An Application Of Goal Programming In The Allocation Of Anti-TB Drugs In Rural Health Centers In The Philippines

Track Title : Healthcare Management

Giselle Joy C. Esmeria
Department of Industrial Engineering
Mapua Institute of Technology
Manila, Philippines

Abstract - Resource allocation, as applied to health industry, is a complex issue. This paper presents a goal programming model for determining the optimal allocation of drugs to different rural health centers. The model aims to balance the allocation of anti-TB drugs to each health center and achieve a higher cure rate of patients afflicted with tuberculosis (TB). The model developed considers the medication requirements for the treatment of patients belonging to category I – Pulmonary Smear Positive Cases and the limited supply of the drugs. The solution to the formulated model is determined with the use of Borland C++ Version 5.02 programming language.

Allocation of resources is very critical when applied to health industry. It is a matter of life and death when supply cannot meet the demand of the patients in the right time and in the right amount. Once the drug supply does not reach the patient on time, the disease will only become worse and will eventually result to death. This paper considers the case of patients afflicted with TB in Category I. Patients in Category I are those new pulmonary smear positive cases who can be cured by taking INH, rifampicin, PZA, Ethambutol (TYPE I) for the first two months and INH, Rifampicin (TYPE II) for the last four months. Unlike other respiratory diseases such as pneumonia, which happens to be the number 1 killer disease in the Philippines, the drugs for TB treatment are of limited brands and cannot be cured by alternative drugs. Thus, making the disease more critical in terms of its supply and demand.

Past records of Manila Health Center (1997) shows that only about 74.42% of TB patients were totally cured in Manila. There is about 10.58% discrepancy from the target cure rate of 85% of the NTP Program.

The main objective of this paper is to present a model that will optimize the allocation of resources for TB treatment considering the supply constraint. This study intends to alleviate the increasing TB cases in the region by balancing the drug allocation to different health centers.

Section 1 of the paper presents the conceptual framework used in the development of the model. Section 2 of the paper formulates the model that will maximize the allocation of anti-TB drugs to 45 health centers in the region. Section 3 provides the algorithm of the program developed in Borland C++ to solve the model. Results of numerical solution are presented in Section 4. The paper closes in Section 5 by making some concluding remarks and suggestions for further research.

1.Conceptual Framework

So far, no study has been made that tackles solely in the application of goal programming in the allocation of drugs in the Philippine government. Normally, people are concerned only with inventories stock-outs and over-stocking problems as well as timing in the distribution.

This section presents the framework of the research. The main consideration in the development of the model is the involvement of supply constraint. This constraint is considered to design a model that will optimize the allocation of available resources. The supply constraint plays an important part of the discussion. The system is exposed to other constraints like the demand which will be determined by counting the number of people with Tuberculosis in each health center, the medication required, and the target cure rate of the disease. One blister pack of medicine is taken for 7 days. *See Figure 1 for the framework.*

2. Model Formulation

This section presents the formulation of the model and assumptions made.

2.1 Assumptions of the Model

The model that is developed is based on the following assumptions:

a. Only available supply will be allocated in different Manila rural health centers. The supply satisfies the target cure rate of 85%. (as required by NTP)
b. A patient will take Type I anti-TB drug for the first two months and Type II drug for the succeeding four months to be completely healed with the disease.
c. A patient will be cured only if there is a continuous supply of Type I and Type II anti-TB drugs for six months. If there is a gap in the allocation, the patient will not be
d. cured and will become resistant only to the drugs.
e. Local government unit will implement the new system of allocation of anti-TB drugs.
f. It is also assumed that each rural health unit will have an allocation of the anti-TB drugs.

2.2. Mathematical Model

The following discusses the formulation of the objective function and the constraints of the model.

2.2.1 Objective Function

The objective function of the model is to meet the target cure rate of at least 85% which is equivalent to minimizing the underachieve deviations in the allocation of the Type I and Type II anti-TB drugs for different health centers in Manila. Thus, the objective function is written as:

$$\boldsymbol{MIN\ Z} = \Sigma D^{-} \qquad (2.1)$$

where Z, value of overall measure of performance is defined as a measure of undesirable deviations.

2.2.2 Goal Constraints

The constraints consider the interrelationships between the variables in the distribution system. The cure rate problem imposes restrictions on the allocation of the limited supply and on the demand of the TB patients. The system constraints are used to set the goals, these include the following:

Goal 1: Satisfy the medication requirement

In order to cure the TB disease, Type I anti-TB drug should be taken for 2 months and Type II anti-TB drug should be taken for 4 months. One blister pack of anti-TB drug lasts only for one week. Type I anti-TB drug is taken daily for two months and Type II anti-TB drug is taken on the third to six months. There should be a continuous supply of drugs for six months in order to cure the said disease. The demand for Type II will depend on the number of Type I distributed to the different health centers. The medication requirement may be expressed as:

$$X_{1j} - 2X_{2j} + Dij^{-} + D_{ij}^{+} = 0 \qquad (2.2)$$

where,

X_{1j} = number of Type I anti-TB drugs to be allocated in location j.
j = number of health centers ($1,..,45$)
X_{2j} = number of Type II anti-TB drugs to be allocated in location j.

D_{ij}^{-} and D_{ij}^{+} = deviational variables

Goal 2: Supply must be properly allocated to each health center

The supply constraint for Type I and Type II anti-TB drug may be expressed as:

$$\Sigma X_{ij} \leq \textit{supply of drugs in b.p.} \quad (2.3)$$

where,

i = type of anti-TB drug
(1 = type I, 2 = type II)

Goal 3 and 4: Satisfy the cure rate of 85%

The supply has not been maximized. The cure rate depends on the amount available for Type I and Type II anti-TB drugs and the actual demand of the drug from the 45 health centers. The input constraint for the allocation of available Type I anti-TB drug to the 45 health centers is expressed as follows:

$$\Sigma X_{1j} \leq \textit{85\% of tot. dem. for type I} \quad (2.4)$$

The input constraint for the allocation of available Type II anti-TB drug to the 45 health centers is expressed as follows:

$$\Sigma X_{2j} \leq \textit{85\% of tot. dem. for type} \quad (2.5)$$

Goal 5: satisfy the drug requirement of each health center

The demand for each decision variable, *Xij*, can neither be lower than 85% of the maximum requirement nor greater than the actual demand. Thus, the constraint maybe expressed as follows:

$$\textit{85\% of the demand} \leq X_{ij} \leq \textit{max.req't} \; (2.6)$$

2.2.3 Non-negativity constraint

The decision variables X_{ij}, and Z will take only positive values.

3. ALGORITHM

This section presents the algorithm for establishing the final tableau in solving the model. Solve GP ( ) function solves for the final tableau of a goal problem. It follows the five basic steps in solving goal problems using the simplex method.

Solve GP( )
Step 1. Initialize solution mix "smix" and priority table "p"
  a) Copy the coefficients of equations in "ecoef" to "smix"
  b) Assign 0's and 1's to d^+'s and d^-'s.
  c) Copy names and ranks from "cj" to "smix.v_j"
  d) Initialize P.Z_j and P.C_j-Z_j to NULL
Step 2. Compute for the initial value of the objective function Z.
Step 3. LOOP until the goal rank equals the number of goals. Do the following:

  a) Place the "pivot column" in an array called "arrayofcol'
  b) CHECK the result

IF result is OPTIMUM, meaning no negative values
  (i) Mark the "GoalSign[goal]" OPTIMUM.
  (ii) Increment the goal rank (goalrank++),
ELSE
  (i) Get the best PIVOT ROW and PIVOT COLUMN
  (ii) Check its FITNESS/VALIDITY

  IF not VALID (meaning, it will not improve Z, obj function)
    (i) Mark the GoalSign[goal] BYPASSED
    (ii) Compute the new Z
    (iii) Increment goal rank
  ELSE
    (i) Copy solution mix "smix" to temporary array smix_p"
    (ii) Compute the new solmix "smix"

(iii) Compute the new priority p
(iv) Check the result of new smix and p

IF “BYPASSED”

(i) Mark the GoalSign[goal] BYPASSED
(ii) Compute new Z
(iii) Increment goal rank

ELSE IF “BEINGREACHED”
(i) Mark goalsign with “BEINGREACHED”
(ii) Copy smix_p to smix
(iii) Compute new Z
(iv) Increment goal rank

ELSE IF “READY TO GO”
(i) Mark goalsign with OPTIMUM
(ii) Copy smix_p to smix
(iii) Compute new Z
(iv) Increment goalrank

c) Compute new P

Step 4. The FINAL TABLEAU is established
Step 5. Shows the solution

Note that in the final tableau, all needed data can be extracted.

4. NUMERICAL RESULTS

In this section, the results of the numerical solution are presented. The data were taken from the actual supply and demand of each health center from the department of health – Manila branch.

Given Supply and Demand:
Total demand of Type I = 11,888 b.p.
Total demand of Type II = 23,776 b. p.
Total supply of Type I = 10,500 b.p.
Total supply of Type II = 20860 b.p.

Demand for each health center is shown in Table 1. The data were then substituted into the equations 2.1 to 2.6 presented in the preceding section. The undesirable deviations for each health center, that is the number of anti-TB drugs, which are under the requirement are also shown in the table.

Result shows that the 85% target cure rate of patients afflicted with tuberculosis has been achieved (*see Table 2*). Table 2 shows the summary of the results using the goal programming method. From the table, it can be seen that all the supply of type I and II anti-TB drugs has been properly allocated to each health center. This only indicates that the solution has met the optimal results. Supply of type I and type II anti-TB drugs comprises about 88% of the total demand. Thus, it is possible to cure 85% of TB patients, if and only if, supply is properly allocated and distributed.. Table 2 also shows that around 1,303 TB patients will be cured, that is around 87.7% of the total number of TB patients in Manila. Compared to the distribution of drugs done by the health sector, there is a big difference in the cure rate. The cure rate can be improved by 13.28% using a goal program model.

The author considered the results as optimal since each health center has given appropriate amount of Type I and Type II drugs. This model satisfies the conditions that the cure rate must be at least 85% and that all health centers will be given allocation of anti-TB drugs.

5. CONCLUSION AND RECOMMENDATION

Based on the results of the study, the following conclusions were derived:

- Limited supply affects the system of distribution and allocation of Type I and Type II anti-TB drugs. However, if given the right tool, that limitation can still be optimized.

  In this research, it has been proven that linear goal programming can be used as a tool to properly allocate the supply of types I and II anti-TB drugs. It is very evident that a cure rate higher than 85% has been achieved.

- Prioritizing goals has a great effect in the allocation of type I and type II anti-TB drugs. This is due to the fact that in goal programming, assigning priorities is important. It is only a matter of decision making which one must be on the top priority and which one is least priority In goal programming, it is not necessary that all goals will be achieved. In real life situation, this is usually the case. Changing priorities can affect the achievement of goals. Indeed, linear goal programming is a flexible tool in allocating resources.

The following topics, which were not covered in this research due to limited time and resources, are hereby recommended for future studies:

1. The model must take into account the variation of the demand distribution of the Anti-TB drugs of the TB patients.
2. Since the goal constraints presented in linear model, one may try to use genetic algorithm to solve the same problem. That is the goals can be solved and presented in a non-linear model.
3. The cost of the anti-TB drugs may be considered in designing the optimal solution to achieve higher cure rate.

Table 1. List of Demand and Undesirable Deviations for each Health Center

RHU	DEMAND		ALLOCATION		UNDER		RHU	DEMAND		ALLOCATION		UNDER	
	TYPE I	TYPE II	TYPE I	TYPE II	TI	TII		TYPE I	TYPE II	TYPE I	TYPE II	TI	TII
1. T. Foreshore	184	368	184	368	0	0	1. Belmonte	416	832	354	707	62	125
2. A. Quezon	536	1072	536	1072	0	0	2. Calabash	152	304	129	258	23	46
3. Bo. Fugoso	432	864	432	864	0	0	3. Dapitan	520	1040	442	884	78	156
4. Dagupan	192	384	192	384	0	0	4. Earnshaw	176	352	150	299	26	53
5. J. Posadas	264	528	264	528	0	0	5. Luzviminda	224	448	190	381	34	67
6. Velasquez	168	336	168	336	0	0	6. Ma. Clara	200	400	170	340	30	60
7. Vitas	152	304	152	304	0	0	8. Legarda	288	576	245	490	43	86
8. Bo. Magsaysay	488	976	488	902	0	74	9. Paltoc	264	528	224	449	40	79
1. Tondo	280	560	269	476	11	84	1. R. Reyes	376	752	320	639	56	113
2. Bo. Obrero	376	752	320	639	56	113	2. Paco	360	720	306	612	54	108
3. A. dela Rama	160	320	136	272	24	48	3. P. Gil	672	1344	571	1142	101	202
4. R. Magsaysay	448	896	381	762	67	134	4. J. Fabella	264	528	224	449	40	79
5. Tayabas	136	272	116	231	20	41	5. Icasiano	320	640	272	544	48	96
6. Aurora	160	320	136	272	24	48	6. Lions	8	16	7	14	1	2
7. Palomar	136	272	116	231	20	41	7. CGEC	56	112	48	95	8	17
1. Lanuza	320	640	272	544	48	96	1. Esperanza	680	1360	578	1156	102	204
2. Dimasalang	248	496	211	422	37	74	2. Vicencio	288	576	245	490	43	86
3. Mabini	72	144	61	122	11	22	3. Kahilum	32	64	27	54	5	10
4. Meisic	144	288	122	245	22	43	4. Mendoza	216	432	184	367	32	65
5. Sn. Nicolas	392	784	333	666	59	118	5. Bg. Barangay	248	496	211	422	37	74
6. Sn. Sebastian	264	528	224	449	40	79	6. Sn. Miguel	120	240	102	204	18	36
7. Fugoso	96	192	82	163	14	29	7. Bacood	120	240	102	204	18	36
							8. Lacson	240	480	204	408	36	72

Table 2. Number Of People Cured Using Goal Programming

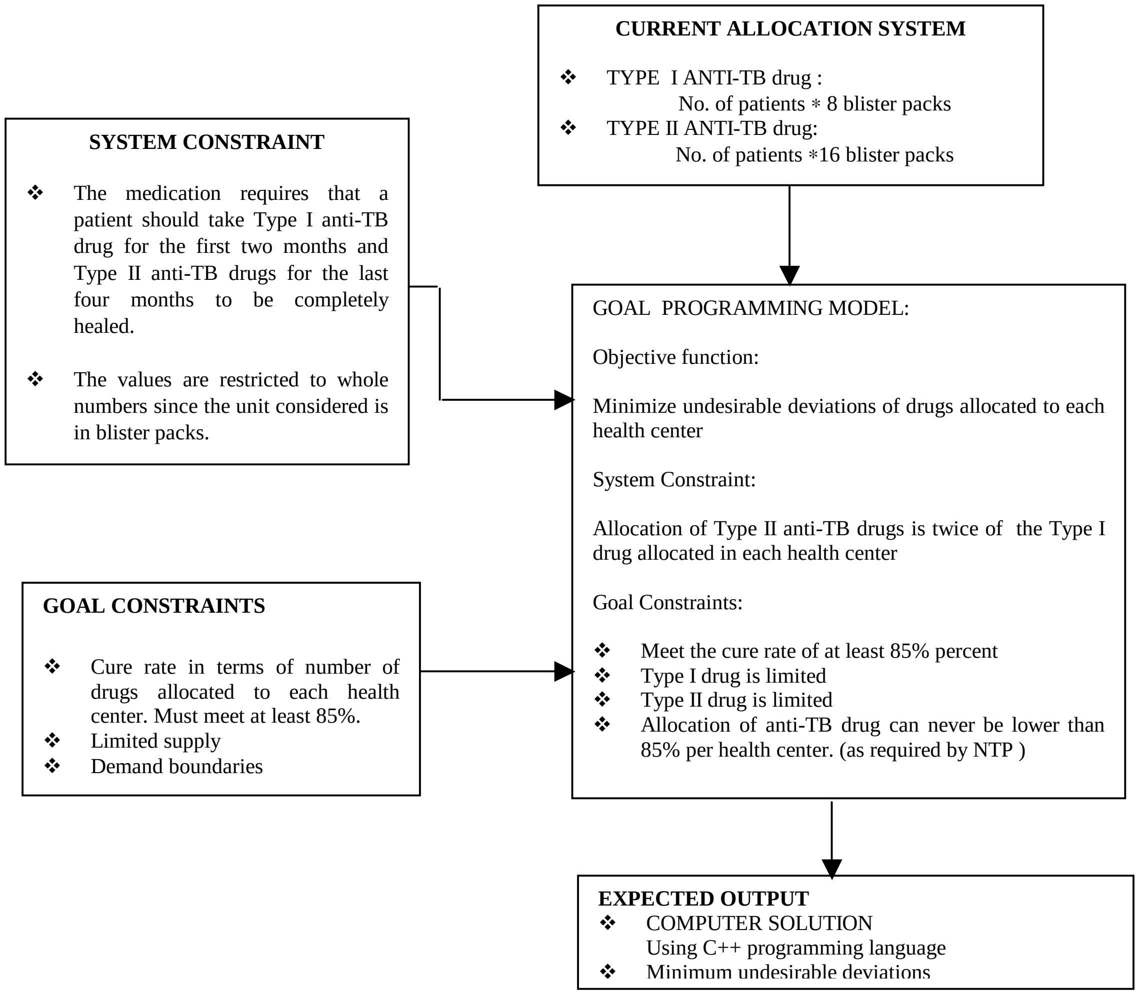
RHU	A	B	C	D	E	F	RHU	A	B	C	D	E	F
1. Tondo Foreshore	23	184	23.0	368	23.0	23	24. Calabash	19	128	16.0	256	16.0	16
2. A. Quezon	67	536	67.0	1072	67.0	67	25. Dapitan	65	440	55.0	880	55.0	55
3. Bo. Fugoso	54	432	54.0	864	54.0	54	26. Earnshaw	22	144	18.0	288	18.0	18
4. Dagupan	24	192	24.0	384	24.0	24	27. Luzviminda	28	184	23.0	368	23.0	23
5. J. Posadas	33	264	33.0	528	33.0	33	28. Ma. Clara	25	168	21.0	336	21.0	21
6. Velasquez	21	168	21.0	336	21.0	21	29. Legarda	36	240	30.0	480	30.0	30
7. Vitas	19	152	19.0	304	19.0	19	30. Paltoc	33	224	28.0	448	28.0	28
8. Bo. Magsaysay	61	488	61.0	976	61.0	61	31. R. Reyes	47	320	40.0	640	40.0	40
9. Tondo	35	264	33.0	528	33.0	33	32. Paco	45	304	38.0	608	38.0	38
10. Bo. Obrero	47	320	40.0	640	40.0	40	33. P. Gil	84	568	71.0	1136	71.0	71
11. Atang dela Rama	20	136	17.0	272	17.0	17	34. J. Fabella	33	224	28.0	448	28.0	28
12. R. Magsaysay	56	376	47.0	752	47.0	49	35. Icasiano	40	272	34.0	544	34.0	34
13. Tayabas	17	112	14.0	224	14.0	14	36. Lions	1	8	1.0	16	1.0	1
14. Aurora	20	136	17.0	272	17.0	17	37. CGEC	7	48	6.0	96	6.0	6
15. Palomar	17	112	14.0	224	14.0	14	38. Esperanza	85	576	72.0	1152	72.0	72
16. Lanuza	40	272	34.0	544	34.0	34	39. Vicencio	36	240	30.0	480	30.0	30
17. Dimasalang	31	208	26.0	416	26.0	26	40. Kahilum	4	24	3.0	48	3.0	3
18. Mabini	9	56	7.0	112	7.0	7	41. Mendoza	27	184	23.0	368	23.0	23
19. Meisic	18	120	15.0	240	15.0	15	42. Bg. Barangay	31	208	26.0	416	26.0	26
20. Sn. Nicolas	49	328	41.0	656	41.0	41	43. Sn. Miguel	15	96	12.0	192	12.0	12
21. Sn. Sebastian	33	224	28.0	448	28.0	28	44. Bacood	15	96	12.0	192	12.0	12
22. Fugoso	12	80	10.0	160	10.0	10	45. Lacson	30	200	25.0	400	25.0	25
23. Belmonte	52	352	44.0	704	44.0	44							

Total No. of Patients Cured : 1,303

Legend :

A = No. of TB patients admitted
B = Number of Type I drug allocated
C = Number of TB patients treated with Type I drug
D = Number of Type II drug allocated
E = Number of TB patients treated with Type II drug
F = Number of TB patients cured

Figure 1. Conceptual Framework



REFERENCES

Arnold, J. R., *Introduction to Materials Management*, Prentice Hall, 1991.

Ballar, R. H., *Business Logistics Management, 3rd ed.*, Prentice-Hall, 1992.

Batnag, D., "Foreign Funds for Health: Supply and Demand Don't Jibe", *Manila Standard*, March 14-15, 1998, pp. 18 & 6.

Budnick, F. , D. McLeavey and R. Mojena, *Principles of Operations Research Management*, *2nd ed.*, Irwin, 1988.

Department of Health (National Capital Region-Regional Field Office), *Annual Accomplishment Report*, 1993-1997.

Department of Health, *Philippine Health Statistics*, 1993.

Department of Health, "Guidelines for Field Management of Logistics of the National TB Control Program", *DOH Administrative Order*, Sept. 26, 1997.

Ebert, R. and E. Adams Jr., *Production Operations Management, 4th ed.*, Prentice-Hall Englewood Cliffs, 1989.

Greene, J. H., *Production and Inventory Control Handbook, 2nd ed.*, Mcgraw-Hill Book Company, 1987.

Hillier, F. and G. J. Lieberman, *Introduction to Operations Research, 6th ed.*, Mcgraw-Hill International Editions, 1995.

Render, B. and R. M. Stair Jr., *Quantitative Analysis for Management, 6th ed.*, Prentice-Hall International Inc., 1997.

Riggs, J. L., *Economic Decision Models for Engineers and Managers*, Cacho Hermanos, Inc., 1968.

Tarcelo, F., “23M Infected Nationwide: TB kills 62 Filipinos Everyday”, *Manila Times*, March 21, 1997, pp. 1 and 5.

“No. 2 Killer : TB affects 1 out of 3 Pinoys”, *Manila Standard*, August 20, 1996, pp. 4.

“Tuberculosis: A Serious Health Threat”, *Manila Bulletin*, September 12, 1998, pp.10.