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Capital Budgeting In Hospitals - A Case Study

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Abstract: In this paper we present a zero-one goal programming model for capital budgeting in hospitals. Capital budgeting is a major task in hospitals because of rising medical costs, due to funds limitations, competition environment among the hospitals. So, the Administrator must take a proper decision about the capital budgeting by using proper tools. Among the many proposed methods of multi criteria decision methods, zero-one goal programming is powerful and widely used tool. The purpose of this paper is to present a model capable of dealing with the problems of multiple conflicting goals, indivisibility of projects, and capital rationing which characterize the unique decision environment of the hospital administrator. Model solution and sensitivity analyses are presented.

Keywords : Capital budgeting, Cash outflow, Zero-one goal programming, Sensitivity analysis.

1. Introduction

In today's highly complicated, technological and competitive health care arena, the public outcry is for administrators, medical staff, and other health care professionals to provide high quality services at lower cost. Health care administrators must therefore find ways to get excellent results from more limited resources. The major problems facing by the hospital administrators are resources allocation and capital budgeting. Capital budgeting is the investment decision-making as to whether a project is worth undertaking or not. It is a big task in hospitals because of rising medical costs, due to funds limitations, competition environment among the hospitals. So, the administrator must take a proper decision about the capital budgeting. There are so many ways **[6, 12, 22, 25,** and **30]** to analyze the capital budgeting in hospitals.

This paper deals with a case study at the ***Mallareddy Hospital*** in Hyderabad in Andhra Pradesh. The government of Andhra Pradesh has implemented ***Aaroghya Sree health scheme*** in 2008 to provide high quality health care services for the poor people through the Private hospitals as well as Government hospitals. But due to lack of funds and administrative grounds the Government hospitals cannot provide such type of services. So, the government has selected a few numbers of hospitals in the state which can provide such type of services and have good track of record in the service (means accreditation certificate issued by the authorized institutions). If the hospitals provide the facilities, the government will give some financial support to the hospitals. So, the hospital administrators are ready to propose new projects to satisfy the patients' needs. But, The National Board of Accreditation for Hospitals has issued new guidelines in 2009. As per the new guidelines every hospital must get accreditation certificate and get approval for every new project from its local agencies. This calls for better decision making techniques in capital budgeting in hospitals by the hospital administrators.

In an excellent summary article, ***Klarman*** **[11]** has discussed the cost-benefit analysis and cost effectiveness approaches for capital budgeting in hospitals. ***Feldstein, P.J*** **[8]** has explained the procedures to prepare budget planning in hospitals. ***Lee*** **[16, 17]** has demonstrated the problems of using traditional resources allocation process in the hospitals. ***Wacht*** **[20]** has discussed the decision process about capital budgeting. In hospitals there are so many ways to analyze the capital budgeting. One of the most used ways is the performance measure of the hospitals. ***Fuchs*** **[26]** has discussed the capital budgeting through the patient satisfaction. ***Li, L.X*** **et al., [18]** have explained different performance measures for health care organizations. By the pressures of the government, insurance companies, communities, and individual consumers have to lower the cost and improve the quality of health care services; various measures have become a critical element in health care service. In this paper we use the ***patient days*** **[10]** as the performance measure for capital budgeting.

2. Data of the Problem

In this paper, we collect the data (some data was taken as hypothetical which was not obtained from the hospital records) from ***Mallareddy Hospital*** in Hyderabad in Andhra Pradesh. It is newly established hospital with 600 bed capacity. There are approximately 100 hospitals in Hyderabad. This hospital management is trying to create its uniqueness in the service among

the already established hospitals. The following Table-1 shows the various projects and corresponding cash out flows, the patient days in blood area, neurology area, cancer area, respiratory area, orthopedic area, and coronary area.

Table-1

Project details	**COF**(Rs)	**Blood** (Pd's)	**Neurology** (Pd's)	**Cancer** (Pd's)	**Respiratory** (Pd's)	**Orthopedic** (Pd's)	**Coronary** (Pd's)
Portable X-ray machine $\mathbf{X_1}$	3,00,000		30	70	20	25	34
ECG machine $\mathbf{X_2}$	1,00,000						62
X-ray view box $\mathbf{X_3}$	1,50,000		32	10		16	10
Pulse oxy meter $\mathbf{X_4}$	5,00,000				25		110
OT table $\mathbf{X_5}$	15,00,000		40	55	10	35	30
Nebulizer $\mathbf{X_6}$	1,50,000				70		
Defibulator $\mathbf{X_7}$	5,00,000			20	55		65
Incubator $\mathbf{X_8}$	3,50,000	110					
Bennet respiratory machine $\mathbf{X_9}$	4,30,000				90		20
Automated chemistry analyzer $\mathbf{X_{10}}$	11,00,000	80	10		65	9	26
Coulter-s analyzer $\mathbf{X_{11}}$	8,00,000	75	15	25	35	7	17
Blood gas analyzer $\mathbf{X_{12}}$	12,00,000	92	8	60	70		30
Ultra sonography $\mathbf{X_{13}}$	15,00,000	10	20	75		10	60
Multi para monitor $\mathbf{X_{14}}$	4,00,000	10	30	10	4		9
C-arms $\mathbf{X_{15}}$	15,00,000		40	25		25	55
Slit lamp $\mathbf{X_{16}}$	3,25,000	10	5	10	9	10	10
Micro scope $\mathbf{X_{17}}$	2,00,000	25	7	13			30
Anesthesia machine $\mathbf{X_{18}}$	15,00,000		10	16		30	9
2Decho $\mathbf{X_{19}}$	20,00,000						110
laparoscope $\mathbf{X_{20}}$	20,00,000		90	20			30

3. Research Methodology

The multi criteria decision-making model (MCDM) is defined as a mathematical model for decision process that allows the decision maker to assess a variety of competing alternatives to achieve asset of goals. One of the most widely used MCDM models is goal programming (GP) model. GP is a more powerful technique than the linear programming (LP), since it can handle multiple objectives as well as a single objective **[3, 27]**. The major difference between LP and GP is that the GP model does not optimize the objective directly, as in the case of LP. Instead, it attempts to minimize the deviations between the desired goals and the realized results. Also, these goals must be prioritized in a hierarchy of importance. Deviational variables can be positive or negative. A positive deviation (d_I^+) represents overachievement of the goal.

A negative deviation variable (d_I^-) represents underachievement of the goal. By utilizing these deviational variables, the general GP model can be defined as follows.

$$\text{Minimize} \sum W_J P_J (d_I^- + d_I^+)$$

Subject to $\sum [A_{IJ} X_{IJ}] + I\, d_I^- - I\, d_I^+ = B_I$

Where W_J is the preemptive weight of each priority J, P_J is the preemptive priority of goal J or constraint J, A_{IJ} is the technological coefficient between decision variable I and constraint J, X_{IJ} is the decision variable I on constraint J, d_I^+ is positive deviation variable, d_I^- is negative deviation variable, and B_I is the right-hand- side value of constraint I.

In the hospital capital budgeting problem, if all the goals are in profit or utility measurements, a linear programming model will be appropriate. But it is not possible in hospital capital budgeting. For example, in a hospital capital budgeting problem, rupee values associated with the purchase of ECG machine are impossible to determine its benefits from reduced

suffering, increased working days of patients, and increase in patients' expected life are to be considered. ***Danting*[6]** and ***Weingartner.H.M***.[**27]** have suggested the use goal programming for capital budgeting in hospitals.

In hospitals some of the projects may be mutually exclusive and dependent. The ordinary goal programming requires multiple runs in order to satisfy mutually exclusive and dependent projects. Moreover, the problems of indivisibility of projects cannot be handled with the ordinary goal programming. These problems can be easily handled by the zero-one goal programming. The zero-one goal programming is a powerful tool to find an optimal solution for an assignment or project selection models in hospitals **[6, 12, 22, 25, 30].**

4. Model Formulation

In order to provide clarity in the model formulation, we present a general model before studying a case study. This goal formulation is just one of many alternative goal combinations possible.

X_i = project i expressed by zero-one value (i=1,2……..m), where the local agency approval, if such is required under the new guideline of NABH, is a prior condition for consideration.

X_i = 1 if i^{th} project is accepted

X_i = 0 if i^{th} project is rejected

COF_i = cash outflow associated with project i

CB = capital budgeting constraint

LDF_P = funds legally designated to be spent on projects X_i Q_i^p (p=1……P)

Q_i^p = a dummy variable and it is equal to 1 when project X_i is included in the set of projects on which LDF_P must be spent, otherwise 0

E_i^k = improvement in the performance measure for department *k* resulting from acceptance of Project i.

DES_k = the desired performance measure improvement in department *k* (k=1……..n)

4.1 System and Goal Constraints Formulation

1) If projects i and j are mutually exclusive then the constraint can be expressed as

$$X_i + X_j \leq 1$$

2) If the acceptance of project i is dependent upon the acceptance of project j. This constraint can be expressed as $X_i - X_j \leq 0$

3) Capital budgeting ceiling goal is $\sum_{i=1}^{m} COF_i + d^- - d^+ = CB$

Where the d^- and d^+ are slack variables (deviations) which in turn are incorporated into the objective function. Thus, the budgeting goal can be satisfied through the minimization of the positive deviations.

4) In order to get accreditation by the NABH, it is necessary to accept at least *l* projects from the projects i = 1 to i = m then the constraint is

$$\sum_{i=1}^{m} X_i + d^- - d^+ = l$$ .This goal can be sought through the minimization of negative deviations

5) Because of some political legal reasons, if the funds are prior earmarked to be spent on designated projects, then the constraint is

$$\sum_{i=1}^{m} COF_i \; X_i \; Q_i^p + d^- - d^+ = LDF_P$$ (p =1……P). This goal can be attained by minimizing the negative deviations.

6) The improvement in the functional area performance goal can be expressed as

$$\sum_{i=1}^{m} E_i^k \; X_i + d^- - d^+ = DES_k$$ (k= 1……..n). This can be achieved by minimizing the negative deviations.

4.2 Objective Function

The objective function for the hospital capital budgeting problem is the minimization of the appropriate deviations which are weighted and/or ranked in the manner dictated by the priority structure of the hospital as determined by hospitals' management members, the medical staff and the administrative staff of the hospital as together or individual.

5. Model Implementation

5.1 System Constraints

Because of the limited space X_5 and X_{19} are mutually exclusive. This constraint can be expressed as $X_5 + X_{19} \leq 1$.

The head of the Cardiology department has requested the administrator that project X_2 cannot be accepted unless the project X_7 is also accepted. This constraint can be expressed as

$$X_2 - X_7 \leq 0$$

5.2 Administrative Goals and Priorities

The Mallareddy hospital administration has provided the following goals in order of their importance.

P_1: The main important goal of the hospital capital budgeting is to limit the expenditures to the budgetary limit of Rs 1, 20, 00,000

P_2: The second goal is in view of getting the accreditation of NABH, the hospital must accept at least five of the following nine projects X_1, X_2 , X_4 ,X_5 ,X_8, X_{11}, X_{13} ,X_{15}, X_{20}

P_3: The third goal is to assure that at least Rs 30, 00,000 to be spent on the projects X_1, X_3 X_5, X_7,X_8,X_{16}, X_{19} to satisfy the legal constraints

imposed by prior earmarking of funds both public and private

P_4: The fourth goal involves the acceptance of at least two of the projects from the set of projects X_2, X_{13}, X_{15}, X_{19} for political and social reasons

P_5: The fifth goal is to improve the performance measure in the coronary area by 400 patient days

P_6: The sixth goal is to improve the performance measure in the neurology area by 250 patient days

P_7: The seventh goal is to improve the performance measure in the blood area by 300 patient days

P_8: The eighth goal is to improve the performance measure in the cancer area by 350 patient days

P_9: The ninth goal is to improve the performance measure in the respiratory area by 400 patient days

P_{10}: The tenth goal is to improve the performance measure in the orthopedic area by 150 patient days

A. System Constraints

$X_5 + X_{19} + d_1^- - d_1^+ = 1$ (mutually exclusive)

$X_2 - X_7 + d_2^- - d_2^+ = 0$ (mutually dependent)

B. Budget Ceiling Goal

$3,00,000X_1 + 1,00,000X_2 + 1,50,000X_3 + 5,00,000X_4 + 15,00,000X_5 + 1,50,00X_6 + 5,00,000X_7 + 3,50,000X_8 + 4,30,000X_9 + 11,00,000X_{10} + 8,00,000X_{11} + 12,00,000X_{12} + 15,00,000X_{13} + 4,00,000X_{14} + 15,00,000X_{15} + 3,25,000X_{16} + 2,00,000X_{17} + 15,00,000\ X_{18} + 20,00,000\ X_{19} + 20,00,000\ X_{20} + d_3^- - d_3^+ = 1, 20, 00,000$

C. Accreditation Goal

$X_1 + X_2 + X_4 + X_5 + X_8 + X_{11} + X_{13} + X_{15} + X_{20} + d_4^- - d_4^+ = 5$

D. Legal Goal

$3,00,000\ X_1 + 1,50,000X_3 + 15,00,000\ X_5 + 5,00,000\ X_7 + 3,50,000X_8 + 3,25,000X_{16} + 20,00,000X_{19} + d_5^- - d_5^+ = 30, 00,000$

E. Political Goal

$X_2 + X_{13} + X_{15} + X_{19} + d_6^- - d_6^+ = 2$

F. Improvement in Coronary area Performance

$34X_1 + 62X_2 + 10\ X_3 + 110\ X_4 + 30\ X_5 + 65X_7 + 20\ X_9 + 26X_{10} + 17\ X_{11} + 30\ X_{12} + 60\ X_{13} + 9X_{14} + 55\ X_{15} + 10\ X_{16} + 30X_{17} + 9\ X_{18} + 110X_{19} + 30X_{20} + d_7^- - d_7^+ = 400$

G. Improvement in Neurology area Performance

$30X_1 + 32\ X_3 + 40\ X_5 + 10X_{10} + 15X_{11} + 8\ X_{12} + 20\ X_{13} + 30X_{14} + 40\ X_{15} + 5\ X_{16} + 7X_{17} + 10X_{18} + 90X_{20} + d_8^- - d_8^+ = 250$

H. Improvement in Blood area Performance

$110X_8 + 80\ X_{10} + 75X_{11} + 92X_{12} + 10\ X_{13} + 10X_{14} + 10\ X_{16} + 25X_{17} + d_9^- - d_9^+ = 300$

I. Improvement in Cancer area Performance

$70X_1 + 10\ X_3 + 55\ X_5 + 20X_7 + 25X_{11} + 60\ X_{12} + 75\ X_{13} + 10X_{14} + 25\ X_{15} + 10\ X_{16} + 13X_{17} + 16X_{18} + 20X_{20} + d_{10}^- - d_{10}^+ = 350$

J. Improvement in Respiratory area Performance

$20X_1 + 25\ X_4 + 10\ X_5 + 70X_6 + 55\ X_7 + 90X_9 + 65\ X_{10} + 35\ X_{11} + 70\ X_{12} + 4\ X_{14} + 9\ X_{16} + d_{11}^- - d_{11}^+ = 400$

K. Improvement in Orthopedic area Performance

$25X_1 + 16X_3 + 35\ X_5 + 9\ X_{10} + 7\ X_{11} + 10X_{13} + 25\ X_{15} + 10X_{16} + 30\ X_{18} + d_{12}^- - d_{12}^+ = 150$

L. Objective Function

$$\text{Minimize} = P_0[d_1^+ + d_2^+] + P_1\ d_3^+ + P_2 d_4^- + P_3\ d_5^- + P_4\ d_6^- + P_5\ d_7^- + P_6\ d_8^- + P_7\ d_9^- + P_8\ d_{10}^- + P_9\ d_{11}^- + P_{10}\ d_{12}^-$$

6. Solution and Sensitivity Analysis

6.1 Solution

We obtained solution for this problem by using QSB$^+$ software. This problem contains 12 constraints and10 goals. The solution to the problem resulted in the acceptance of 13 of the 20 projects, i.e., $X_2 = 1$, $X_3 = 1$, $X_5 = 1$, $X_7 = 1$, $X_8 = 1$, $X_{10} = 1$, $X_{12} = 1$, $X_{13} = 1$, $X_{14} = 1$, $X_{15} = 1$, $X_{17} = 1$, $X_{18} = 1$, $X_{20} = 1$, and remaining variables are equal to 0.The following Table-2 shows the achievement of the goals.

Table-2

Sl. No	Name of the Goal	Achieved/ Not achieved
1.	P_1: Budget ceiling goal	Achieved
2.	P_2: Accreditation goal	Achieved
3.	P_3: Legal goal	Achieved
4.	P_4: Political goal	Achieved
5.	P_5:Improvement in Coronary area performance	Achieved
6.	P_6: Improvement in Neurology area performance	Achieved

7.	P_7: Improvement in Blood area performance	Achieved
8.	P_8: Improvement in Cancer area performance	Not achieved
9.	P_9: Improvement in Respiratory area performance	Not achieved
10.	P_{10}: Improvement in Orthopedic area performance	Not achieved

6.2 Sensitive Analysis

Sensitivity analysis is an evaluation method that is used once a satisfying solution has been found. This analysis provides decision maker with potential alternatives based on how the acceptable result is affected by changes in the input data. If it is desirable to test the sensitivity of the solution to change in the model's priority structure in which the blood area performance goal is make subordinate to the cancer area performance goal, this can be easily evaluated by rerunning the model with the revised set of goal priorities. Again, as in the first running of the model, there is complete attainment of the first seven goals (P_1 throughP_7) and the goals P_8, P_9, P_{10} are not achieved, but 14 projects are accepted out of 20.

7. Conclusion

In this paper we used the Zero-one goal programming model to analyze the capital budgeting analysis which involves multiple conflicting goals, indivisibility of projects. This model is one of the possible models of Zero-one goal programming models. I hope this model will useful to analyze the capital budgeting problems in the hospitals.

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