sets, then existing within the non-solution set. The six criterion vectors were:

1. CERT (certificated salaries);
2. CLAS (classified salaries);
3. SUPL (supplies and materials);
4. INST (instructional materials);
5. CAPI (capital outlay); and
6. COMP (budgetary composites).

Of the remaining 4 vectors, employee benefits (BENE), contractual services (CONT), and travel expenditures (TRAV), the lack of $p \leq .10$ significance is not viewed as an indication of potential invalidity, due to the mean-trends observed. The relatively confounded p-level for administrative perception (PERC) of $p = .67$, is understandable based upon the ordinal scaling for PERC, in which each ordinal graduation (1, 2, 3, ..., 31) is represented. Similarly, solution #2 is:

[1 2 4 5 7 11 15 16 17 23]

demonstrated 5 of the 10 criterion vectors to produce statistically-significant ($p \leq .10$) greater criterion mean-weights for the solution set. These five criterion vectors were:

1. SUPL (supplies and materials);
2. INST (instructional materials);
3. CONT (contractual services);
4. CAPI (capital outlay); and
5. COMP (budgetary composites).

The remaining five criterion mean weights are acceptable, though not at the desired $p \leq .10$ level. Much of the inability to gain the desirable $p \leq .10$ level can be attributed to the large proportion of zero-cells (scant index) within the constraint matrix.

Reliability analysis of restricted results. For the purposes of this study, reliability tests represented the administration of post hoc analyses to determine if the resulting solutions were 'predictable' based upon the multiple data distribution configurations of the criterion vectors; that is, whether a particular program unit's inclusion (versus exclusion) within the solution set was predictable. Parametric discriminant function analysis procedures were utilized to evaluate the extent of such predictability. In order to predict the original solution set #1:

[1 2 3 4 5 7 9 11 15 17]

a total of 5 criterion distributions were required. Listed in the order of their importance (i.e., amount of variance explained and order of entry into discriminant construction), these criteria are:

1. COMP (budgetary composites);
2. SUPL (supplies and materials);
3. CAPI (capital outlay);
4. CERT (certificated salaries); and
5. CLAS (classified salaries).

The discriminant re-prediction (reclassification of solution set membership) resulted in 1 mis-inclusion for a final 96.77 percent accuracy (repredicability) factor. In turn, solution #2:

[1 2 4 5 7 11 15 16 17 23]

required the following 3 criterion distributions in order to predict membership within the solution set (in order of importance/entry):

1. COMP (budgetary composites);
2. CONT (contractual services); and
3. INST (instructional materials).

The discriminant re-prediction for the second solution formed upon restricted optimality resulted in 1 mis-exclusion for a final 96.77 percent accuracy factor. The reader will note, that the criterion distribution COMP was the only vector utilized in both discriminant formulizations.

Non-solution results. While maximization (optimality) produced a solution set for each cyclic iteration of the various criterion vectors, minimization was unable to produce a solution vector, when the criterion vectors being 'minimized' were the 3 vectors:

1. CERT (certificated salaries);
2. TRAV (travel expenditures); and
3. COMP (budgetary composites).

Non-solutions based upon TRAV can be discounted based upon the high proportion of zero-cell entries (29 of 31 possible cells equal to 0); in which case, the model could not 'make up its mind'. Non-optimality under the guidance of CERT and/or COMP however, is an interesting result. Precisely stated (and hopefully in English), neither the CERT nor the COMP vector(s) could summate to a small enough final value (minimum), such that the optimal objective function vector could physically pass-through the feasibility region geometrically constructed via the 11 constraint matrix inequalities. (The authors apologize for the last statement!)

Effect of the Relaxed Environment Upon Optimality

The relaxed environment which constrained the ROLBAK decision-making was constructed using an expected solution index (ESI) of value 10; and a perceived expendability value of 600. That is, the design of the solution set was required to exhibit the qualities of potential solution with 10 possible "average" member units for each of the 8 object categories used in constraints. The reader will note, that since the RHS-value for administrative perception (PERC) was increased to value 600, program units with greater 'perceived expendability' levels could still become members of the solution set -- that is, refunded for continuation. As with the restricted environment discussed in the preceding section, each constraint was cycled through the relaxed model (sequentially) as the objective function.

Optimality under maximization. ROLBAK produced a distinct solution set for each of the 10 cyclical objective functions utilized during optimal maximization of the relaxed model. In fact, only the program units:

Programmatic savings ranged from a low of 202.0 (1000's dollars) based upon TRAV:

[1 4 5 6 7 11 15 16 17 21 26]

to a high of 218.5 (1000's dollars) based upon CONT:

[1 2 3 4 6 7 9 15 17 18 23 26].

Unit membership ranged from a high of 13 (INST) to a low of 10 (PERC). Not one of 7 solutions under minimization was identical to the 10 solutions under maximization.

Validity analysis of relaxed results. The approach to validating the results of th ROLBAK execution under relaxed conditions differed from that previously discussed within the restricted state. Since 17 distinct solution sets were formed based upon both maximization and minimization under relaxed conditions, validation of the effect of solution set construction upon individual criterion mean-weight differences was effected in two related ways. First, the frequency of $p \leq .10$ occurrences, where each defined objective function (CERT, CLAS, ..., COMP) produced desirable mean-value weights across the criterion constraints was explored, utilizing (as before) oneway analysis of variance procedures. These results are indicated as:

$$[\, N_R \ (p \leq .10) \,].$$

Secondly, the frequence of $p \leq .10$ occurrences, where criterion constraint values (CERT, CLAS, ..., COMP) reflect desirable mean-value weights across the cyclic objective functions, were studied; and indicated as:

[N_C ($p \leq .10$)].

Figure 21 summarizes these N_R and N_C summations for optimality results under both maximization and minimization. The N_R-frequencies are analogous to those previously defined for the restricted environment. Based upon the computed percents for the total frequencies possible, <u>10</u> and <u>7</u> (for maximization and minimization, respectively), the N_R values appear relatively identical; likewise for the N_C frequencies. Summing both the N_R and N_C values, and ranking those sums (where 1 = high and 10 = low), an ordinal measure of relative weight can be developed. Finding the absolute value of the difference between these sum (N_R) and (N_C) ranks (i.e. | DIFF-RANKS |), presents a measure of relative consistency between N_R and N_C values. The authors have previously thought that the greater the consistency, the greater the resulting value of the particular criterion vector. Thus, the smaller the rank-difference, the more valuable the criterion involved. However, careful examination of the ranks of N_R and N_C demonstrates that the correlation between the two vectors of rank to be non-parallel (correlation (N_R, N_C) = -0.666). And furthermore, that the correlation between the N_R and N_C values, and their difference (DIFF-RANKS) to be nearly non-existent (+0.129 and -0.048, respectively). Further study is required in this area to study these issues of consistency and utility.

<u>Reliability analysis of relaxed results</u>. As with restricted results, discriminant functions were utilized to determine the predictablity of the obtained solution vectors. For the relaxed environment however, membership in any particular solution set was not the dependent variable; rather, the frequency of each individual program unit being chosen for refunding across all criterion objective functions (i.e. the selection tally for the tracking matrix) was used as the dependent (to be predicted)

Figure 21. Summary of [$N_R(p \leq .10)$] and [$N_C(p \leq .10)$] Values from Figures 19 and 20.

	[Objective Functions (N_R)] ... [Criterion Constraints (N_C)]									
	CERT	CLAS	BENE	SUPL	INST	CONT	TRAV	CAPI	PERC	COMP
Maximization										
[$N_R(p \leq .10)$]	5	4	7	5	6	4	5	3	5	4
PCT (TOT=10)	50.0	40.0	70.0	50.0	60.0	40.0	50.0	30.0	50.0	40.0
[$N_C(p \leq .10)$]	4	3	2	7	7	1	2	10	2	10
PCT (TOT=10)	40.0	30.0	20.0	70.0	70.0	10.0	20.0	100.0	100.0	
Minimization										
[$N_R(p \leq .10)$]	3	--	5	4	5	6	5	--	5	--
PCT (TOT=7)	42.9	--	71.5	57.2	71.5	85.8	71.5	--	71.5	--
[$N_C(p \leq .10)$]	4	2	--	6	5	--	1	7	1	7
PCT (TOT=7)	57.2	28.6	--	85.8	71.5	--	14.3	100.0	14.3	100.0
Sum (N_R)	8	4	12	9	11	10	10	3	10	4
[RANK]	[7.0]	[8.5]	[1.0]	[6.0]	[2.0]	[4.0]	[4.0]	[10.0]	[4.0]	[8.5]
Sum (N_C)	8	5	2	13	12	1	3	17	3	17
[RANK]	[5.0]	[6.0]	[9.0]	[3.0]	[4.0]	[10.0]	[7.5]	[1.5]	[7.5]	[1.5]
| DIFF-RANKS |	2.0	2.5	8.0	3.0	2.0	6.0	3.5	8.5	3.5	7.0

where:

[$N_R(p \leq .10)$] = N of p ≤ occurrences where each defined objective function (CERT, CLAS, ..., COMP) produced desireable mean-value weights across the criterion constraints.

[$N_C(p \leq .10)$] = N of p ≤ .10 occurrences, where criterion constraint values (CERT, CLAS, ..., COMP) reflect desireable mean-value weights across the cyclic objective functions.

variable. Under maximization, the re-prediction of the selection frequency (i.e. the N of inclusion across 10 successful executions) required 5 criterion distributions to formulate the discriminant functions. In order of entry and importance, they were:

1. COMP (budgetary composites);
2. INST (instructional materials);
3. CAPI (capital outlay);
4. PERC (administration perception); and
5. CLAS (classified salaries).

The discriminant re-prediction (reclassification of total inclusion frequency) resulted in 4 over-estimates and 5 under-estimates for a final 70.97 percent accuracy (repredictability) factor. Minimization results on the other hand required 6 criterion distributions to formulate the discriminant functions:

1. COMP (budgetary composites);
2. BENE (employee benefits);
3. CONT (contractual services);
4. TRAV (travel expenditures);
5. CAPI (capital outlay); and
6. SUPL (suplies and materials).

Discriminant re-prediction yielded 3 over-estimates and 2 under-estimates for a total accuracy factor of 83.87 percent. It would seem, that the criterion distributions are much more useful in predicting individual inclusion, then in determining total inclusion across all criterion objective functions.

Non-solution results. As was evidenced in the restricted environment results, only minimization within a relaxed region produced instances (3) of non-solution; they were:

1. CLAS (classified salaries);
2. CAPI (capital outlay); and
3. COMP (budgetary composites).

PART IV

FUTURE OF ROLBAK MODELING AND RELATED MAM FRAMEWORKS

SUMMARY OF THE "MAM" FRAMEWORK AND "ROLBAK"

This study has sought to demonstrate the utility of the multiple alternative modeling formulation (MAM) in determining program units for continued funding during a fiscal crisis. Based upon an acceptance of criterion-referenced model for simulating future, probable decisioning alternatives, the MAM fiscal model, ROLBAK, evaluated various forms of data under different system goals (constraints), in order to observe the effect upon decision-making; that is, which program units to continue, and which to deallocate. Like the school closure and curriculum activity packaging models preceding it, this fiscal roll-back model will assist program administrators as they seek to continue program operation at an optimal level, though in a state of reduced funding.

The Multiple-Alternatives Formulization

The multiple-alternatives model (MAM) has been devised for the situations in which multiple solutions are required. School closures require more than one site be selected to remediate existing declining enrollment impacts and wastage of low per-capita expenditures. Curriculum activity packaging requires the best possible mix of instructional activities to match desired outcomes. And, funding crises require some select number of programs be designated for discontinuance.

The MAM concept models these evaluation complexes through the use of systems of linear inequalities and equalities. Each inequality (or equality) represents a specific objective pre-defined by the decision-maker; criterion referenced and labeled a constraint (to final solution selection). The system of inequalities and equalities relate each constraint objective to each of the decision alternatives being modeled (evaluated for potential inclusion with the final solution set). In addition, some one or several criterion vectors is (are) selected to act as the overall guide to decisional optimality, as the objective function.

The ROLBAK Multiple Alternatives Model

The ROLBAK modeling structure studied within this paper, presents a MAM-adaptation to assist decision-makers when program areas must be 'cut'(i.e. deallocated) due to reduced funding. ROLBAK exists as a sane and rational alternative to the usual percentage-cut across-the-board; and allows the administrator to systematically criterion-reference such complex decisions.

Criterion-referenced constraints have been shown to potentially include budgets by object classification, surveyed perception of affected participants, and total budgetary composite control. In addition, the utility of varying criterion control (objective function) has been illustrated.

Complex Approaches to Complex Issues

The authors maintain that issues involving many potential solutions are indeed too complex for the human mind to comprehend. Main-effects and interactive-effects modeling simulations provide a valid and reliable methodology for evaluating the MAM environment. Without such formulations, complex decision-making is little more than 1-part "experience" and

4-parts "blind luck" (and often with less than successful results).

But the main areas of criticism will still prevail. First, that the need to quantify the criteria requires a greater committment to criterion-referencing than many decision-makers possess. Secondly, that high degrees of time, effort and sophistication are required of individuals who possess little of the above. And finally, that the system requires optimally a computer; and human-based solutions should 'never' (?) be based upon computer analysis.

As social scientists and humans, simultaneously, we acknowledge these misgivings for what they are; and disagree amicably (sometimes).

The Future of MAM Design

The matching of micro-computerized hardware and software to desired instructional objectives; the evaluation of item analysis techniques for designing computer-assisted survey techniques; and the consolidation of school districts -- are a relatively small but representative sampling of areas where this author is currently developing future MAM applications. Wherever a potential for multiple solutions exists, the multiple alternatives model will be there. Multiple alternatives modeling is not the wave of the future -- it is the available tool of today. Do it!!!

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