A Resource Allocation Model for Hospital Administration

Praveen Kumar K M
Department of Mathematics, Brindavan College of Engg.
School of Mathematics, Reva University
Rukmini Knowledge Park, Kattigenahalli, Yelahanka,
Bangalore, Karnataka, Bangalore.

Harish Babu G A
Department of Mathematics, Reva ITM,
School of Mathematics, Reva University
Rukmini Knowledge Park, Kattigenahalli, Yelahanka
Bangalore, Karnataka, Bangalore.

***Abstract*— This paper is devoted to the application of goal programming to medical care planning. More specially, the paper presents a goal programming resource allocation model for hospital administration. It is possible to formulate a complex multi-year resource allocation model that serves the purpose of long-range planning for the hospital. The scope of this study is limited, however, to the planning horizon of one year. It is felt that this limited scope will allow a clearer representation of the model- development. Once it is completed for one year, the basic model can be expanded for a longer planning horizon by forecasting parameter changes.**

Keywords—Goal Programming, Health Care, Resources

INTRODUCTION

In recent years, hospital administration has become a very complex management process. The great demand for hospital care is understandable in view of increased concern for health care on the part of the Indian population as a whole, increased institutional protection for health and accident, and of course increasing population. Rapidly rising salaries of medical personnel, coupled with these factors, have accelerated the increase of hospital costs. However, another important contributor to the cost increase is inefficient resource allocation and ineffective utilization of existing facilities, a result of the increased complexity of hospital operations. The administration of virtually every hospital is a unique management problem. It would be difficult to find two hospitals that offer identical services to the same type of patients through identical management processes. Hence, it is difficult to design a general model that can be applied to all hospitals. However, the basic functions of the hospital are more or less universal among all types of medical facilities. Therefore, once an aggregative resource allocation model is designed for a hospital, it can be easily modify to fit the unique characteristics of the hospital for application.

Various models have been developed and improved over the past 35 years. They can aid in improving the effectiveness of the decision-making process in an organization. Arthur [1] gave a multiple objective nurse scheduling model. An application of linear programming in hospital resource allocation was given by Grant and Henden [2]. Stinnett and Pattiel [4] have given a mathematical model for the efficient allocation of health-care resources. In the present study, a GP Model has been used for resource allocation in a hospital. GP is a variation of linear programming. Charnes and Cooper [6] conceptualized the name goal programming. It was applied to an analytical process that solved multiple, conflicting, non commensurate problems. A goal that is not completely achieved has an under-achievement (negative deviation) or over achievement (positive deviation) of the goal. If the objective is to exceed stated goals, the objective function will only contain a negative deviational variable, d^-. If the objective is to be under the stated goal, the objective function will contain a positive deviational variable, d^+.

DATA OF THE PROBLEM

In this study, Lokpriya hospital in Meerut city is selected for the model design. With no resident physicians, patients are generally admitted by their personal physicians or through the emergency ward. The hospital's emergency room is staffed by local doctors on a rotation basis according to an agreement with the hospital. The hospital has 125 beds and employs 86 employees, excluding local physicians. Tables (1) & (2) outline the model variables and other pertinent information needed for this study. The salaries given are an average of the salaries earned by each person in the individual personnel category. The figures for each category are arbitrarily determined upon the request of the hospital administrator. The personnel classifications were made in relation to the assignment of personnel expenses within the various accounting designations utilized by the hospital. Although a number of split assignments are possible and often practiced, an attempt is made here to minimize these for the model design.

Table (1) Hospital Personnel, Desired Personnel Proportions

Average Salaries and Desired Pay Increases

Variable	**Position**	**Desired % of total Employees**	**Average Salary**	**Desired % Pay Increase**
x_1	*Nursing service administration*	5.81	89,700	6
x_2	*Medical & surgical nurse*	27.90	88,800	7
x_3	*Pediatric nurse*	3.49	89,400	8

x_4	*Obstetric nurse*	4.65	89,100	6
x_5	*Operating & recovery room nurse*	4.65	91,800	8
x_6	*Service & supply room nurse*	2.33	82,400	7
x_7	*Emergency room nurse*	3.49	90,000	9
x_8	*Intensive care nurse*	2.33	93,600	10
x_9	*Laboratory technician*	4.65	81,600	5
x_{10}	*Pathologist*	3.49	92,400	10
x_{11}	*Cardiologist*	1.16	91,200	10
x_{12}	*Radiologist*	3.49	1,96,800	10
x_{13}	*Dietician*	13.95	85,000	8
x_{14}	*Plant operation & maintenance*	2.33	82,200	5
x_{15}	*House keeping*	8.14	69,600	5
x_{16}	*Laundry & linen*	1.16	70,800	5
x_{17}	*Administrative service*	6.98	90,600	6

Table (2) Expenses and Reserves

Expenses

Variable	**Category**	**Total for past year**	**Total for coming year (5% increase)**
y_1	*Nursing division*	12,80,000	13,44,000
y_2	*Physician's fee (emergency ward)*	16,40,000	17,22,000
y_3	*General services (X-ray, medical supplies, etc.)*	18,30,000	19,21,500
y_4	*Administration*	4,60,000	4,83,000
y_5	*Miscellaneous*	14,50,000	15,22,500

Reserves for coming year

Variable	**Category**	**Amount**
z_1	*Radiology equipment*	2,40,000
z_2	*Contingency reserve*	5,80,000

GOALS AND THEIR PRIORITIES

The administrator must determine the goals of the hospital and their priorities in order to accomplish the optimum allocation of resources. This process usually involves a group decision by the hospital administrator and the board of directors. The administrator lists the following goals in order of importance.

- Secure the necessary manpower to provide adequate services to the patient. The administrator feels that the existing personnel will be sufficient to provide adequate services for the coming year.
- Replace and / or acquire new equipment that is required to provide the services of the hospital (this figure should be in addition to funds provided by depreciation).
- Provide adequate pay increases to all personnel in keeping with the economy and the community labor market (see table (1) for the administrator's desired pay increases).
- Provide funds for expenses.
- Achieve the desired distribution of each personnel category (see table (1).
- Minimize costs and breakeven in the operation.

Formulation of Goal Constraints

With the data defined in Tables (1) & (2), the G.P. model constraints for resource allocation are formulated as follows:

(i) Personnel Requirement

The hospital presently employs 86 persons and the administrator feels that the existing personnel must be retained in order to provide satisfactory services to the patient.

$$\sum_{i=1}^{17} x_i + d_1^- - d_1^+ = 86$$

(ii) New Equipment

A new x-ray equipment is required if the x-ray service is to be continued for the coming year. The new equipment is estimated to cost Rs. 2,40,000. Also it is desired to reserve Rs. 5,80,000 in the contingency fund for emergencies.

$z_1 + D_2^- - D_2^+ = 2{,}40{,}000$
$z_2 + d_3^- - d_3^+ = 5{,}80{,}000$

(iii) Employee Pay Increase

The administrator feels that the minimum pay increase should be 5% and the maximum should be 10% for any given personnel category. The figure before each group of variables (also see table 1) is the personnel pay increase.

$$0.05\,(81{,}600\,x_9 + 82{,}200\,x_{14} + 69{,}600\,x_{15} + 70{,}.800\,x_{16}) + 0.06\,(89{,}700\,x_1 + 89{,}100\,x_4 + 90{,}600\,x_{17}) + 0.07\,(88{,}800\,x_2 + 82{,}400\,x_6) + 0.08\,(89{,}400\,x_3 + 91{,}800\,x_5 + 85{,}000\,x_{13}) + 0.09\,(90{,}000\,x_7) + 0.10\,(93{,}600\,x_8 + 92{,}400\,x_{10} + 91{,}200\,x_{11} + 1{,}96{,}800\,x_{12}) + d_4^- - d_4^+ = z_3$$

(iv) Funds For Expenses

(a) Nursing Division Fund : $y_1 + d_5^- - d_5^+ = 13{,}44{,}000$

(b) Fund for Physician's Fee: $y_2 + d_6^- - d_6^+ = 17{,}22{,}000$

(c) General Services fund : $y_3 + d_7^- - d_7^+ = 19{,}21{,}500$

(d) Administrative Expenses: $y_4 + d_8^- - d_8^+ = 4{,}83{,}000$

(e) Miscellaneous Expenses: $y_5 + d_9^- - d_9^+ = 15{,}22{,}500$

PERSONNEL DISTRIBUTION

According to the trend of demand for hospital services, the administrator has established the desired number of employees in each personnel classification as a proportion of the total employees as shown in Table 1. If we denote a_i as the desired no. of employees in the i^{th} category as a proportion of the total no. of employees, 17 separate equations can be expressed by a general equation as:

$x_i - a_i + d_{i+9} - d_{i+9} = 0 \quad (i = 1, 2, \text{- -- - - - } 17)$

For example, for the desired number of nurses in the nursing service administration, the constraint will be

$x_1 - 5 + d_{10}^- - d_{10}^+ = 0$

COST MINIMIZATION

The total cost for the hospital operation is calculated in this constraint. Hence, this constraint identifies the resource requirements to achieve the set of goals presented by the administrator. If a certain maximum resource is previously determined, it could be used so as to identify the degree of goal achievements with the given resources. In order to simplify the constraint, let bi represent the average salary figure for the i^{th} personnel category as shown in Table 1. (i.e.Rs.89,700.00 for the nursing service administration, etc.). Then the cost minimization constraint will be

$$\sum_{i=1}^{17} b_i x_i + \sum_{i=1}^{5} y_i + \sum_{i=1}^{2} z_i + d_{27}^- - d_{27}^+ = O$$

Objective function The objective function for the model is

$$\text{Min. } Z = p_1 d_1^- + p_2 (d_2^- + d_3^-) + p_3 d_4^- + p_4 \sum_{i=5} d_i^- + p_5 \sum_{i=10} d_i^- + p_6 d_{27}^-$$

RESULTS AND DISCUSSION

The LGP problem used in the study contains 79 variables (decision and deviational), 27 constraints and 6 goals. The solution of the problem is obtained by using QSB+ software package (based on modified simplex method). The solution of the problem is as follows

Goal Attainment		**Achieved/ Not achieved**
Manpower for service	(p1)	: Achieved
Equipment acquisition	(p2)	: Achieved
Employee pay increase	(p3)	: Achieved
Expenses	(p4)	: Achieved
Distribution of personnel	(p5)	: Achieved
Minimize cost	(p6)	: Not possible

Variables

$x_1 = 5$	$x_{11} = 1$	$y_1 = 13,44,000$
$x_2 = 24$	$x_{12} = 3$	$y_2 = 17,22,000$
$x_3 = 3$	$x_{13} = 12$	$y_3 = 19,21,500$
$x_4 = 4$	$x_{14} = 2$	$y_4 = 4,83,000$
$x_5 = 4$	$x_{15} = 7$	$y_5 = 15,22,500$
$x_6 = 2$	$x_{16} = 1$	$z_1 = 2,40,000$
$x_7 = 3$	$x_{17} = 6$	$z_2 = 5,80,000$
$x_8 = 2$	$z_3 = 5,65,402$	$x_9 = 4$
$d_{27}^+ = 1,55,77,700$		$x_{10}=3$

The solution of the above model indicates that all the goals can be achieved at the total cost of Rs.1,55,77,700. Since cost minimization is treated as the goal with the lowest priority factor, it is impossible to minimize the cost to zero.

REFERENCES

1. Arthur JL and Ravindran A [1981]: *A multiple objective nurse scheduling model*. IIE Transactions, 13, 55-60.
2. Grant EW and Hendon FN [1987]: *An application of linear programming in hospital resource allocation*. Journal of Health Care Market, 7, 69-72.
3. Franz LS et al. [1989]: *A mathematical model for scheduling and staffing multiclinic health regions*. European Journal of Operations Research,41(2), 277 – 289.
4. Stinnett AA and Paltiel AD [1966]: *Mathematical programming for the efficient allocation of health care resources*. Journal of Health Economics, 15(5), 641-653.
5. Brien – Pallas L et al. [2001]: *Forecasting models for human resources in health care*. Journal of Advance Nursing, 33 (1), 120-129.
6. Charnes A and Cooper WW [1961]: *Management models and the industrial applications of linear programming*.Vols1&2, John Wiley and Sons, New York.
7. Asadoorian J, Locker D [2006]: *The impact of quality assurance programming: a comparison of two Canadian dental hygienist programs*. Journal of Dental Education, 70(9), 965-971.
8. Beaulieu H et al. [2000]: *A mathematical programming approach for scheduling physicians in the emergency room*. Health Care Management Science, 3(3), 193-200
9. Brody GH et al. [2004]: *The Strong African American Families Program*: *translating research into prevention programming*. Child Development, 75(3), 900-917.
10. de Guise E et al.[2005]:*Overview of traumatic brain injury patients at a tertiary trauma centre*. Canadian Journal of Neurology Science, 32(2), 186-193.
11. Ferguson EL et al. [2006]: *Design of optimal food-based complementary feeding recommendations and identification of key "problem nutrients" using goal programming*. Journal of Nutrition, 36(9), 2399-2404.
12. Gaweda AE et al. [2005]: *Individualization of pharmacological anemia management using reinforcement learning*. Neural Networks, 18(5-6), 826-834.
13. Alois Geyer et al.: *Scenario tree generation and multi-asset financial Optimization problem*, Operations Research Letters, 2013, 41, 494-498.