RESOURCE ALLOCATION WITHIN SECONDARY SCHOOLS: A GOAL PROGRAMMING APPROACH

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The objective of this paper is to develop and implement a static educational resource-allocation model so that estimates of the resources necessary to satisfy a set of pre-specified conflicting educational outputs can be obtained. The outputs are ranked by secondary school administrators in order of their importance. The optimal resource mix is that which meets, as closely as possible, the output target values given by the school administrators. If the exact attainment is not possible, the output solution vector will be that which minimizes both the positive and negative deviations from the pre-specified targets. Since the determination of a price vector for the outputs of a state's educational system is virtually impossible, (and hence the determination of marginal values necessary for optimization in the traditional sense is unavailable), a model which computes efficient output vectors in terms of the physically necessary resource requirements will allow the school administrator to alter the input mix based on the subjective rankings of the output target values.

This study presents a goal programming/input-output model for the Pennsylvania secondary school system. The goals (output targets) of the model represent the Goals of Quality Education as defined by the Pennsylvania Educational Quality Assessment Program (E.Q.A.), and a brief description is presented in Table I. The data employed in the model consist of an aggregation of the individual rankings of the goals as expressed by twenty-eight school administrators in Pennsylvania; a primal objective function reflecting the priorities of the goals; a set of technical production constraints which represent the influence of input factors which can often be controlled by the school administrator; and a set of factor-availability constraints. The data reflecting administrator preferences and resource availability are drawn from a questionnaire submitted to selected school principals who have been participants in the E.Q.A. program. The technical production relationship has been estimated by Cohn [2].

This paper is divided into four major sections: (1) the presentation of a theoretical model; (2) a discussion of the data; (3) the empirical results; and (4) conclusions. The product of this study is twofold. First, it presents a workable model which can be applied directly to public school systems where a constrained efficient input mix is desirable. Second, the empirical results for Pennsylvania suggest that it is possible to increase the level of attainment of school outputs by altering the input mix available during the short period and to attain that resource mix which, over the long term, produces the most efficient output vector, given the subjective preferences and the state of the technological arts.

THEORETICAL MODEL

The goal programming approach to creating effective decision models has restrictive assumptions and requirements (Lee [2], pp. 32-35). One assumption is that the environment contains goals which are incompatible and incommensurable. A conflict area for the decision maker is therefore established, and, given a set of realistic constraining relationships, it is impossible to completely satisfy all of the goals simultaneously. With a set of incompatible and incommensurable goals, it must be assumed that the decision maker can correctly and meaningfully specify and ordinally rank his goals. The ranking assumption permits goal j to be revealed preferred to goal j+1 (assuming that each goal can be met only at the expense of the other). The establishment of priority factors is based on the ranking assumption and hence reflects the decision maker's subjective preference map. In addition to the ranking property, it must be assumed that the decision maker can specify deviational variables to be associated with each goal. It is necessary to be able to determine whether or not it is preferable to underachieve (d^-), overachieve (d^+), or exactly attain ($d^- - d^+$) each goal.[1] It is necessary also that goal attainment and the level of resource use measurements be proportional to the magnitudes which would be encountered if the model consisted of individual activities. The assumption and requirement that both the objective function and constraints are additive will insure that no joint interaction exists between any activities of either the goal attainment function or the constraining functions. In a goal programming model, non-integer solutions must be acceptable. The requirement of fractional solutions has the disadvantage that what may be optimal in terms of the model may be totally unrealistic in the real world. It must also be assumed in the model that the technical coefficients are constant, which invokes the requirement that the model must be evaluated from a static-analytic approach. Finally, it must be assumed that the number of constraints in the model exceeds the number of variables in order to prevent a trivial solution.

By properly specifying and examining the decision environment relevant to a particular situation, it is possible to formulate the constraints, choice space and objective function of the decision model. Once these three components have been established, it is possible to specify a goal programming model.

Suppose there exists an (M X N) simultaneous input-output model representing a school system where the outputs of the system are the desired goals of the production process, with M outputs and N inputs. Suppose, also, that the school administrator is able to assign priority weights to the outputs in such a manner that P_i is strictly preferred to P_{i+1}. Also, suppose that the estimated reduced form coefficients of the input-output-model and the level of resource availability are acceptable as constraining the system, and that some target level of goal attainment is desirable. The goal programming model might then take the form:

(1) MINIMIZE:

$$Z = \sigma_1^{\pm} P_1 d_1^{\pm} + \sigma_2^{\pm} P_2 d_2^{\pm} + \ldots + \sigma_m^{\pm} P_m d_m^{\pm} +$$

$$\sum_{j=1}^{n} P_{m+1} (\sigma_{m+i}^{+} d_{m+i}^{+} + \sigma_{m+i}^{-} d_{m+i}^{-})$$

(2) SUBJECT TO:

$$b_{11}X_1 + b_{12}X_2 + \ldots + b_{1n}X_n - d_1^{+} + d_1^{-} = T_1 - S_1$$

$$b_{21}X_1 + b_{22}X_2 + \ldots + b_{2n}X_n - d_2^{+} + d_2^{-} = T_2 - S_2$$

$$\vdots$$

$$b_{m1}X_1 + b_{m2}X_2 + \ldots + b_{mn}X_n - d_m^{+} + d_m^{-} = T_m - S_m$$

(2')

$$X_1 + d_{m+1}^{-} - d_{m+1}^{+} = X_1^*$$

$$X_2 + d_{m+2}^{-} - d_{m+2}^{+} = X_2^*$$

$$\vdots$$

$$X_n + d_{m+n}^{-} - d_{m+n}^{+} = X_n^*$$

(3) $X_j \leq h_j$ and $h_j \geq K_j$ $\quad i = 1, \ldots, m$

$(T_i - S_i),\ d_i^{+},\ d_i^{-} \geq 0$ $\quad j = 1, \ldots, n$

where:

Z = the objective function of the model with the priority factors, determined by the administrators preference function, associated with each goal.

b_{ij} = the estimated reduced form input coefficient from the simultaneous system. These coefficients represent those inputs over which the decision-maker has control.

X_j = the inputs over which the administrator has control. These inputs may be altered by the decision-maker when he attempts to optimize his objective function.

d_i^{+} = deviational variable representing the overachievement of goal i with its value determined ex post in solution.

d_i^{-} = deviational variable representing the underachievement of goal i (also determined ex post).

P_i = the preemptive priority factor for the ith goal.

T_i = the predetermined target level for each goal.

S_i = the contribution to the ith goal attributable to the socio-demographic variables and the variables over which the educational administrator has no control. The expression for S_i is additive and linear.

K_j = the level of resource utilization.

h_j = the level of resource availability.

$\sigma_i^{\pm}$ = an ex-ante determined coefficient of regret (weighting factor) associated with goals which occupy the same priority level in the objective function. The coefficient of regret gives the relative importance of goal i to goal j when each occupies priority level k. Also, it is required that $\sigma_i^{\pm} \geq 0$.

m = the number of goals, including subgoals.

n = the number of inputs over which the administrator has control.

X_j^* = the desired value of the subgoal associated with each manipulable variable.

TABLE I
GOALS OF QUALITY EDUCATION

Goal	Short Name	Target Output Number
I	Self Concept	1
II	Understanding Others	2
III-V	Verbal Basic Skills	3
III-M	Math Basic Skills	4
IV	Learning Attitudes	5
V	Citizenship	6
VI	Health Habits	7
VII-P	Creativity Potential	8
VII-O	Creativity Output	9
VIII	Vocational Development	10
IX	Knowledge of Past	11
X	Readiness for Change	12

Source: Cohn and Millman [2], p. 58. A more detailed description is contained in Beers [1] and Cohn and Millman [2], Table A-1.

In the above model, note that the objective function (1) incorporates the preemptive priority factors of the decision maker. The priority factors indicate which goal should be met first and continue through to the last goal. The preemptive priority factors, however, do not indicate how much goal i is preferred over goal j. The objective function also expresses the deviational variable (d_i) in terms of either + or -. In the actual model either one or both deviations will be assigned to each goal (priority level), depending on the decision maker's preferences. The case where both signs appear associated with a single priority level indicates that the decision maker seeks to exactly attain his goals and thus wishes to minimize both under and overachievement.

The expression $\sum_{i=1}^{m} P_{m+1} (\sigma_{m+i}^{+} d_{m+i}^{+} + \sigma_{m+i}^{-} d_{m+i}^{-})$ allows for the set of factor constraints, as given in (2'), to enter into the objective function as a subgoal. The factor availability subgoal must also be assigned a priority factor (P_{m+1}). It is necessary in this model that the factor constraints be incorporated directly into the objective function since they will determine the boundaries of the choice space and hence determine the feasible region. When no boundaries are explicitly expressed in the model, then $-\infty \leq K_j \leq +\infty$ is the boundary. Also, in the set of factor constraints, the positive and negative deviational variables indicate that the attainment of a target level of factor utilization, X_j^*, is desired. The assignment of a priority level to the factor constraints depends upon the decision maker's particular goal structure and hence may range from the highest to the lowest point in the ordering.

The constraints (2) reflect the input-output technical coefficients of production. The deviational variables associated with each production constraint reflect a particular goal of the system. It should be noted that $-d_i^+ + d_i^-$ incorporated into the production constraints suggest that only the exact achievement of the goal is desirable, and therefore both positive and negative deviations are to be minimized. This is only one particular case, and the decision maker could indicate that either over or underachievement is desirable.

The objective function of the general model thus relates the priorities (P_i) of a goal to the production function associated with that goal. That is, $P_1 d_1^{\pm}$ indicates that the highest priority of the model is to be assigned to the exact achievement of goal one. Goal one ($d_1^{\pm} = d_1^- - d_1^+$) is reflected by the first production constraint with its right hand side value assigned as a target for that goal. If the statement $P_1 d_m^{\pm}$ appeared in the objective function, then top priority is assigned to the mth goal which is reflected by the mth production constraint. The objective function also reflects the desired level of resource utilization and availability by its inclusion of the factor subgoal. Each deviational variable within the subgoal priority expression relates some indicated level of resource usage. The expression $+d_{m+1}^- - d_{m+1}^+$ suggests that only some specific level of resources should be used and hence implies a very restricted boundary; however, this need not necessarily be the case.

The constraint set (2') also reflects the boundary constraints. It states that X_j is constrained by resource availability and legal or institutional constraining factors. And constraint set (3) imposes non-negativity restrictions on the deviational variables, the target values, and the X_j desired values.

The solution to a goal programming model using input-output-information and the ranked goals of the administrator provides an empirical identification of the input requirements, in terms of manipulable factors, necessary to attain all of the specified goals. Even though these resource requirements are identified, no assurance can be given that all goals are attained because the school system may not be able to purchase or secure the necessary inputs.

AN EMPIRICAL MODEL

The Data

The data employed in the goal programming/input-output model presented in this study can be divided into two categories: (1) objective data designed to estimate the technical production relationships of the school system, and (2) subjective data designed to establish an ordered set of priorities with priority weights for a prespecified set of goals for the school system. The subjective data are also designed to establish the relative importance of various decision variables in a school's production process.

Input-Output data: The data describing the technical production relationship for the Pennsylvania secondary school system consist of a set of simultaneous production functions estimated by Cohn [2]. That study is based on output measures and input variables for fifty-three public secondary schools in Pennsylvania for the 1971-72 school year. Output data are based upon performance in basic skills and replies to various instruments measuring both cognitive and affective traits. The ten initial goals of quality education, presented in Table I, were modified by the Pennsylvania Department of Education to consist of a set of twelve measurable outputs of an educational program, by separating Goal III into verbal and mathematical skills, and by separating Goal VII into creativity potential and output. The manipulable input variables are presented in Table 2.

Two-stage least squares regression methods were applied to the data from which the reduced-form coefficients of the educational inputs were estimated. Since we are concerned here with a management model, we must distinguish between manipulable and non-manipulable inputs. The non-manipulable variables included in the study were composed of 14 different socio-cultural and demographic characteristics of the students. These were reduced, by means of factor analysis, to a set of four socio-economic factors (SEFAC). Although initially it was believed that the SEFAC variables would be an important explanatory element in the regression equations, test results indicate that they exert a minimal contribution to the predicted outputs of the system.[2]

Subjective data: To obtain information concerning the preference rankings and the availability of resources, a survey was conducted of the fifty-three school systems for which input-output data were already available. Of the fifty-three principals surveyed, twenty-eight acceptable responses were obtained and used in this study.

The twelve goals were ranked in order of their importance from 1 to 12, inclusive. A ranking of 1 designated the highest priority and 12 the lowest. The principals were also asked to indicate whether or not he or she would be willing to overachieve (+), underachieve (-), or exactly achieve (0), a particular goal, given budgetary limitations and resource availability. The priority rankings for each questionnaire do not permit any two goals to occupy the same priority level; however, when the objective function of the model is specified, two or more goals may occupy the same priority level. If it is the case that the same priority level is assigned to two or more goals in the objective function, then each must be appropriately weighted by its coefficient of regret.[3]

Resource use data: Since the manipulative inputs represent elements over which the administrator exercises some control, each principal surveyed was asked to assign maximum, desired, and minimum values to the specified set of input factors. In addition, the principal was asked to indicate whether or not he or she would prefer to overachieve (d_i^+), underachieve (d_i^-), or exactly achieve (d_i^0) the indicated desired level for each goal.

Although the full set of inputs contains eighteen manipulable factors, it was necessary to present only twelve variables to the principals. The justification for not listing all of the con-

TABLE 2
MANIPULATIVE INPUT VARIABLES USED BY COHN

Label	Description	Goal Program Symbol
TEDUC	Teacher's education	X_1
GUIDANCE	Counselors/pupil	X_2
TLOD	Teacher load	X_3
CSIZ	Class size	X_4
AEE	Average extracurricular expenditure/pupil	X_5
TSALARY	Teacher's salary	X_6
PSUP	Paraprofessional support	X_7
CUG	Curriculum units/grade	X_8
PRCO	Preparation coefficient (teacher specialization)	X_9
SFRAT	Student/academic faculty ratio	X_{10}
BOOKSP	Library books/pupil	X_{11}
TEXPER	Teacher's teaching experience	X_{12}
LIBRARY	Accessibility of library	X_{13}
CLPRACT	Teacher classroom practices	X_{14}
INNOVATE	School usage of innovations	X_{15}
BRAT	Ratio of actual enrollment to building capacity	X_{16}
AMAN	Administrative man hours/pupil	X_{17}
AXMAN	Auxiliary man hours/pupil	X_{18}

Source: Cohn and Millman [2], p. 59.

trollable factors and requesting the principals' responses rests primarily on the fact that certain of the variables do not lend themselves to the necessary quantification by school administrators. Also, some of the variables were based on the student or teacher's response along with that of the principal's. All of the eighteen manipulative variables are, however, included in the goal programming model.[4] Table 3 presents the descriptive statistics for the resource factors.

Target Values: The computation of the target values for the goals is based on the assumption that the student observations used by the Pennsylvania Department of Education during the E.Q.A. program were normally distributed. Thus, based on the Tchebysheff theorem, three standard deviation units above or below the initial target mean should capture the true population mean.[5] It is assumed, however, that the principals would prefer to have a value greater than the computed mean of the goal. As a result, the initial target value for the ith goal is computed as:

(4) $T_i^* = Y_i + 3\gamma_i$

where:

$\hat{\gamma}$ = the ith estimated standard deviation.

The contribution of the socio-economic variables (SEFAC) to the educational output targets should be removed since the administrator exercises no control over their input into the productive process. Since the SEFAC variables exert a very negligible influence on the target level of each goal, they were assigned a value of zero in the goal programming model.[6]

The initial target values, with the exclusion of the SEFAC variables, however, reflect the influence of both manipulative and non-manipulative variables. It is, therefore, necessary to remove this influence of the non-manipulative factors from the output targets since they cannot be controlled. In order to net the non-manipulative factors, we use the relation:[7]

(5) $\tilde{T}_i = T_i^* - [\alpha_i + (B_{nmi})(\bar{X}_{nmi})]$,

where:

$\tilde{T}_i$ = the target value of the ith goal reflecting only the influence of the manipulative factors.

T_i^* = the initial target value of the ith goal as expressed by (4).

α_i = the estimated intercept of the ith production relationship.

b_{nmi} = the estimated reduced form coefficient of the ith non-manipulative variable.

$\bar{X}_{nmi}$ = the mean of the ith non-manipulative factor.

The Objective Function

The objective function of the goal programming model is based on the concept of a value restricted transitive ranking and the simple majority rule decision criterion.[8] Based on the twenty-eight acceptable responses from our survey, we examined the binary choices of each principal for each possible pair of goals. Aggregation was based on the rule that for goal i to be preferred to goal j, at least fifteen principals (simple majority) must prefer i to j. Also, in order to determine the position of goals i, j, and k, in the ranking, we examined the frequency of binary comparisons between goals i and j, j and k, and i and k, respectively. Recalling that P_i represents the ith priority level of the jth output target ($d_i \pm$), the objective function takes the form:[9]

(6) $$Z = P_1(\sigma_3^+d_3^+ + \sigma_5^+d_5^+) + P_2d_4^+ + P_3[\sigma_1^+d_1^+ + (\sigma_2^+d_2^+ + \sigma_2^-d_2^-)] + P_4d_4^+ + P_5(\sigma_8^+d_8^+ + \sigma_8^-d_8^-) + P_6(\sigma_{12}^+d_{12}^+ + \sigma_{12}^-d_{12}^-) + P_7d_7^+ + P_8[(\sigma_9^+d_9^+ + \sigma_9^-d_9^-) + \sigma_{10}^+d_{10}^+] + P_9(\sigma_{11}^+d_{11}^+ + \sigma_{11}^-d_{11}^-) + P_{10}[\sum_{i=13}^{66} (\sigma_i^+d_i^+ + \sigma_i^-d_i^-)].$$

GOAL PROGRAMMING RESULTS

The results of the goal programming model are presented in Table 4. The column labled RHS: Target Value provides the values estimated in expression (5) above. The priority column reflects the value-restricted ranking of (6). The overachievement (d_i^+) and underachievement (d_i^-) columns provide the ex post values of the deviational variables associated with each goal in the objective function. The sign column indicates the ex ante deviational variables assigned in the

TABLE 3
RESOURCE (FACTORS) STATISTICS

	Minimum Values			Desired Values			Maximum Values		
	Min-Min Value	Mean	Max-Min Value	Min Value	Mean	Max Value	Min-Max Value	Mean	Max-Max Value
TEDUC (X_1)	2	3.9	5	4	4.93	6	5	6.4	7
GUIDANCE (X_2)	100	202.7	300	200	267.9	400	250	392	600
TLOD (X_3)	5	15.0	30	17	26.1	30	25	33	40
CSIZ (X_4)	8	18.6	25	20	25	32	25	33.3	40
AEE(X_5)	0	18.6	75	2	44	150	5	60.3	200
TSALARY (X_6)	8500	10614	12000	10000	12642	16000	13500	17394	20000
PSUP (X_7)	0	16.5	40	0	31.25	48	0	37.4	50
CUG (X_8)	5	18.5	50	10	34.7	60	12	46.7	80
PRCO (X_9)	1	2.2	5	2	3.5	10	3	5.3	8
SFRAT (X_{10})	10	16.2	20	18	22.55	35	22	30.6	40
BOOKSP (X_{11})	3	9.7	20	8	20.85	100	10	31.4	50
TEXPER (X_{12})	0	3.2	8	2	8.9	19	10	17.8	37
LIBRARY (X_{13})*		1.0			4.37			5.0	
CLPRACT (X_{14})*		11.0			38.09			55.0	
INNOVATE (X_{15})*		12.0			33.55			60.0	
BRAT (X_{16})*		0.75			1.08			2.0	
AMAN (X_{17})*		1.0			3.95			10.0	
AXMAN (X_{18})*		1.0			8.02			16.0	

* Designated variables excluded from Questionnaire.

NOTE: The variables X_2, X_3, and X_6 are defined in this table somewhat differently than in the model. The results are based, however, upon consistent definitions of all variables.

TABLE 4
VALUE RESTRICTED GOAL PROGRAMMING RESULTS

RHS: Target Value	Goal	Priority	d_i^+ (Overachievement)	d_i^- (Underachievement)	Sign	$\sigma_i^+ d_i^+$ or $\sigma_i^- d_i^-$: Value or Over- or Underachievement
5.574	1	3	13.256	0.0	$-d_1^+$	17.259
6.194	2	3	0.0	6.903	$-d_2^+ + d_2^-$	20.363
1.620	3	1	0.685	0.0	$-d_3^+$	0.723
1.023	4	2	0.0	0.0	$-d_4^+$	0.0
22.802	5	1	0.0	0.0	$-d_5^+$	0.0
9.715	6	4	45.056	0.0	$-d_6^+$	45.056
0.0	7	7	11.338	0.0	$-d_7^+$	11.338
6.492	8	5	20.592	0.0	$-d_8^+ + d_8^-$	36.037
6.305	9	8	0.0	15.353	$-d_9^+ + d_9^-$	33.085
4.295	10	8	18.516	0.0	$-d_{10}^+$	23.552
13.644	11	9	17.821	0.0	$-d_{11}^+ + d_{11}^-$	33.255
0.0	12	6	6.205	0.0	$-d_{12}^+ + d_{12}^-$	15.791

objective function. Note that on levels one, three, and eight, two goals occupy the same priority level in the ranking. Also, for goals two, eight, nine, eleven, and twelve exact achievement is desired. As a result, their coefficients of regret are assigned a value greater than one. The column $\sigma_i^+ d_i^+$ or $\sigma_i^- d_i^-$: Value of Over- or Underachievement gives the magnitude of non-attainment of each goal. The minimized Z-value is 236.45.

From Table 4 it is clear that goals four and five (priority level one and two) have been exactly met. Also, goals one, three, six, seven, eight, ten, eleven, and twelve have been exceeded; only goals two and nine have not been achieved. Although the target values for goals two and nine have been underattained by an amount exceeding their initial target values, the target value, in solution, is zero.

The resource requirements necessary for solution are presented in Table 5. The impact of the restriction that in goal programming models non-

TABLE 5
VALUE RESTRICTED ORDERING RESOURCE REQUIREMENTS: INTERPRETATION

Variable	Required Usage	Interpretation
(X_1) TEDUC	6.3	Teachers should possess a Master's degree plus two years.
(X_2) GUIDANCE	.005	The pupil/counselor ratio in solution is 200 to one.
(X_3) TLOD	3.0	Optimal teaching loads are established at three classes per day or fifteen classes per week.
(X_4) CSIZ	18.6	The average number of students per class.
(X_5) AEE	20.3	The number of dollars spent in the school district per student for extracurricular activities.

(X_6)	TSALARY	173.40	**Scales** back to an average annual salary of $17,340 per teacher.
(X_7)	PSUP	16.5	Paraprofessional support per week, in hours.
(X_8)	CUG	18.6	The number of different subject matter courses available for student registration per grade.
(X_9)	PRCO	4.05	Number of different subject matter preparations per teacher per week.
(X_{10})	SFRAT	30.6	The ratio of students to academic (teaching and non-teaching) faculty.
(X_{11})	BOOKSP	9.7	The number of library books available for check out per pupil.
(X_{12})	TEXPER	3.2	Total years of teacher service in education.
(X_{13})	LIBRARY	1.0	Library accessibility index. Solution values may range from 1 (minimum accessibility) to 5 (maximum accessibility).
(X_{14})	CLPRACT	11.0	Teacher classroom practices. Solution values may range from 11 to 55.
(X_{15})	INNOVATE	59.8	School usage of twelve or more relatively new educational practices. Solution values may range from 11 to 60.
(X_{16})	BRAT	0.75	An index of crowding of physical plant.
(X_{17})	AMAN	1.0	Administrative man-hours per student. The solution value can range between 1.0 and 10.0 man-hours per student.
(X_{18})	AXMAN	1.0	Auxilliary man-hours per student. The solution values may range between 1.0 and 16.0.

integer solutions must be acceptable is readily apparent. For instance, the optimal level of teacher education is seen to be 6.3 academic years, which would provide certification at least at the level of Master's plus two years. Two quite interesting results are concerned with the BRAT variable and the AMAN variable. Since BRAT reflects the building occupancy ratio and a value of one indicates that actual occupancy equals state rated capacity, the solution value of .75 indicates that overcrowding of the physical plant should be avoided when possible. Building programs currently are emphasizing the modular and open classroom concepts, and thus are attempting to remove classroom crowding conditions. The AMAN and AXMAN variables reflecting the level of administrative man-hours per student and auxiliary man-hours per student, respectively, have a solution of 1.0. This result is interesting because it indicates that in the actual production of education outputs, the administrative and auxiliary support functions are rather secondary. Instead of purchasing more administrative and auxiliary services, these resources could possibly be allocated more effectively along other channels.

CONCLUSION

Probably the most immediate and obvious conclusion is that, properly specified, the goal programming approach to decision making within educational systems appears to be useful. Thus, the present approach is a step forward in the development of educational decision models.

No attempt was made here to determine the financial feasibility of securing the resource mix necessary for the level of goal attainment presented above. Once financial information is incorporated into the constraints, an even closer approximation of the real world can be made. The concern here has been, however, to determine the physical level of resources required to meet, as closely as possible, the school principal's priorities.

The sample size employed here is very small. Only one specification of the input-output model used for the technical constraints has been tried, and different specifications could yield different goal programming results. Since it has been demonstrated here that the methodology is operable and applicable to public education, we feel that efforts should be intensified to thoroughly define and specify the educational environment.[10]

Footnotes

[1]The term "exactly attain" reflects a situation where deviations in both directions are minimized, but does not guarantee that both deviational variables would be reduced to zero (at least one deviational variable, however, must be reduced to zero).

[2]For a discussion of the manipulable and non-manipulable variables, the estimated reduced form coefficients, and the contribution of the SEFAC variables to the system's output, see Morgan [5], pp. 135-137. See also Cohn and Millman [2], p. 63. In single equation educational production functions, the socio-economic factors generally do exert a very strong explanatory influence. However, in a simultaneous input-output system as developed by Cohn, the influence of socio-cultural and demographic factors has not been proven.

[3]See Morgan [4], pp. 145-146 for a discussion of the priority frequency matrix for the goals. The value of the implicit weights ($\sigma_i^{\pm}$) used in the objective function can be computed from the goal deviation frequency matrix. The computation takes the form: $\sigma_i^{\pm} = [\frac{1}{2}n^o + n^{\pm}/N]^{-1}$, where

$\sigma_i^{\pm}$ = the weight associated with both positive and negative deviations from the ith goal;
n^o = the frequency of responses where exact attainment was indicated for the ith goal;
$n^{\pm}$ = the frequency of responses indicating that over (d^+) or under (d^-) achievement would be desirable;
N = the total number of responses.

[4]For a discussion of the values for the variables excluded from the questionnaire, see Morgan [4], pp. 154-157.

[5]For a description of the initial output means and standard deviations, see Cohn [2], p. 58. The level of confidence is at least 89 percent and could be 99 percent if the normality assumption is appropriate.

[6]See Morgan [4], p. 136.

[7]See Morgan [4], p. 185 for a discussion of the values for $\hat{T}_i$; T_i^*; α_i; b_{nmi}; and $\overline{X}_{nmi}$.

[8]See Sen and Pattaniak [8] for a discussion of the value restricted social rankings.

[9]For a discussion of the compilation, significance, and implication of the value restricted preference ranking among school administrators, see Morgan, McMeekin, and Cohn [6].

[10]A more detailed analysis is contained in Morgan and Cohn [5], which will be made available upon request.

References

1. Beers, J.S. The Ten Goals of Quality Education: Rationale and Measurement. Harrisburg, PA: Pennsylvania Department of Education, 1970.

2. Cohn, E. with Millman, S.D. Input-Output Analysis in Public Education. Cambridge: Ballinger Publishing Co., 1975.

3. Lee, Sang M. Goal Programming for Decision Analysis. Philadelphia: Auerback Publishers, Inc., 1972.

4. Morgan, J.M. Goal Programming and Resource Allocation Within the Pennsylvania Secondary School System. Unpublished doctoral dissertation. Columbia: University of South Carolina, 1977.

5. Morgan, J.M. and Cohn, E. Goal Programming and Resource Allocation Within Educational Systems. Unpublished Working Paper, Western Kentucky University and the University of South Carolina, 1977.

6. Morgan, J.M., McMeekin, G.C., and Cohn, E. "Value Restricted Preferences and Educational Planning." Unpublished Working Paper, Department of Economics, Western Kentucky University, 1977.

7. Russel, N.F. Public School and Community Conditions: Definition and Measurement. Harrisburg, PA: Pennsylvania Department of Education, 1971.

8. Sen, A. and Pattaniak, P.K. "Necessary and Sufficient Conditions for Rational Choice Under Majority Decision." Journal of Economic Theory. I (1969): 178-202.