A Goal Programming Model for Rationing Grants to a Health Care System

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Abstract — **Most public health programs are created through a political process and the health administrator's resource allocation decision is influenced not only by the relative performance of the subunits but also by political considerations. This paper presents a goal programming model for rationing available grants to competing health care subunits on the basis of performance subject to resource and political constraints. Performance is defined in terms of output adjusted for non-compliance on the identified quality of care and administrative efficiency criteria. The quality and efficiency criteria are those specified by the Federal Agency as amended by local funding authorities and subunit administrators through a Delphi process. The method has the advantage of flexibility and can be easily adapted to suit prevailing financial and political conditions. In particular, it can be used as a viable analytical tool in health-care and other public service agencies where political considerations are important in resource allocation decisions.**

Keywords—Goal Programming, Resource Allocation

INTRODUCTION

The efficient and effective allocation of resources by a higher level organization to competing subunits and programs has always been a challenge to managers. In health-care systems, this problem is complicated further by a rising demand for more public services which is not matched by a commensurate increase in funding, the absence of clearly specified goals, and the lack of objective criteria that can be used as a reliable basis for allocating the available funds. In spite of these inherent problems, however, the spiralling cost of health-care and the dramatic increase of public expenditures in health related activities inspired many a researcher to find better ways of utilizing health resources. Thus several management science models dealing with different aspects of health-care have been proposed [1, 2]. However, such models have, in the main, failed to weather the test of implementation [3].

In the absence of more objective and applicable tools to aid them in decision making, managers in the health field tend to stick to the traditional methods of making decisions. For example, in resource allocation decisions, health administrators often use past funding history as a basis for allocating resources to competing subunits in spite of the obvious inefficiency of this approach. To reverse this trend, models which present the situation more realistically and which can readily be understood and applied by health administrators need to be developed; and, at the same time, efforts to apply existing models should be enhanced. This paper is concerned with the application of goal programming model in resource allocation decisions. In health-care, goal programming models have been developed for various purposes. These include allocating aggregate hospital resources [4,5,6,8], analyzing capital budgeting and capital investment options [9], planning the location of multi-level emergency medical services [10], budgeting nursing department expense in hospitals [11], and allocating Special Supplemental Fund Program for Women, Infants and Children [1,2].

Most of the models deal with allocating resources within a single facility such as hospitals, and the problem of rationing funds to competing health-care agencies is not adequately treated. Moreover, in non-profit organizations, internal resource allocations tend to be based on a political process and the relative power difference of the subunits affects the resource allocation decision. Since public health programs are often created by a political process, health administrators need to consider both subunit performance and the political factor in their grant distribution decisions. However, the importance of the political ingradient in health resource allocation decisions at lower administrative levels is not sufficiently covered in the literature. A goal programming model for allocating health resources to subunits is developed, and the application of the model in one primary health-care system is demonstrated. The study setting is a local primary health-care system which allocates Federal grants to competing community health centers every year.

DATA OF THE PROBLEM

The above model was used to allocate the available health care funds by a local funding agency to twelve community health centers during the 2005 fiscal year.

The total amount of funding in 2004 was Rs. 43,09,150 and in 2005, this was reduced to Rs. 42,56,150. The health administrators from the funding agency and the subunits jointly determined that the maximum reduction rate to poor performers and the maximum increase rate to good performers

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in 2005 should be restricted to 15 and 25% respectively, of the preceding year's funding level. Table 1 presents the desired allocation levels to each health center in 2005 based on 2004 performance, and the minimum and maximum 2005 allocations to each health center.

Table 1. Specified Grant Allocation Goal Levels

Health Center	Desired current year's allocation based on performance (B_i) Rs.	Minimum allocation current year (R_i=0.15) Rs.	Maximum Allocation Current Year (r_i=0.25) Rs.
1	2,86,000	2,86,960	4,22,000
2	2,58,350	1,15,047	1,69,187
3	3,94,950	1,59,800	2,35,000
4	5,11,600	4,33,330	6,37,250
5	3,43,900	3,29,715	4,84,875
6	1,57,900	1,01,405	1,49,125
7	4,15,400	3,17,900	4,67,500
8	6,48,200	8,85,105	13,01,625
9	2,61,750	1,26,097	1,85,437
10	2,16,650	2,04,000	3,00,000
11	3,51,550	2,88,617	4,24,437
12	4,09,900	4,14,800	6,10,000
Total	42,56,150	36,62,776	53,86,436

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MODEL FORMULATION

In this paper, a linear programming model that can be used to assist the administrator of a primary health care system in his decision to allocate the available grant to competing health centers is presented. The following notations are used in the model:

***Notations*:**

$A_{i,t}$ = Grant allocation to health center *i* during the current budget year (*i*=1,2……..N).

$A_{i,t-1}$ = Grant allocation to health center *i* during the preceding budget year.

R_i = The maximum percentage reduction based on the previous year's funding level.

r_i = The maximum percentage increase based on the previous year's funding level.

B_i = Desired allocation level to health center *i* based on performance.

d_0^- = Negative deviation (under-achievement) on the budget goal.

d_i^- = Negative deviation (under-achievement) on the *ith* overall allocation goal B_i.

d_i^+ = Positive deviation (over-achievement) on the *ith* overall allocation goal B_i.

g_i = Weight attached to d_i^-.

h_i = Weight attached to d_i^+.

D_i^+ = Positive deviation (over-achievement) on the *ith* minimum allocation goal.

u_i = Weight attached to D_i^+

Y_i^- = Negative deviation on the *ith* maximum allocation goal.

v_i = Weight attached to Y_i^-

P_x = Pre-emptive priority level assigned to goal $x(x=1,2\ldots.)$ depending on the order of goals.

G_t = The total available grant fund for the current budget year.

Goals

In the grant allocation decision considered here, health administrators ranked the goals as follows:

Priority 1:
Do not exceed the total available grant fund.

Priority 2:
Allocate available funds on the basis of performance.

Priority 3:
Limit funding cut to poor performers to a fixed percent of their preceding year's allocation.

Priority 4:
Limit increase in funding to good performers to a fixed percent of their preceding year's allocation.

The complete goal programming formulation of the health grant allocation problem is given as follows:

$$\text{Minimize}\, Z = P_1\left(d_0^-\right) + P_2\left(\sum_{i=1}^{N} g_i d_i^-\right) + P_2\left(\sum_{i=1}^{N} h_i d_i^+\right) + P_3\left(\sum_{i=1}^{N} u_i D_i^+\right) + P_4\left(\sum_{i=1}^{N} v_i Y_i^-\right)$$

Subject to the constraints:

1. ***Performance Goal Constraint:***

$$A_{i,t} + d_i^- - d_i^+ = B_i\,;(i=1,2,\ldots\ldots N)$$

2. *Grant Goal Constraint:*

$$\sum_{i=1}^{N} A_{i,t} + d_0^- = G_t$$

3. *Minimum Funding Goal Constraint:*

$$A_{i,t} - D_i^+ = (1-R_i)A_{i,t-1}\,;(i=1,2,\ldots\ldots\ldots.N)$$

4. *Maximum Funding Goal Constraint:*

$$A_{i,t} + Y_i^- = (1+r_i)A_{i,t-1}\,;(i=1,2,\ldots\ldots\ldots.N)$$

$$A_{i,t}, d_0^-, d_i^-, d_i^+, D_i^+, Y_i^-, R_i, r_i, \geq 0$$

Goal Programming Formulation

The complete goal programming formulation based on Table 1 is given as follows:

I. Performance Goal Constraints

$$A_1 + d_1^- - d_1^+ = 2{,}86{,}000$$
$$A_2 + d_2^- - d_2^+ = 2{,}58{,}350$$
$$A_3 + d_3^- - d_3^+ = 3{,}94{,}950$$
$$A_4 + d_4^- - d_4^+ = 5{,}11{,}600$$
$$A_5 + d_5^- - d_5^+ = 3{,}43{,}900$$
$$A_6 + d_6^- - d_6^+ = 1{,}57{,}900$$
$$A_7 + d_7^- - d_7^+ = 4{,}15{,}400$$
$$A_8 + d_8^- - d_8^+ = 6{,}48{,}200$$
$$A_9 + d_9^- - d_9^+ = 2{,}61{,}750$$
$$A_{10} + d_{10}^- - d_{10}^+ = 2{,}16{,}650$$
$$A_{11} + d_{11}^- - d_{11}^+ = 3{,}51{,}550$$
$$A_{12} + d_{12}^- - d_{12}^+ = 4{,}09{,}900$$

II. MINIMUM FUNDING GOAL CONSTRAINTS

$$A_1 - D_1^+ = 2{,}86{,}960\,; \qquad A_2 - D_2^+ = 1{,}15{,}047$$
$$A_3 - D_3^+ = 1{,}59{,}800\,; \qquad A_4 - D_4^+ = 4{,}33{,}330$$
$$A_5 - D_5^+ = 3{,}29{,}715\,; \qquad A_6 - D_6^+ = 1{,}01{,}405$$
$$A_7 - D_7^+ = 3{,}17{,}900\,; \qquad A_8 - D_8^+ = 8{,}85{,}105$$
$$A_9 - D_9^+ = 1{,}26{,}097\,; \qquad A_{10} - D_{10}^+ = 2{,}04{,}000$$
$$A_{11} - D_{11}^+ = 2{,}88{,}617\,; \qquad A_{12} - D_{12}^+ = 4{,}14{,}800$$

III. MAXIMUM FUNDING GOAL CONSTRAINTS

$$A_1 + Y_1^- = 4,\ 22{,}000; \qquad A_2 + Y_2^- = 1{,}69{,}187$$
$$A_3 + Y_3^- = 2{,}35{,}000\,; \qquad A_4 + Y_4^- = 6{,}37{,}250$$
$$A_5 + Y_5^- = 4{,}84{,}875\,; \qquad A_6 + Y_6^- = 1{,}49{,}125$$
$$A_7 + Y_7^- = 4{,}67{,}500\,; \qquad A_8 + Y_8^- = 13{,}01{,}625$$
$$A_9 + Y_9^- = 1{,}85{,}437\,; \qquad A_{10} + Y_{10}^- = 3{,}00{,}000$$
$$A_{11} + Y_{11}^- = 4{,}24{,}437\,; \qquad A_{12} + Y_{12}^- = 6{,}10{,}000$$

IV. GRANT GOAL CONSTRAINT

$$A_1 + A_2 + A_3 + ------- + A_{12} + d_0^- = 42{,}56{,}150$$

Objective function

$$Minimize\ \ Z = P_1 d_0^- + P_2[1.133d_1^- + 2.557d_2^- + 2.812d_3^- + 1.343d_4^- + 1.187d_5^- + 1.773d_6^- + 1.486d_7^- + 0.833d_8^- + 2.363d_9^- + 1.208d_{10}^- + 1.402d_{11}^- + 1.112d_{12}^-] + P_2[0.883d_1^+ + 0.391d_2^+ + 0.356d_3^+ + 0.745d_4^+ + 0.842d_5^+ + 0.564d_6^+ + 0.673d_7^+ + 1.200d_8^+ + 0.423d_9^+ + 0.828d_{10}^+ + 0.713d_{11}^+ + 0.899d_{12}^+] + P_3[0.883D_1^+ + 0.391D_2^+ + 0.356D_3^+ + 0.745D_4^+ + 0.842D_5^+ + 0.564D_6^+ + 0.673D_7^+ + 1.200D_8^+ + 0.423D_9^+ + 0.828D_{10}^+ + 0.713D_{11}^+ + 0.899D_{12}^+] + P_4[1.133Y_1^- + 2.557Y_2^- + 2.812Y_3^- + 1.343Y_4^- + 1.187Y_5^- + 1.773Y_6^- + 1.486Y_7^- + 0.833Y_8^- + 2.363Y_9^- + 1.208Y_{10}^- + 1.402Y_{11}^- + 1.112Y_{12}^-]$$

The deviational weights used in this study are based on the index of effectiveness with which 2004 funds were utilized. The index of effectiveness for each health center is computed as the ratio of efficiency-and quality-adjusted performance level for 2004 (B_i) to the actual funding level for the same period (A_i). The effectiveness indices are used as weights for negative deviations from the performance-based allocation goal for each health center. This indicates the funding agency's desire to minimize negative deviations from the performance based allocation goals of high performers compared with low performers. For positive deviations from the performers-based allocation goals, the inverse values of the above indices are used as weights indicating that the funding agency is less interested in minimizing the over-achievement of good performers compared with poor performers (Table 1).

Similarly, for maximum allocation goal, it is assumed that the funding agency has greater desire to minimize deviations from the maximum allowable funding level for good performers. Hence, the effectiveness indices are used as weights for deviations from the maximum allocation goals. For the minimum allocation goal, however, the reverse situation is assumed-that the funding agency is less interested in minimizing deviations from the specified minimum levels for good performers. Thus, the weights used for the minimum allocation goals are the inverse of the above ratios.

RESULTS AND DISCUSSION

The linear goal programming model used in this study contains 61variables (decision and deviational), 37constraints, and 4 goals. The solution of the problem is obtained by using QSB+ software package. The results are shown in Table 6.2.

Table 2 Model's Solution

1	2	3	4	5
A_1= 2,86,960	$d_1^- = 0$	$d_1^+ =$ 960	$D_1^+ = 0$	$Y_1^- =$ 1,35,040
A_2= 1,69,187	$d_2^- =$ 89,163	$d_2^+ = 0$	$D_2^+ =$ 54,140	$Y_2^- = 0$
A_3= 2,35,000	$d_3^- =$ 1,59,950	$d_3^+ = 0$	$D_3^+ =$ 75,200	$Y_3^- = 0$
A_4= 5,11,600	$d_4^- = 0$	$d_4^+ = 0$	$D_4^+ =$ 78,270	$Y_4^- =$ 1,25,650
A_5= 3,43,900	$d_5^- = 0$	$d_5^+ = 0$	$D_5^+ =$ 14,185	$Y_5^- =$ 1,40,975
A_6= 1,49,125	$d_6^- =$ 8,775	$d_6^+ = 0$	$D_6^+ =$ 47,720	$Y_6^- = 0$
A_7= 4,67,500	$d_7^- = 0$	$d_7^+ =$ 52,100	$D_7^+ =$ 1,49,600	$Y_7^- = 0$
A_8= 8,85,105	$d_8^- = 0$	$d_8^+ =$ 2,36,905	$D_8^+ = 0$	$Y_8^- =$ 4,16,520
A_9= 1,85,437	$d_9^- =$ 76,313	$d_9^+ = 0$	$D_9^+ =$ 59,340	$Y_9^- = 0$
A_{10}= 2,16,650	$d_{10}^- = 0$	$d_{10}^+ = 0$	$D_{10}^+ =$ 12,650	$Y_{10}^- =$ 83,350
A_{11}= 3,90,886	$d_{11}^- = 0$	$d_{11}^+ =$ 39,336	$D_{11}^+ =$ 1,02,269	$Y_{11}^- =$ 33,551
A_{12}= 4,14,800	$d_{12}^- = 0$	$d_{12}^+ =$ 4,900	$D_{12}^+ =$ 0	$Y_{12}^- =$ 1,95,200
Total Grant = 42,56,150 and $d_0^- = 0$				

It can be noted that the model's solutions deviated from the performance based allocation goals B_i (Table 1) for all health centers except 4, 5 and 10. Positive deviations of the model's solution from the performance goals can be interpreted as the political cost or subsidy that the administrator is willing to pay in order to avoid reprisals from poor performers and the communities they serve. The negative deviations from the performance goals can be interpreted partly as funds withheld from good performers to avoid possible inefficiency in resource utilization due to a sudden large increase in funding, and partly as a means of making funds available for subsidizing the poor performers. The negative deviations from the performance goal of good performers can also be considered as the price of political compromise they (i.e. good performers) are willing to pay in the short run.

To evaluate if the solutions were consistent with the 2004 performance levels of the subunits, the allocations were compared with the index of effectiveness in utilizing 2004 funds. It can be noted from Table 3 that health centers that ranked high on the fund utilization effectiveness index received increases and those that ranked low suffered cuts.

Table 3 Comparison of the Model's Solution with the Preceding Year's Actual Fund Allocations

Health Center	2004 Performance Level	Actual 2004 fund allocation Rs.	Fund utilization effectiveness index for 2004	Effectiveness Rank	2005 allocation per the model's solution Rs.	Percent change of the model's solution over (under) 2004 allocations
1	2,86,000	3,37,600	0.847	10	2,86,960	-15
2	2,58,350	1,35,350	1.908	2	1,69,187	+25
3	3,94,950	1,88,000	2.100	1	2,35,000	+25
4	5,11,600	5,09,800	1.003	7	5,11,600	+0.35
5	3,43,900	3,87,900	0.887	9	3,43,900	-11.35
6	1,57,900	1,19,300	1.324	4	1,49,125	+25
7	4,15,400	3,74,000	1.110	5	4,67,500	+25
8	6,48,200	10,41,300	0.623	12	8,85,105	-15
9	2,61,750	1,48,350	1.764	3	1,85,437	+25
10	2,16,650	2,40,000	0.903	8	2,16,650	-10
11	3,51,550	3,39,550	1.035	6	3,90,886	+15
12	4,09,900	4,88,000	0.839	11	4,14,800	-15
Total	42,56,150	43,09,150				

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