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

Track Title : Healthcare Management

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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 overstocking 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 cured and will become resistant only to the drugs.

d. Local government unit will implement the new system of allocation of anti-TB drugs.

e. 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:

\[ \min Z = \sum D^- \]  \hspace{1cm} (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:

\[ X_{ij} - 2X_{2j} + D_{ij}^- + D_{ij}^+ = 0 \]  \hspace{1cm} (2.2)

where,

\[ X_{ij} = \text{number of Type I anti-TB drugs to be allocated in location } j \]

\[ j = \text{number of health centers (} 1, \ldots, 45 \) \]

\[ X_{2j} = \text{number of Type II anti-TB drugs to be allocated in location } j \]
$D_{ij}^-$ 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:

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

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:

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

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

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

Goal 5: satisfy the drug requirement of each health center

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

$$85\% \text{ of the demand} \leq X_{ij} \leq \text{max.req’t} \quad (2.6)$$

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 “ecof” to “smix"

b) Assign 0’s and 1’s to $d^+$’s and $d^-$’s.

c) Copy names and ranks from “cj” to “smix.vj”

d) Initialize $P.Z_i$ 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 = 20,860 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>
<thead>
<tr>
<th>Table 1. List of Demand and Undesirable Deviations for each Health Center</th>
</tr>
</thead>
<tbody>
<tr>
<td>RHU</td>
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<tr>
<td>-----</td>
</tr>
<tr>
<td>Type I</td>
</tr>
<tr>
<td>1. T. Foreshore</td>
</tr>
<tr>
<td>2. A. Quezon</td>
</tr>
<tr>
<td>3. Bo. Fugoso</td>
</tr>
<tr>
<td>4. Dagupan</td>
</tr>
<tr>
<td>5. J. Posadas</td>
</tr>
<tr>
<td>7. Vitas</td>
</tr>
<tr>
<td>8. Bo. Magsaysay</td>
</tr>
<tr>
<td>1. Tondo</td>
</tr>
<tr>
<td>2. Bo. Obrero</td>
</tr>
<tr>
<td>4. R. Magsaysay</td>
</tr>
<tr>
<td>5. Tayabas</td>
</tr>
<tr>
<td>6. Aurora</td>
</tr>
<tr>
<td>7. Palomar</td>
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<td>2. Dimasalang</td>
</tr>
<tr>
<td>3. Mabini</td>
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<td>5. Sn. Nicolas</td>
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<td>7. Fugoso</td>
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<td>8. Lacson</td>
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### Table 2. Number Of People Cured Using Goal Programming

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<th>B</th>
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<th>D</th>
<th>E</th>
<th>F</th>
<th>RHU</th>
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<th>B</th>
<th>C</th>
<th>D</th>
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<td>368</td>
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</table>

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

**CURRENT ALLOCATION SYSTEM**
- TYPE I ANTI-TB drug: No. of patients * 8 blister packs
- TYPE II ANTI-TB drug: No. of patients * 16 blister packs

**SYSTEM CONSTRAINT**
- The medication requires that a patient should take Type I anti-TB drug for the first two months and Type II anti-TB drugs for the last four months to be completely healed.
- The values are restricted to whole numbers since the unit considered is in blister packs.

**GOAL CONSTRAINTS**
- Cure rate in terms of number of drugs allocated to each health center. Must meet at least 85%.
- Limited supply
- Demand boundaries

**GOAL PROGRAMMING MODEL:**
- Objective function: Minimize undesirable deviations of drugs allocated to each health center
- System Constraint: Allocation of Type II anti-TB drugs is twice of the Type I drug allocated in each health center
- Goal Constraints:
  - Meet the cure rate of at least 85% percent
  - Type I drug is limited
  - Type II drug is limited
  - Allocation of anti-TB drug can never be lower than 85% per health center. (as required by NTP)

**EXPECTED OUTPUT**
- COMPUTER SOLUTION
  - Using C++ programming language
- Minimum undesirable deviations
REFERENCES


