International Journal of Mathematics And its Applications
Volume 5, Issue 3–B (2017), 137–143.
ISSN: 2347-1557
Available Online: http://ijmaa.in/

International Journal of Mathematics And its Applications

# An AHP Based Weighted Goalprogramming Model for Financial Management of a Health Care System

**Research Article**

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**Abstract:** In this paper, we present an analytical hierarchy process (AHP) based weighted goal programming model (WGP) for financial management of health care system in Hyderabad. The data are collected from the health care system's financial statements from 2010 to 2016. In this study, we considered four financial metrics such as liability, equity, income, asset, profit and proportion of values in the statement. The problem was solved using PM-QM for windows and the results are analysed. The proposed model can be used as a tool for health care systems/financial institutes in making decisions and develop strategies to deal with various economic scenarios.

**Keywords:** Financial management, financial metrics, analytical hierarchy process(AHP), weighted goal programming model(WGP).


## 1. Introduction

The management of financial statements is a process of evaluating the relationship between component parts of financial statements to get a better understanding of the firm's position and performance. Financial analysts often assess firm's production and productivity performance, profitability performance, liquidity performance, working capital performance, fixed assets performance, fund flow performance and social performance. we can classify the techniques of financial analysis as three categories.

(1). Accounting techniques: Ratio analysis, trend analysis. Cash outflow analysis

(2). Statistical techniques: mean, mode, median, standard deviation, coefficient of variation, correlation and regression analysis, analysis of time series, index number, t-test, Chi-square test, diagrams and graphs.

(3). Mathematical methods: Financial analysis also involves the use of certain mathematical tools such as Programme Evaluation and Review Techniques (PERT), Critical Path Method (CPM), and Linear Programming.

The first two categories are limited to discuss just the financial performance of health care system, but not optimize the resource and discuss the goals defined by the management are achieved or not. In this study, we use mathematical models. For efficient performance of health care system, the financial management is very important. A health care system without proper financial management can't meet the requirements of the patients/users. The dynamic condition assembles vulnerability and irreconcilable circumstance while divided data makes it difficult to develop a set of reliable numerical tools

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or solution analysis for the decision maker's inclinations. Simple linear programming is not capable of analyzing multi-objective goals. Using a goal programming model, however, would enable health care systems to measure or analyze these various goals. The remaining parts of the paper are outlined as follows: literature review, methodology, data of the problem, resulst and discussion, followed by conclusion.

# 2. Literature Review

The literature review is conducted in two sections. First section is related to various financial metrics and second section is related to mathematical models.

## 2.1. Literature Review Related to Financial Metrics

There are several studies on financial performance of health care system. We review some studies. Munja Lee [1] had used liquidity, stability, growth, activity, and profitability to discuss financial analysis of health care system. Claverley et.al.,[2] discussed the financial performance of a health care system by using the capital structure, short-term cash holdings and profitability. Goldstein et.al [3] used net income on shareholders equity, cash holdings, working capital flow, short -term liquidity, debt structure, accounts receivable recovery, return on asset and cash flow are as indicators for the financial performance of health care system. Trinh et.al [4] used fixed asset acquisition, profitability, working capital efficiency, liquidity, and debt service coverage ratio are the indicators for health care system performance. An efficient asset–liability management requires health care systems to optimize profit as well as monitor and reduce various risks. Tektas et al., [5] stated that asset and liability management is a multidimensional process requiring coincident interaction among different dimensions. The position of asset and liability will determine liquidity preference and desired outcomes. Thus, health care systems have to create strategies to make efficient use of funds and analyze the various goals such as maximizing profitability, asset, income, equity and minimize liability. We will examine six goals of top health care system in Hyderabad. The data are collected from the financial statements of the health care system. The name of the health care system is not revealed, because of the corporate security. The goals to be examined are: (1). asset accumulation, (2). liability reduction, (3). equity wealth, (4). income, (5). profitability, and (6). optimum management item on the financial statement. We will use an analytical hierarchy process based weighted goal programming to analyze the structure and variations in the proportion of items in the selected health care system financial statement.

## 2.2. Literature Review Related to Mathematical Models

Chambers and Charnes [6] pioneered the development of a deterministic linear programming model in assets and liability. If the decision makers stated multiple criteria in their managerial problems; hence, the linear programming model is unable to combine all the criteria simultaneously. Goal programming is widely used tool in multi criteria decision analysis [7] and the goal programming technique has been introduced in order to solve multi-objective problems. Ignizio [8] proposed a goal programming model to analyze multiple conflicting objectives while taking into account the constraints and preference of the decision maker. Since then, goal programming techniques has been applied to many areas such as, plant management [9], portfolio decision analysis [10], marketing executive tour scheduling [11], nurse scheduling [12], agriculture [13], tourism [14], chemical industry [15], project selection[16], health care planning [17] and many more. In the field of financial management, goal programming has been used in, assets and liability management [18], financial planning [19], portfolio selection [20], funding allocation [21]. The goal programming model can be extended and integrated with other methods. Tunjo and Zoran [22] used Taylor's formula to formulate the linearization of fractional functions before applying it in goal programming

technique to find the optimal solution. Soheyla,etal.,[23] developed a goal programming model combined with AHP to find optimum management of assets, liabilities and equity for a bank. Mohammadi et al., [24] used a fuzzy analytic hierarchy process (FAHP) and goal programming The optimal model for liquidity management. This study focuses on combination of methods analytical hierarchy process and weighted goal programming.

# 3. Methodology

In this paper, we used weighted goal programming method and analytical hierarch process to obtain the weights of the goals. The methods are discussed in the following Sections 3.1 and 3.2

## 3.1. Weighted Goal Programming Model

The generalized weighted goal programming model is formulated as follows

Minimize $z = \sum_{k=1}^{K} \sum_{i=1}^{m} w_{ki} P_k \left(d_i^- + d_i^+\right)$

Subject to $\sum_{i=1}^{m} a_{ij} x_j + d_i^- - d_i^+ = b_i \qquad (j = 1, 2, \ldots, n)$

$x_j,\ d_i^-,\ d_i^+$ =nonnegative variables $(i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n)$. Where

$Z$ = the sum of the weighted deviational variables

$w_{ki}$ =The relative weight assigned to k priority level for the $i^{th}$ goal constraint

$P_k$ =the $k^{th}$ pre-emptive priority

$d_i^-$ = a negative deviational variable describing under achievement of the $i^{th}$ goal

$d_i^+$ = a positive deviational variable describing over achievement of the $i^{th}$ goal

$a_{ij}$ = technical coefficient for the decision variable $x$

$x_j = j^{th}$ decision variable

$b_i$ =the right-hand-side value for the $i^{th}$ goal constraint

In the goal programming the objective function is the minimization of the deviational variables. For a goal both the under achievement $(d_i^-)$ and over achievement $(d_i^+)$ cannot achieved at a time, hence either one or both deviational variables is zero, that is $d_i^- \times d_i^+ = 0$.

## 3.2. Analytical Hierarchy Process

In this study, we use analytical hierarchy process (AHP) to get the weights of the goals in the model. The importance of one priority over the another can be judged by numerical value using a scale of 1-9 where 1 denotes equal importance and 9 denotes the absolutely highest importance. The result of these comparisons using the AHP scale is a square $n \times n$ matrix. A pair wise comparison is based on evaluating two elements (alternatives or criteria) at a time. A pairwise comparison is the process of comparing the relative importance, preference, or likelihood of two elements with respect an element in the level above. When all the pair wise comparisons are done, we calculate the priorities and a measure of consistency of our judgement. Generally, the consistency ratio should be less than 0.10 (10%). The number of comparisons would be $\left(\frac{n(n-1)}{2}\right)$, where $n$ is the number of criteria in the model. Detailed description of the theoretical aspects of AHP can be found in Saaty [25]. To prioritize the financial metrics we have prepared set of questionnaire and was distributed among a great number of financial analyst/accountant and the judgements are considered. The AHP weights are obtained as asset (0.231157), liability (0.194363), equity (0.168173), profit (0.160122), income (0.096916), and financial management (0.149269), here $\lambda_{\max} = 10.0491$, $C.I = 0.809827$, $CR = 0.65309$.

# 4. Data of the Problem

The following Table 1 shows the data of the health care system in Rs millions.

| Item(goal) | year | | | | | | | total |
|---|---|---|---|---|---|---|---|---|
| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | |
| asset | 6,196.62 | 5,980.23 | 9,640.36 | 14,632.9 | 13,575.63 | 16,963.33 | 17,828.42 | 84,817.49 |
| liability | 5,228.46 | 5,350.15 | 5,438.24 | 5,050.31 | 5,550.09 | 7,959.93 | 9,821.75 | 44,398.93 |
| equity | 15,417.78 | 17,721.65 | 23,522.66 | 27,275.97 | 29,647.25 | 31,610.71 | 34,301.31 | 1,79,497.33 |
| profit | 1,519.64 | 1,817.18 | 2,309.90 | 3,091.08 | 3,307.20 | 3,465.95 | 3,694.39 | 19,205.34 |
| income | 18,587.45 | 23,522.66 | 28,279.20 | 33,488.18 | 38,840.88 | 46,380.62 | 54,779.64 | 2,43,878.63 |
| total | 46,949.95 | 54,391.87 | 69,190.36 | 83,538.44 | 90,921.05 | 1,06,380.54 | 1,20,425.51 | 5,71,797.72 |

**Table 1.**

The Table 2 shows the coded values (in Rs trillions) of the health care system. We coded the values because to enable the analysis with small values.

| Item(goal) | year | | | | | | | total |
|---|---|---|---|---|---|---|---|---|
| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | |
| asset | 0.0062 | 0.0060 | 0.0096 | 0.0146 | 0.0136 | 0.0170 | 0.0178 | 0.0848 |
| liability | 0.0052 | 0.0054 | 0.0054 | 0.0051 | 0.0056 | 0.0080 | 0.0098 | 0.0444 |
| equity | 0.0154 | 0.0177 | 0.0235 | 0.0273 | 0.0296 | 0.0316 | 0.0343 | 0.1795 |
| profit | 0.0015 | 0.0018 | 0.0023 | 0.0031 | 0.0033 | 0.0035 | 0.0037 | 0.0192 |
| income | 0.0186 | 0.0235 | 0.0283 | 0.0335 | 0.0388 | 0.0464 | 0.0548 | 0.2439 |
| total | 0.0470 | 0.0544 | 0.0692 | 0.0835 | 0.0909 | 0.1064 | 0.1204 | 0.5718 |

**Table 2.**

The decision variables are defined as follows:

$$x_1 = \text{the amount of financial statement in year 2010}$$

$$x_2 = \text{the amount of financial statement in year 2011}$$

$$x_3 = \text{the amount of financial statement in year 2012}$$

$$x_4 = \text{the amount of financial statement in year 2013}$$

$$x_5 = \text{the amount of financial statement in year 2014}$$

$$x_6 = \text{the amount of financial statement in year 2015}$$

$$x_7 = \text{the amount of financial statement in year 2016}$$

## 4.1. The Goal Constraints

**Priority 1:** Asset accumulation goal-the management of healthcare wants to maximize the asset accumulation. we have to minimize the negative deviational variable $d_1^-$.

$$0.0062x_1 + 0.0060x_2 + 0.0096x_3 + 0.0146x_4 + 0.0136x_5 + 0.0170x_6 + 0.0178x_7 + d_1^- - d_1^+ = 0.0848$$

**Priority 2:** Liability goal-the management wants to minimize the liability. So, we need to minimize the over achievement of the goal, that is positive deviational variable $d_2^+$.

$$0.0052x_1 + 0.0054x_2 + 0.0054x_3 + 0.0051x_4 + 0.0056x_5 + 0.0080x_6 + 0.0098x_7 + d_2^- - d_2^+ = 0.0444$$

**Priority 3:** Equity goal-the equity is to be maximized. So, the under-achievement variable $d_3^-$ is to be minimized.

$$0.0154x_1 + 0.0177x_2 + 0.0235x_3 + 0.0273x_4 + 0.0296x_5 + 0.0316x_6 + 0.0343x_7 + d_3^- - d_3^+ = 0.1795$$

**Priority 4:** Income goal-the management wants to maximize the income. We have to minimize the under-achievement variable $d_4^-$.

$$0.0186x_1 + 0.0235x_2 + 0.0283x_3 + 0.0335x_4 + 0.0388x_5 + 0.0464x_6 + 0.0548x_7 + d_4^- - d_4^+ = 0.2439$$

**Priority 5:** Profitability goal-To maximize the profit, the under-achievement variable $d_5^-$ is to be minimized.

$$0.0015x_1 + 0.0018x_2 + 0.0023x_3 + 0.0031x_4 + 0.0033x_5 + 0.0035x_6 + 0.0037x_7 + d_5^- - d_5^+ = 0.0192$$

**Priority 6:** Financial statement managing goal-To maximize the proportion of the values in the financial statement the under-achievement variable $d_6^-$ is to be minimized.

$$0.0470x_1 + 0.0544x_2 + 0.0692x_3 + 0.0835x_4 + 0.0909x_5 + 0.1064x_6 + 0.1204x_7 + d_6^- - d_6^+ = 0.5718$$

### 4.2. Objective Function

Minimize $Z = P_1(0.231157)d_1^- + P_2(0.194363)d_2^+ + P_3(0.168173)d_3^- + P_4(0.160122)d_4^- + P_5(0.096916)d_5^- + P_6(0.149269)d_6^-$

## 5. Results and Discussion

The problem was solved by using POM-QM for windows (formerly DS for windows). The following Table 3 shows the results.

| Goal priority | Negative deviation variable ($d_i^-$) | positive deviation variable ($d_i^+$) |
|---|---|---|
| $P_1$ $P_1$ | 0 | 0.04231 |
| $P_2$ | 0 | 0 |
| $P_3$ | 0 | 0.05817 |
| $P_4$ | 0 | 0.27245 |
| $P_5$ | 0.21691 | 0 |
| $P_6$ | 0 | 0.15514 |

**Table 3.** **deviational variables**

The Table 3 shows the values of positive and negative deviational variables related to the goals from $P_1$ to $P_6$. The first priority $P_1$ is to maximize the total assets. The goal is fully achieved because the negative deviational variable $d_1^- = 0$ but positive deviational variable $d_1^+ = 0.04231$ this means the asset of the health care system can be increased 0.04231 trillion. The goal of liability reduction $P_2$ is also achieved since both $d_2^+ = 0$ and t $d_2^- = 0$, this means the liability can't be changed. The third priority goal $P_3$ is also achieved since the negative deviational variable $d_3^- = 0$ but $d_3^+ = 0.05817$, this means the equity amount 0.05817 trillion can be increased in the 6-year period. The fourth priority goal $P_4$ is maximizing income is also achieved, since the negative deviational variable $d_4^- = 0$, but the positive deviational variable $d_4^+ = 0.27245$, this indicates that the income can be increased by 0.27245 trillion. The profitability goal is not achieved, since $d_5^- = 0.21691$ and $d_5^+$ are zero, this indicates the total profit can be decreased 0.21691 trillion in the 6 years period. Lastly the goal $P_6$ of maximizing the proportion of the value given in the financial statement is achieved, because the negative deviational variable $d_6^- = 0$, but the positive deviational variable $d_6^+ = 0.15514$ indicates that the proportion of the values given in the financial statement can be increased by 0.15514 trillion.

# 6. Conclusion

The model used in this paper indicates that the financial performance of health care system is good, because all the goals are achieved except one goal, namely profitability can be modified to increase the aspiration level. The proposed model can serve as a guideline for a health care system in making decisions to deal with various economic scenarios. Furthermore, the proposed model can be used as a tool or solution system that helps health care systems or other financial institutions to create a plan blueprint and identify their ideal goal level or benchmark that can be achieved in the future

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