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Formulation of the Mixed-Integer Goal Programming Model for Flour Producing Companies*

[1]M.E. Nja and [2]G.A. Udofia
[1]Department of Mathematics and Statistics,
Cross River University of Technology, Calabar, Nigeria
[2]Department of Mathematics, Statistics and Computer Science,
University of Calabar, Calabar, Nigeria

Abstract: Based on production times of three products, a procedure for obtaining an optimal mixed integer goal programming model for flour producing companies is developed. With this model, the magnitudes of goal deviations for each of the goals formulated are determined. Three derived models are obtained from the first by changing priority factors for non-basic activities, interchanging goals and changing goal levels, for this purpose. Fresh optimality should be discouraged if the goals are properly prioritized. This model is cost-effective and can be adapted for use, by flour producing firms and indeed manufacturing industries in general.

Key words: Priority coefficients, priority rankings, sensitivity analysis, goal deviation, goal level, optimization, priority factors

INTRODUCTION

Goal programming, developed by Ijiri *et al*. (1965), Lee (1972) and Ignizio (1976) is an extension of the linear programming model employed in solving optimal-mix problems subject to some specified goal constraints. The objective function is designed to minimize the sum of goal deviations with a view to minimizing the cost associated with goal under achievements and goal over achievements. This is supported by Li and Yu (1996). The goal programming model can be stated in matrix form as Min $Z = Wd^{-} + Wd^{+}$:

$$\text{s.t. } AX = b, X = 0$$

The matrix AX was restructured by Shapiro (1979) as shown below. Let B denote the mxm non singular submatrix of A and let's reorder the columns of A so that A = (B, N), the matrix B is called a basis. X can similarly be partitioned so that $X = (X_B, X_N)$, where X_B is basic variable column vector and X_N is the non-basic variable column vector.

Thus, the equation AX = b can be written as:

$$BX_B+NX_N = b$$

The solution of the system:

$$AX = b$$

Corresponding Author: M.E. Nja, Department of Mathematics and Statistics, Cross River University of Technology, Calabar, Nigeria
Tel: +234-8056450784

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is characterized by the vectors:

$$(X_B, X_N) \in Ir^n$$

where, X_N is any vector in IR^{n-m} and $X_B = B^{-1}b - B^{-1}NX_N$.

Attempts to apply goal programming in the solution of problems affecting production management have been made by several scholars. Shim and Siegel (1980) demonstrated goal programming with sensitivity analysis using an illustrated production model to determine policy variables and goal deviations. They also examined the effects on optimality in the face of change in priority factors and goal level using the duality theory of linear programming. Phillips *et al.* (1976) defined a mixed integer programming as one which restricts some of the decision variables to be integers while others can assume fractional values. Cobb and Warner (1973), Lee (1972) and Trivedi (1981) employed the mixed integer goal programming model in resource allocation to solve management problems related to quality service. Thierauf *et al.* (1975) also employed the model to solve problems associated with production planning. Fabrycky *et al.* (1987) and Gupta and Evans (2009) used the model to demonstrate the importance of goal ranking and weighting of multiple goal priority factors. In formulating the mixed integer goal programming problem, priority coefficients are used to rank the goals. Courtney *et al.* (1972) worked on the application of goal programming on a production set-up by imposing pre-emption on the priority factors as they followed the existence of linear programming packages as the basic vehicle for analysis.

Kumar *et al.* (2004) formulated a mixed integer goal programming problem for vendor selection problem in which three goals were indicated. With more than five constraints the model has the capability to handle realistic situations in a fuzzy environment. Selen and Hott (1986) incoperated the mean flow-time and throughput time as additional criteria in formulating the mixed integer goal programming model for the standard flow-shop scheduling problem in the search for an optimal sequence.

Alpar and Srikanth (1989) and Gharehgozli *et al.* (2009) used mixed integer goal programming formulation in finding an optimal solution in a scheduling problem for closed-shop environments where production goes to inventory rather than directly to the customer. Cardona and Sánchez (2007) incoperated the separation goal into their optimization model for fuel ethanol production process design. Sasikumar *et al.* (2009) employed integer goal programming model by introducing a heuristic based approach for solving the vehicle routing problem of their party reverse logistics. It is the problem of designing optimal routes from one depot to a number of customers.

In every goal programming model formulation, the goals are unique and relative to the environment-technical, economic and social. This is also upheld by Ilori and Irefin (1997). Present mixed integer goal programming model is designed for flour production and is adaptable for use by other manufacturing industries. The company produces three types of products. The production process is such that the three product types pass through 6 processing units, namely, screen room, breaking room, separation room, grinding room, purifying room and packaging room. Each of the rooms (units) houses a machine through which a product-type passes in the production process. The time spent by each product in each room is tabulated along side their corresponding machine capacities and the profit per unit product. This forms the main data in this study. There are a total of seven goals each with a corresponding deviation or pair of deviations. Where the deviations are paired, one must of necessity be zero. In line with the approach adopted by Charnes and Cooper (1961), numerical values are assigned to priority factors while using the preemptive classification of goal programming in the sense of Hillier and Lieberman (2001). Top on the list of goals is the profit goal of meeting a profit of \$φ per week.

MODEL NOTATION

Subscripts

i	=	Order of goal	i	=	1, 2, 3,…..,m
j	=	Order of activity	j	=	1, 2, 3,…..,n
k	=	Order of ranking	k	=	1, 2, 3,…..,m

Data Requirement
Primal

a_{ij} = Quantity contributed towards the achievement of the ith goal for the jth activity
x_j = Quantity of product to be produced under activity j
b_i = Target level of the ith goal
d^-_i = Value of the under achievement of the ith goal
d^+_i = Value of the over achievement of the ith goal
$w^-_{i,k}$ = Relative weight of the d^-_I in the kth rank
$w^+_{i,k}$ = Relative weight of the d^+_I in the kth rank
p_k = Ranking coefficient for all deviations having the kth priority of being avoided
m = No. of goals

Dual

U_i = Level of performance per unit of goal i
P_k = Ranking coefficient for all deviations having the kth priority of being avoided

Decision Variables

x_j = Quantity of product to be produced under activity j
d^-_i = Value of the under achievement of goal i
d^+_i = Value of the over achievement of goal i
U_i = Level of performance per unit of goal i

Priority Coefficients and the Corresponding Goals

P_1 = A profit target of \$ö per week should be met
P_2 = Stock-out should be avoided in the Screen room to ensure steady inventory of finished goods
P_3 = Avoid over utilization in the purifying unit because the purifying machine is prone to frequent breakdown
P_4 = Idle time should be avoided in the packaging room to make for full utilization of the part-time workers (casuals)
P_5 = Avoid under utilization in the breaking room

P_6 = Available production time in the separation and grinding rooms should be fully utilized but not exceeded. It is three times as important that this be done in the grinding room than in the separation room

Deviation Variables with their Corresponding Priority Rankings

$d^-_1(P_1)$ = Under achievement of the profit goal
$d^-_2(P_2)$ = Stock out in the screen room
$d^-_3(P_5)$ = Under utilization of production time in the breaking room
$d^-_4(P_6)$ = Idle time in the separation room
$d^-_5(P_6)$ = Idle time in the grinding room
$d^+_6(P_3)$ = Excess time in the purifying unit
$d^+_7(P_4)$ = Overtime in packing room

STATEMENT OF GOAL EQUATIONS AND EFFECTIVENESS FUNCTION

With the goals, priority coefficients, corresponding deviational variables and weights stated above, we now state the equations corresponding to the goals as follows:

Profit goal : $\$\alpha_1 + \$\alpha_2 + \$\alpha_3 + d^-_1 - d^+_1 = \$\varphi$
Inventory goal : $t_{11}x_1 + t_{12}x_2 + t_{13}x_3 + d^-_2 - d^+_2 = \beta_1$
Underutilization goal : $t_{21}x_1 + t_{22}x_2 + t_{23}x_3 + d^-_3 - d^+_3 = \beta_2$
Production time goal (1) : $t_{31}x_1 + t_{32}x_2 + t_{33}x_3 + d^-_4 - d^+_4 = \beta_3$
Production time goal (2) : $t_{41}x_1 + t_{42}x_2 + t_{43}x_3 + d^-_5 - d^+_5 = \beta_4$
Overutilization goal : $t_{51}x_1 + t_{52}x_2 + t_{53}x_3 + d^-_6 - d^+_6 = \beta_5$
Idle time goal : $t_{61}x_1 + t_{62}x_2 + t_{63}x_3 + d^-_7 - d^+_7 = \beta_6$

where t_{ij} is the production time for the ith department and jth product, β_i is the capacity for the ith department as shown in Table 1.

The effectiveness function: It is formulated as:

$$\text{Minimize } Z = P_1d^-_1 + P_2d^-_2 + P_5d^-_3 + 3\ P_6d^-_4 + P_6d^-_5 + P_3d^-_6 + P_4d^+_7$$

Weights

The goal on production time attaches more importance to the separation room than the grinding room in the ratio of 3:1, respectively.
Accordingly,

$W_{i,k}$ ($W_{3,1}$ = 3) for the separation room
$W_{i,k}$ ($W_{4,1}$ = 1) for the grinding room

Table 1: Production times (min) for three products

Departments	Product 1 (x_1)	Product 2 (x_2)	Product 3 (x_3)	Capacity
Screen room	t_{11}	t_{12}	t_{13}	β_1
Breaking room	t_{21}	t_{22}	t_{23}	β_2
Separation room	t_{31}	t_{32}	t_{33}	β_3
Grinding room	t_{41}	t_{42}	t_{43}	β_4
Purifying room	t_{51}	t_{52}	t_{53}	β_5
Packing room	t_{61}	t_{62}	t_{63}	β_6
Profit per unit of time	$\$\alpha_1$	$\$\alpha_2$	$\$\alpha_3$	

THE MIXED INTEGER GOAL PROGRAMMING MODEL

This formulation derives from the reasoning of Shim and Sigel (1980) who developed t heir goal programming model in which the initial matrix was obtained using the deviational variables as slacks. They also constructed the dual problem and showed that a duality based sensitivity analysis produces optimal ranges for the priority factors. In this study, the formulation of the mixed integer goal programming model is made in pairs of the primal and dual problems.

With these goal constraints and weights, we now formulate the goal programming model for present production problem as:

Model 1: Primal

The effectiveness function and goal constraints.

$$\text{Minimize } Z = P_1d^-_1+P_2d^-_2+P_5d^-_3+3\ P_6d^-_4+P_6d^-_5+P_3d^+_6+P_4d^+_7$$

Subject to:

$\alpha_1 x_1+\alpha_2 x_2+\alpha_3 x_3+d^-_1-d^+_1 = \varphi$
$t_{11} x_1+t_{12} x_2+t_{13} x_3+d^-_2-d^+_2 = \beta_1$
$t_{21} x_1+t_{22} x_2+t_{23} x_3+d^-_3-d^+_3 = \beta_2$
$t_{31} x_1+t_{32} x_2+t_{33} x_3+d^-_4-d^+_4 = \beta_3$
$t_{41} x_1+t_{42} x_2+t_{43} x_3+d^-_5-d^+_5 = \beta_4$
$t_{51} x_1+t_{52} x_2+t_{53} x_3+d^-_6-d^+_6 = \beta_5$
$t_{61} x_1+t_{62} x_2+t_{63} x_3+d^-_7-d^+_7 = \beta_6$
$x_1, x_2, x_3, d^-_1, d^+_2, d^-_3, d^+_3, d^-_4, d^-_5, d^-_6, d^+_6, d^-_7, d^+_7, \geq 0$

Model 1: Dual

The dual of this problem can be written as:

$$\text{Max } U = \varphi U_1+\beta_1U_2+\beta_2U_3+\beta_3U_4+\beta_4U_5+\beta_5U_6+\beta_6U_7$$

Subject to:

$\alpha_1U_1+t_{11}U_2+t_{21}U_3+t_{31}U_4+t_{41}U_5+t_{51}U_6+t_{61}U_7 \leq 0$
$\alpha_2U_1+t_{12}U_2+t_{22}U_3+t_{32}U_4+t_{42}U_5+t_{52}U_6+t_{62}U_7 \leq 0$
$\alpha_3U_1+t_{13}U_2+t_{23}U_3+t_{33}U_4+t_{43}U_5+t_{53}U_6+t_{63}U_7 \leq 0$
$U_1 \leq P_1$
$-U_1 \leq 0$
$U_2 \leq P_2$
$-U_2 \leq 0$
$U_3 \leq P_5$
$-U_3 \leq 0$
$U_4 \leq 3P_6$
$U_5 \leq P_6$
$U_6 \leq 0$
$-U_6 \leq P_3$
$U_7 \leq 0$
$-U_7 \leq P_4$
U_i (I = 1,2,…,7) unrestricted in sign.

For purposes of sensitivity analysis, three derived models are obtained from the first in order to obtain a model with the most optimal production mix.

Model 2: Primal: Changes in Priority Factors for Non-Basic Activities

Changing from: P_5d_3 to: Fd_3 The model becomes:

$$\text{Minimize } Z = Td^-_1+P_2d^-_2+Fd^-_3+3P_6d^-_4+P_6d^-_5+P_3d^+_6+Pd^+_7$$

Subject to:

$\alpha_1 x_1+\alpha_2 x_2+\alpha_3 x_3+d^-_1-d^+_1 = \varphi$
$t_{11} x_1+t_{12} x_2+t_{13} x_3+d^-_2-d^+_2 = \beta_1$
$t_{21} x_1+t_{22} x_2+t_{23} x_3+d^-_3-d^+_3 = \beta_2$
$t_{31} x_1+t_{32} x_2+t_{33} x_3+d^-_4-d^+_4 = \beta_3$
$t_{41} x_1+t_{42} x_2+t_{43} x_3+d^-_5-d^+_5 = \beta_4$
$t_{51} x_1+t_{52} x_2+t_{53} x_3+d^-_6-d^+_6 = \beta_5$
$t_{61} x_1+t_{62} x_2+t_{63} x_3+d^-_7-d^+_7 = \beta_6$
$x_1, x_2, x_3, d^-_1, d^+_1, d^-_2, d^+_2, d^-_3, d^+_3, d^-_4, d^-_5, d^-_6, d^+_6, d^-_7, d^+_7, \geq 0$

Model 2: Dual Problem

$$\text{Max } U = \varphi U_1+\beta_1U_2+\beta_2U_3+\beta_3U_4+\beta_4U_5+\beta_5U_6+\beta_6U_7$$

Subject to:

$\alpha_1U_1+t_{11}U_2+t_{21}U_3+t_{31}U_4+t_{41}U_5+t_{51}U_6+t_{61}U_7$	≤ 0
$\alpha_2U_2+t_{21}U_2+t_{22}U_3+t_{23}U_4+t_{24}U_5+t_{25}U_6+t_{26}U_7$	≤ 0
$\alpha_3U_3+t_{31}U_2+t_{23}U_3+t_{33}U_4+t_{34}U_5+t_{35}U_6+t_{36}U_7$	≤ 0
U_1	$\leq F$
$-U_1$	≤ 0
U_2	$\leq P_2$
$-U_2$	$\leq F$
U_3	$\leq P_5$
$-U_3$	≤ 0
U_4	$\leq 3P_6$
U_5	$\leq P_6$
U_6	≤ 0
$-U_6$	$\leq P_3$
U_7	≤ 0
$-U_7$	$\leq P_4$

U_i (I = 1,2,…,7) unrestricted in sign.

Model 3: Primal

Interchanging inventory goal (Goal 2) with over utilization goal (Goal 5) for basic activities

$$\text{Minimize } Z = P_1d^-_1+P_3d^-_2+P_5d^-_3+3P_6d^-_4+P_6d^-_5+P_2d^+_6+P_4d^+_5$$

Subject to:

$\alpha_1 x_1+\alpha_2 x_2+\alpha_3 x_3+d^-_1-d^+_1 = \varphi$
$t_{51} x_1+t_{52} x_2+t_{53} x_3+d^-_2-d^+_2 = \beta_5$
$t_{21} x_1+t_{22} x_2+t_{23} x_3+d^-_3-d^+_3 = \beta_2$
$t_{31} x_1+t_{32} x_2+t_{33} x_3+d^-_4-d^+_4 = \beta_3$
$t_{41} x_1+t_{42} x_2+t_{43} x_3+d^-_5-d^+_5 = \beta_4$
$t_{11} x_1+t_{12} x_2+t_{13} x_3+d^-_6-d^+_6 = \beta_1$
$t_{61} x_1+t_{62} x_2+t_{63} x_3+d^-_7-d^+_7 = \beta_6$
$x_1, x_2, x_3, d^-_1, d^+_1, d^+_2, d^-_3, d^+_3, d^-_4, d^-_5, d^-_6, d^+_6, d^-_7, d^+_7, \geq 0$

Model 3: Dual Problem

$$\text{Max } U = \varphi U_1+\beta_1 U_2+\beta_2 U_3+\beta_3 U_4+\beta_4 U_5+\beta_5 U_6+\beta_6 U_7$$

Subject to:

$\alpha_1 U_1+t_{51}U_2+t_{11}U_3+t_{31}U_4+t_{41}U_5+t_{11}U_6+t_{61}U_7 \leq 0$
$\alpha_2 U_1+t_{52}U_2+t_{12}U_3+t_{32}U_4+t_{42}U_5+t_{12}U_6+t_{62}U_7 \leq 0$
$\alpha_3 U_1+t_{53}U_2+t_{13}U_3+t_{33}U_4+t_{43}U_5+t_{13}U_6+t_{63}U_7 \leq 0$
$U_1 \leq P_1$
$-U_1 \leq 0$
$U_2 \leq P_3$
$-U_2 \leq 0$
$U_3 \leq P_5$
$-U_3 \leq 0$
$U_4 \leq 3P_6$
$U_5 \leq P_6$
$U_6 \leq 0$
$-U_6 \leq P_2$
$U_7 \leq 0$
$-U_7 \leq P_4$
U_i (I = 1,2,…,7) unrestricted in sign.

Model 4: Primal: Changes in Goal Levels (β_i)

Let the second goal level $\beta_{1,}$ change by an amount 30. Then the model becomes

$$\text{Minimize } Z = P_1 d^-_1+P_2 d^-_2+P_5 d^-_3+3P_6 d^-_4+P_6 d^-_5+P_3 d^+_6+P_4 d^+_7$$

Subject to:

$\alpha_1 x_1+\alpha_2 x_2+\alpha_3 x_3+d^-_1-d^+_1 = \varphi$
$t_{11} x_1+t_{12} x_2+t_{13} x_3+d^-_2-d^+_2 = \beta_1+30$
$t_{21} x_1+t_{22} x_2+t_{23} x_3+d^-_3-d^+_3 = \beta_2$
$t_{31} x_1+t_{32} x_2+t_{33} x_3+d^-_4-d^+_4 = \beta_3$
$t_{41} x_1+t_{42} x_2+t_{43} x_3+d^-_5-d^+_5 = \beta_4$
$t_{51} x_1+t_{12} x_2+t_{13} x_3+d^-_6-d^+_6 = \beta_5$
$t_{61} x_1+t_{62} x_2+t_{63} x_3+d^-_7-d^+_7 = \beta_6$
$x_1, x_2, x_3, d^-_1, d^+_1, d^-_2, d^+_2, d^-_3, d^+_3, d^-_4, d^+_4, d^-_5, d^+_5, d^-_6, d^+_6, d^-_7, d^+_7, \geq 0$

i.e.,

$$b = \begin{pmatrix} b_1 \\ b_2+30 \\ b_3 \\ b_4 \\ b_5 \\ b_6 \\ b_7 \end{pmatrix} = \begin{pmatrix} \varphi \\ \beta_1 \\ \beta_2+30 \\ \beta_3 \\ \beta_4 \\ \beta_5 \\ \beta_6 \end{pmatrix} = b + \in e_2$$

$$e_2^T = (0,1,0,0)$$

Model 4: Dual

The dual of model 4 is:

$$\text{Max } U = \varphi U_1+(\beta_1+30)U_2+\beta_2U_3+\beta_3U_4+\beta_4U_5+\beta_5U_6+\beta_6U_7$$

Subject to:

$\alpha_1U_1+t_{11}U_2+t_{21}U_3+t_{31}U_4+t_{41}U_5+t_{51}U_6+t_{61}U_7 \le 0$
$\alpha_2U_1+t_{12}U_2+t_{22}U_3+t_{32}U_4+t_{42}U_5+t_{52}U_6+t_{62}U_7 \le 0$
$\alpha_3U_1+t_{13}U_2+t_{23}U_3+t_{33}U_4+t_{43}U_5+t_{53}U_6+t_{63}U_7 \le 0$
$U_1 \le P_1$
$-U_1 \le 0$
$U_2 \le P_2$
$-U_2 \le 0$
$U_3 \le P_5$
$-U_3 \le 0$
$U_4 \le 3P_6$
$U_5 \le P_6$
$U_6 \le 0$
$-U_6 \le P_3$
$U_7 \le 0$
$-U_7 \le P_4$
U_i (I = 1,2,…,7) unrestricted in sign.

DISCUSSION

Unlike the traditional linear programming, goal programming permits the substitutability of different skill levels, different categories of workers, flexibility of time and other manipulations which cannot be handled by linear programming. In this model, optimality is achieved if there are negative entries at higher priority levels in the E_j-e_j row. However, optimality may be lost if there are changes in priority factors for non-basic activities or if there are changes in goal levels. The purpose of presenting four models, each with its dual is to obtain a model with the most optimal production mix. This approach agrees with that of Alpar ans Srikanth (1989), where optimal solutions were sought for the scheduling problem in a cereal blending/processing factory. As mentioned in the introduction, in every goal programming model formulation, the goals are unique and relative to the environment. This view talies with that of Ilori and Irefin (1997), when they considered the issues of technology decisions. The economic and technical environment of the company should provide necessary parameters for the efficient formulation of the mixed integer goal programming model. Such a model addresses the problems of fund application, capacity utilization, goal prioritization, job sequencing and the task of profit maximization. Model 1 and its dual is the main model of analysis. The rest of the models (2 and 2', 3 and 3', 4 and 4') were obtained for purposes of post-optimality (sensitivity) analysis.

CONCLUSION

Post-optimality analysis is indispensable in the application of goal programming in a production industry. This is because better solutions could be obtained on rearranging priority factors or changing goal levels. However, in employing post-optimality analysis, one should not underrate the importance of goal ranking. Fresh optimality should as much as possible be discouraged if the goals are properly prioritized except for purposes of determining the rate at which the objective function value changes.

REFERENCES

Alpar, P. and K.N. Srikanth, 1989. A comparison of analytical and knowledge-based approaches to close-shop scheduling. Anal. Operat. Res., 17: 347-361.

Cardona, C.A. and Ó.J. Sánchez, 2007. Fuel ethanol production process design trends and integration opportunities. Bioresour. Technol., 98: 2415-2457.

Charnes, A. and W.W. Cooper, 1961. Management Models and Industrial Application of Linear Programming. John Wiley and Sons, New York.

Cobb, P. and D.M. Warner, 1973. Task substitution among skill classes of nursing personnel. Nursing Res., 22: 130-137.

Courtney, J.F.Jr., T.D. Klastorin and T.W. Ruefli, 1972. Goal programme approach to urban-suburban location preference. Manage. Sci., 18: 258-268.

Fabrycky, W.J., P.M. Ghare and P.E. Torgersen, 1987. Applied Operations Research and Management Science. Prentice Hall of India Private Ltd., New Delhi.

Gharehgozli, A.H., R.T. Moghaddam and N. Zaerpour, 2009. A fuzzy-mixed integer goal programming model for a parallel-machine scheduling problem with sequence-dependent set up times and release dates. Robotics Comput. Integr. Manuf., 25: 853-859.

Gupta, A. and W.G. Evans, 2009. A goal programming model for the operation of closed-loop supply chains. Eng. Optimizat., 41: 713-735.

Hillier, F.S. and G.J. Lieberman, 2001. Introduction to Operations Research. 7th Edn., Mc Graw Hill, Boston.

Ignizio, J.P., 1976. Goal Programming and Extensions. Heath, Lexington Books, Lexington, Mass, Lexington, MA.

Ijiri, Y., D. Orne, A. Rao, J. Robert, J.K. Shim and J. Seigel, 1965. Management Goals and Accounting for Control. Rand-Mc Nally, Chicago, New York.

Ilori, M.O. and I.A. Irefin, 1997. Technology decision making in organizations. Technovation, 17: 153-160.

Kumar, M., P. Vrat and R. Shanker, 2004. A fuzzy goal programming approach for vendor selection problem in a supply chain. Comput. Ind. Eng., 46: 69-85.

Lee, S.M., 1972. Goal Programming for Decision Analysis Philadelphia Pennsylvania. Auerbach Publishing, Boston.

Li, L.H. and P.L. Yu, 1996. An efficient method for solving linear goal programming problems. J. Optimization Theory Appli., 90: 465-469.

Phillips, D.T., A. Ravindran and J.J. Solberge, 1976. Operations Research Principles and Practice. John Wiley and Sons, Inc., New York.

Sasikumar, P., G. Kannan and A.N. Haq, 2009. A heuristic based approach to vehicle routing model for Third Party Reverse Logistics Provider. Int. J. Services Technol. Manage., 12: 106-125.

Selen, W. and D. Hott, 1986. A mixed-integer goal programming formulation of the standard flow-shop scheduling problem. J. Opl. Res. Soc., 37: 1121-1128.

Shapiro, J.F., 1979. Mathematical Programming Structures and Algorithms. John Wiley and Sons, Toronto.

Shim, J.K. and J. Siegel, 1980. Sensitivity analysis of goal programming with preemption. Int. J. Syst. Sci., 11: 393-401.

Thierauf, R.J., J. Robert and R.C. Klekamp, 1975. Decision Making Through Operations Research Principles and Practice. John Wiley and Sons. Inc., New York.

Trivedi, V.M., 1981. A mixed-integer goal programming model for nursing service budgeting. Operat. Res., 29: 1019-1034.