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*Original Article*

# Material Planning with Goal Programming in MATLAB

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***Abstract -*** *Material Requirement Planning (MRP) is an important part of production management because it ensures the timely availability of materials while reducing costs and surplus inventory. This study introduces a Goal Programming (GP)-based optimization model for material planning in a furniture manufacturing company that produces three product types: dining tables, folding chairs, and fittings. The suggested methodology combines MRP concepts with preemptive multi-objective optimization to address common challenges in the manufacturing process and ultimately to reduce production costs, inventory holding costs, and expenses related to resource idle time and overtime. The mathematical formulation is built on a preemptive priority structure and solved using two computing approaches: Microsoft Excel Solver for baseline linear programming cost minimization and MATLAB's goal attain function for multi-objective goal programming. The suggested model achieves zero excess in priority production goals while keeping total production costs at 10.3% of the LP-derived optimum. The combination of MRP and Goal Programming is demonstrated to provide a practical, scalable, and computationally efficient decision-support framework for production managers in small and medium-sized manufacturing industries, outperforming conventional single-objective planning approaches reported in the literature.*

***Keywords -*** *Goal Programming, Integer linear programming, Linear programming problems, Multi-Objective Linear Programming, Simplex method.*

## 1. Introduction

Material planning is a popular replenishment planning technique in large-scale manufacturing companies, where excellent inventory control and production scheduling are essential for maintaining operational effectiveness and customer satisfaction [1]. Systems for Material Requirements Planning (MRP) are widely used decision-support tools that assist companies in determining the quantity and timing of material acquisition and production [2]. Using information from the Master Production Schedule (MPS) and the Bill of Materials (BOM), MRP determines material requirements and arranges procurement and production activities in a time-phased manner [3]. This tactic helps companies reduce inventory costs, avoid supply shortages, and maximize resource utilization [4]. Because of changing consumer demand, limited resources, inventory constraints, and the need for cost-effective operations, production planning is becoming increasingly complex in modern manufacturing environments. Aggregate Production Planning (APP) has garnered significant attention as a means of satisfying market demand while balancing production capacity, inventory levels, and labor requirements [5]. Recent studies that incorporate uncertainty into production planning models have demonstrated the value of optimization strategies in improving planning decisions under dynamic manufacturing conditions [6].

Furthermore, supply chains now have more opportunities to improve inventory and purchase responsiveness due to the implementation of Demand-Driven Material Requirements Planning (DDMRP) [7]. Researchers have increasingly used fuzzy programming and goal programming techniques to deal with uncertainty and many competing objectives in production contexts. Aggregate production planning issues involving supply-chain constraints, warehouse capacity limitations, and uncertain demand have all been successfully addressed by fuzzy goal programming models [8]. The significance of integrated decision-making frameworks for enhancing overall system performance under uncertainty has also been shown by production-distribution planning and routing optimization studies [9]. These advancements demonstrate the increasing demand for sophisticated optimization methods that may concurrently take into account several operational goals.[10] One of the most popular multi-objective optimization methods for managing competing goals in production and operations management is Goal Programming (GP). While taking into account priorities among conflicting goals, including cost reduction, inventory minimization, and resource usage, GP helps decision-makers minimize deviations from intended target values [11]. The concept is still regarded as a good strategy for multi-objective planning and resource allocation, and it has been effectively applied to many industrial decision-making situations [12].

Despite the enormous body of literature on MRP, aggregate production planning, and goal programming, most current research focuses on theoretical formulations, uncertainty modelling, or large-scale industrial implementations. The practical application of MATLAB-based Goal Programming-based material planning models for small and medium-sized industrial settings, especially in the furniture manufacturing industry, has received little attention. Additionally, there aren't many studies that combine MRP concepts with Goal Programming using easily implementable computational tools to address surplus production reduction and production cost minimization simultaneously. The current work creates a goal programming-based material planning model for furniture manufacturing and uses MATLAB and Excel Solver to apply the solution in order to close this research gap. In order to reduce production costs and surplus output while meeting product demand criteria, the suggested method combines MRP concepts with multi-objective optimization. The study shows how Goal Programming may be used as a useful decision-support tool for production management and material planning in industrial sectors.

## 2. Scope and Objectives of Study

### 2.1. Technological Development

In order to assist local businesses in managing inventories in a job shop manufacturing setting, numerous manufacturing organizations are currently creating Material Requirements Planning software utilizing the C programming language. An algorithm is implemented to capture the logic behind MRP processing. Simplifying the computation of material and schedule requirements is the main goal of MRP software. This system generates time-phased needs for raw materials, component parts, and subassemblies using three primary inputs: the BOM, inventory data, and the MPS. By working backward from the due dates and accounting for lead times and other relevant information, the system determines the amount and timing of dependent demand item procurement necessary to satisfy MPS requirements. How much and when to order. The main objectives of an MRP system are to: (1) ensure that products, components, and materials are accessible for scheduled production and customer deliveries; (2) maintain inventory levels as low as practical; and (3) effectively coordinate procurement, delivery, and manufacturing operations. The usefulness of goal programming in assisting with managerial decision-making, vendor evaluation, and production planning tasks has been shown in earlier research. Goal programming-based decision models that take into account several performance criteria at once can greatly enhance vendor evaluation and selection procedures. In a similar vein, goal programming has been effectively used to solve production planning optimization issues in order to enhance operational effectiveness and resource utilization in manufacturing settings [13]. Additionally, flexibility measures have been incorporated into production systems using linear programming models, improving responsiveness to evolving operational requirements [14]. Additionally, weighted goal programming techniques have been successful in resolving multi-objective optimization issues where multiple competing objectives need to be met at the same time [15]. Studies on material requirement planning have concentrated on merging optimization techniques with traditional MRP systems to improve inventory control and production efficiency. MRP works well in job shop settings where production scheduling, quantities, and sequencing must be flexible. The usage of MATLAB-based computational models to effectively address challenging industrial planning issues has grown. By reorienting its application, it is possible to leverage the advantages of MRP while remaining competitive with material-centric techniques like Just-In-Time (JIT). Goal programming is still acknowledged as a useful method for handling several competing goals in supply-chain and manufacturing systems.

### 2.2. Research Objectives

To further explore this issue, the effectiveness of quantity distribution was analyzed using Linear Interactive and Discrete Optimizer (LINDO) software. They tackled a multi-objective Material Requirement Planning (MRP) problem using the Goal Programming methodology [16]. The company stated three main objectives:

- To reduce the expenses associated with routine production processes.
- To reduce the expenses related to working overtime.
- To reduce the expense of keeping inventory, especially if it costs more than ₹100 per item.

## 3. Techniques

### 3.1. Goal Programming Problem Formulation and Description

Goal Programming (GP) and Linear Programming (LP) problems are similar in formulation, despite some important differences. GP extends LP by accommodating multiple objectives, explicitly incorporating specific goals, and assigning different levels of priority to each objective [17]. The model relies solely on deviational variables and uses two main types of variables: variables for decisions and variables for deviations. Additionally, it contains two kinds of constraints: goal constraints, which represent target values with related priorities and deviations, and structural (or system) constraints, which operate similarly to those in conventional LP. Goal Programming can be classified based on how goal importance is treated. This method is referred to as non-preemptive goal programming when all of the goals are equally or similarly important. On the other hand, preemptive goal programming assigns a priority level ($P_1$ to $P_m$) to each goal, making sure that higher priority goals are met before taking into account lower priority ones for order of importance [18]. The goals are expressed as linear equations with target values and two deviation variables: positive deviation ($d^+$) for overachievement and negative deviation ($d^-$) for underachievement. Depending on the goal, minimizing either $d^-$ or $d^+$ ensures that the desired outcome is achieved or maintained. According to earlier research, the goals of goal programming include lowering excess inventory, avoiding raw material shortages, guaranteeing prompt product delivery, eliminating production disruptions, cutting operating expenses, and increasing overall profitability [19]. Goal programming reduces unwanted deviations from target values in a hierarchical manner by giving priority to the most important goals first and addressing lower-priority goals only when higher-priority goals are achieved.

This structured prioritization is expressed mathematically in the Goal Programming model.

$$di^+ + di^- = 0$$

Goal programming has been effectively applied in real-world scenarios for resource allocation, vendor evaluation, and managerial decision-making issues employing optimization tools. Adjusting goal priorities can assist in finding effective solutions while simultaneously achieving several competing objectives, according to studies [20]. Goal programming has also been successfully used in production scheduling and planning settings where decision-makers must strike a compromise between operational performance objectives, cost, and resource utilization [21].

It is crucial to understand that there are two primary categories of constraints in a GP model: goal constraints and system constraints. Because they represent the current operational capabilities rather than the intended results, system constraints are stricter and must be satisfied first. Additionally, it can be concluded from the discussion that deviational variables in GP are mutually exclusive.

### *3.2. Formulation of the General Goal Programming Model*

This study tackles a multi-objective Material Requirement Planning (MRP) problem using a Goal Programming model. The company has outlined three primary objectives:

- Reducing production costs (production-related goal).
- Minimizing inventory holding costs (inventory goal).
- Lowering the costs associated with both overtime usage and idle time of resource utilization goal [22].

This scenario's generic Goal Programming paradigm can be expressed mathematically as a minimization issue.

Objective:

Minimize: $Ꝣ = \sum_{i=0}^{n} d_i^- + d_i^+$

1. Goal Constraints (for i = 1 to m):

$$\sum_{j=1}^{n} a_{ij}x_j - d_i^- + d_i^+ = b_i$$

2. System Constraints (for i = m+1 to m + p):

$$\sum_{j=1}^{n} a_{ij}x_j - d_i^- + d_i^+ \leq/\geq b_i$$

Terminology Explained,
$m$: Number of objectives
$p$: Number of limitations of the system
$n$: Number of variables of decision-making
Ꝣ: The Objective function – total deviation (to be minimized)
$x_j$: The $j^{th}$ decision variable
$a_{ij}$: Coefficient of $x_j$ in the $i^{th}$ goal or constraint
$b_i$: Right-hand side value for the $i^{th}$ constraint
$d_i^-$: Negative deviation (underachievement from the $i^{th}$ goal)
$d_i^+$: Positive deviation (overachievement from the $i^{th}$ goal).

## 4. Results and Discussion

Two companies produce three products: Dining, Foldings, and Fittings. In the month of June company has a contractual obligation to supply 12 units of Dining, 8 Units of Foldings and 24 units of Fittings products per week. Production details are as given below:

**Table 1. Problem reading details**

| Factory | Cost per day (₹ ,00) | Production (Unit/Day) | | |
|---|---|---|---|---|
| | | Dining | Foldings | Fittings |
| X | 180 | 6 | 3 | 4 |
| Y | 160 | 1 | 1 | 6 |

Find out :
- Minimization of cost of Production(production goal).
- Minimization of excess Production(Extra production).

### *4.1. Analysis*

In order to solve this problem, construct it as a linear program and include variables

x = Number of days/weeks Mine X operates
y = Number of days/weeks Mine Y operates
with $x \geq 0$ and $y \geq 0$.
Minimize: Z = 180x+160y
Subject to,
$6x+1y\geq12$
$3x+1y\geq8$
$4x+6y\geq24$

Operational limits $x\leq5$, $y\leq5$ (we assumed both factories can work no more than five days per week)

Non-negativity $x\geq0$, $y\geq0$

To determine the cost target, the problem was first solved using the Linear Programming (LP) simplex method through Excel Solver. The obtained optimal cost value was then used as the target cost goal in the Multi-Objective Linear Programming (MOLP) framework [23]. Using the simplex method with cost minimization as the objective, the problem was resolved, yielding an estimated minimum weekly cost of ₹ 765.71 (in hundreds). Based on this, the first cost-related goal is set at ₹ 800 (in hundreds) per week. Additionally, minimizing excess production has been established as another key goal to reduce material waste. By focusing on these objectives, the company aims to maximize profits and enhance overall productivity.

**Table 2. Excel solver cost result**

| Factory | Cost per day (₹,000) | Production(unit/day) | | | Decision | |
|---|---|---|---|---|---|---|
| | | Dinning | Foldings | Fittings | | |
| X | 180 | 6 | 3 | 4 | 1.714286 | X |
| Y | 160 | 1 | 1 | 6 | 2.857143 | Y |
| Total | 765.7142857 | 13.143 | 8 | 24 | | |
| | | | | | | |
| Constraints (Minimum Required) | | | | | | |
| Dinning | | 12 | | | | |
| Foldings | | 8 | | | | |
| Fitting | | 24 | | | | |


**Fig. 1 Graphical solution**

## 5. Goal Programming Formulation for the Problem

To address these two objectives using Goal Programming (GP), additional variables are introduced to capture deviations from each goal. First, specific numeric targets must be established for each objective. The two objectives are:

Reduce costs: The company is willing to pay up to ₹ 800 per week to cut down on excess production, even if the previously determined minimum operational cost was ₹ 765.71 per week. As a result, the target cost goal for the Goal Programming model is set at ₹ 800.

Reduce surplus production: The three grades have weekly target quantities of 12, 8, and 24 units, respectively.

$$180x + 160y = 800 + C+ - C-$$

With the exception of deviations recorded by the positive and negative deviation variables C+ and C-, respectively, this equality constraint stipulates that the entire production cost from Companies X and Y, represented by 180x+160y, must equal the goal cost of ₹ 800. In this case, C+ denotes any amount that the cost surpasses the objective (positive deviation), and C- denotes any amount that the cost falls short of the objective (negative deviation).

It is standard practice in Goal Programming to represent deviations above the target value using a plus sign (+), and deviations below the target using a minus sign (−). The definitions of C+ and C− follow this standard convention. Attention is now directed toward the objective of minimizing excess production. Letting D+ (Dining), F1+ (Foldings) and F2+ (Fittings) (all ≥0) be the upward deviation (Overachievement) and D-, F1- and F2- (all ≥0) be the downward deviation (Underachievement) for Dining, Fittings and Folding. The three equality equations are as follows:

One important point to note is that the above equations allow for the possibility that the company may choose not to fulfill the entire supply requirement for certain grades. In these situations, the target—which stands for the contracted supply quantity—deviates downward. The negative deviation variables D−, F1−, and F2− can be adjusted to zero and eliminated from the model if the business wants to rule out this possibility and guarantee full delivery. As a result, the Two Mines problem's Goal Programming formulation, which seeks to balance conflicting objectives, becomes:

$$180x+160y = 800+C^{+}-C^{-}$$
$$6x+y = 2+D^{+}-D^{-}$$
$$3x+y = 8+F1^{+}-F1^{-}$$
$$4x+6y = 24+F2^{+}-F2^{-}$$
$$x \leq 5$$
$$y \leq 5$$
$$x, y, C^{+}, C^{-}, D^{+}, D^{-}, F1^{+}, F1^{-}, F2^{+}, F2^{-} \geq 0$$

The following phase usually entails giving the deviation variables weights that represent the relative relevance of each goal in light of these factors and limitations. Next, minimizing the overall weighted sum of deviations is the goal.

This method, called weighted goal programming, offers an organized method for managing and prioritizing several, perhaps incompatible goals.

### *5.1. Priority Approach*

Under the priority-based Goal Programming approach, it is assumed that the organization always fulfills the stipulated supply volumes for each product type. Consequently, D−, F1−, and F2−, the negative deviation variables, are set to zero and can be removed from the model. This leaves us with the following active deviation variables: C+, C−, D+, F1+, and F2+.

The priority-based method involves assigning priority levels to each goal—Priority Level 1 representing the most critical objective, followed by Priority Level 2, and so on. The goals are addressed sequentially: a lower-priority goal is considered only after the higher-priority goal has been satisfactorily achieved.

For demonstration purposes, the following priority structure is assumed by management:

Priority level 1 – Minimize excess production of the Dining product.

Priority level 2 – Minimize total cost.

Priority level 3 – Minimize excess production of the combined Foldings and Fittings Products.

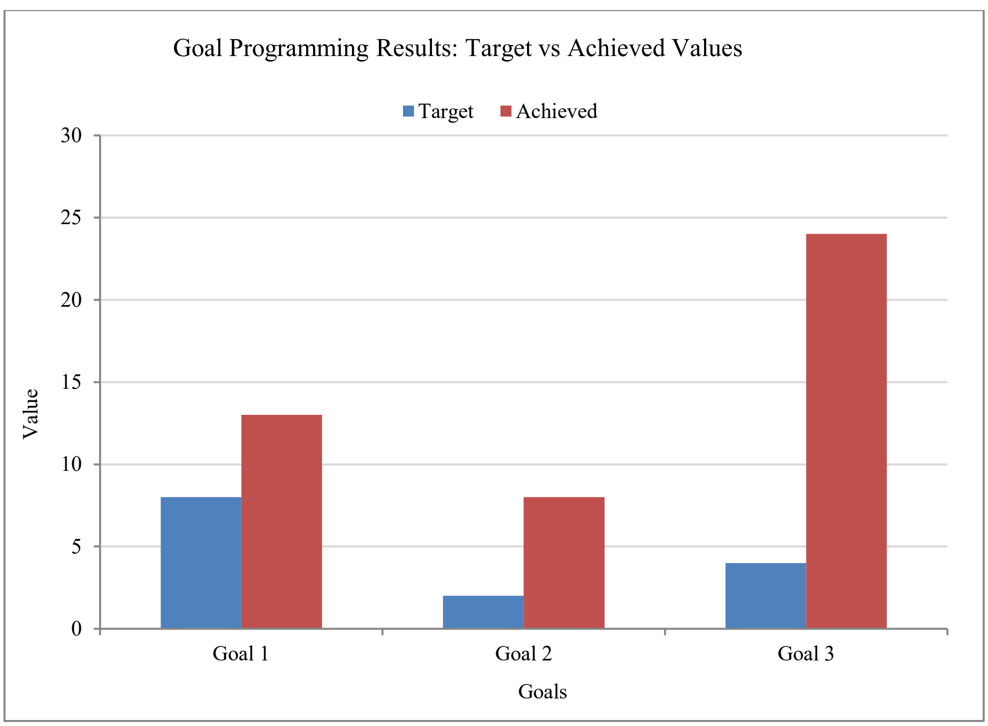


**Fig. 2 Graphical analysis of the goal method**

**Table 3. Excel solution for costing factor**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Goal Programming** | | | | | | | | | | |
| **MINIMIZE** | | | | | | | | | | |
| 1.714286 | 2.857143 | | | | | | | | | |
| 180 | 160 | | | | | | 765.7143 | | | |
| x | y | C+ | C- | D+ | F1 | F2 | | | | Solver |
| 6 | 1 | | | | | | 13.14286 | >= | 12 | 765.7143 |
| 3 | 1 | | | | | | 8 | >= | 8 | 2 |
| 4 | 6 | | | | | | 24 | >= | 24 | TRUE |
| 1 | | | | | | | 1.714286 | <= | 5 | TRUE |
| | 1 | | | | | | 2.857143 | <= | 5 | 32767 |
| | | | | | | | | | | 0 |

**Table 4. Excel sheet solution for first goal**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **First goal** | | | | | | | | | | |
| **MINIMIZE** | | | | | | | | | | |
| 1.333333 | 4 | 80 | 0 | 0 | 0 | 5.333333 | | | | |
| | | | | 1 | | | 0 | | | |
| x | y | C+ | C- | D+ | F1 | F2 | | | | Solver |
| 180 | 160 | -1 | 1 | | | | 800 | = | 800 | 0 |
| 6 | 1 | | | -1 | | | 12 | = | 12 | 7 |
| 3 | 1 | | | | -1 | | 8 | = | 8 | TRUE |
| 4 | 6 | | | | | -1 | 24 | = | 24 | TRUE |
| 1 | | | | | | | 1.333333 | <= | 5 | 32767 |
| | 1 | | | | | | 4 | <= | 5 | 0 |

From Table 3, we determined the minimum cost of ₹ 765.71 using Excel Solver based on the formulated equations. Building on this minimized cost, we now proceed to solve the multi-objective problem, commonly referred to as the GP Problem.

Table 4 presents the first goal, represented by the equation 6x + y = 12. The objective is to satisfy the target demand for Dining products. The goal is to ensure that the Dining product number should not be less than or more than 12 Units/week.

This solution indicates that it is possible to achieve zero excess production of the Dining product, represented by a zero value for the upward deviation variable D+. However, this comes at the expense of an upward deviation of 80 units from the cost goal and an upward deviation of 5.333 units from the Fittings product goal F2+.

**Table 5. Excel solution for the second goal**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Second goal** | | | | | | | | | | |
| **MINIMIZE** | | | | | | | | | | |
| 1.333333 | 4 | 80 | 0 | 0 | 0 | 5.333333 | | | | |
| | | 1 | -1 | | | | 0 | | | |
| x | y | C+ | C- | D+ | F1 | F2 | | | | Solver |
| 180 | 160 | -1 | 1 | | | | 800 | = | 800 | 80 |
| 6 | 1 | | | -1 | | | 12 | = | 12 | 7 |
| 3 | 1 | | | | -1 | | 8 | = | 8 | TRUE |
| 4 | 6 | | | | | -1 | 24 | = | 24 | TRUE |
| 1 | | | | | | | 1.333333 | <= | 5 | TRUE |
| | 1 | | | | | | 4 | <= | 5 | 32767 |
| | | | | 1 | | | 0 | = | 0 | 0 |

**Table 6. Excel solution for the third goal**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Third goal** | | | | | | | | | | |
| **MINIMIZE** | | | | | | | | | | |
| 1.333333 | 4 | 80 | 0 | 0 | 1.11E-16 | 5.333333 | | | | |
| | | | | | 1 | 1 | 5.333333 | | | |
| x | y | C+ | C- | D+ | F1 | F2 | | | | Solver |
| 180 | 160 | -1 | 1 | | | | 800 | = | 800 | 5.333333 |
| 6 | 1 | | | -1 | | | 12 | = | 12 | 7 |
| 3 | 1 | | | | -1 | | 8 | = | 8 | TRUE |
| 4 | 6 | | | | | -1 | 24 | = | 24 | TRUE |
| 1 | | | | | | | 1.333333 | <= | 5 | TRUE |
| | 1 | | | | | | 4 | <= | 5 | 32767 |
| | | | | 1 | | | 0 | = | 0 | 0 |
| | | 1 | -1 | | | | 80 | = | 80 | |

Table 5 presents the achievement of the second goal, represented by the equation $180x + 160y = 800$. The objective is to satisfy the specified production cost target. The goal is to ensure that the folding product number is not less than or more than 800.

Table 6 presents the achievement of the third goal, represented by the equations $3x + y = 8$ and $4x + 6y = 24$. The objective is to satisfy the target demand for Folding and Fittings products. The goal is to achieve those Fittings product numbers should not be less than or more than 24 Units/week.

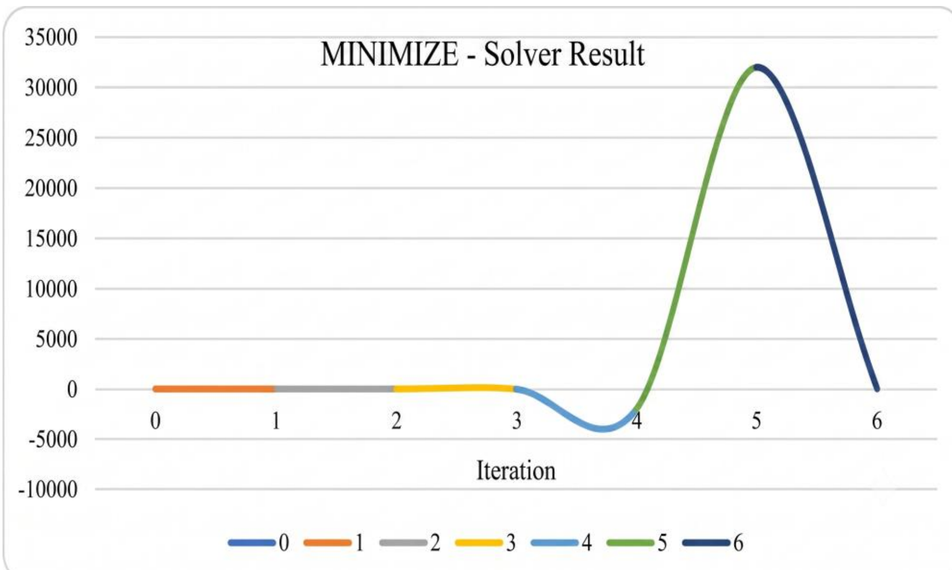


**Fig. 3 Graphical solution of goal method**

We can reasonably interpret this solution as having the same objective function value, while also satisfying all the constraints imposed by the first and second priority levels.

### *5.2. Solution through MATLAB Code*

function [x, fval, attainfactor, exitflag, output, lambda] = untitled (x0, goal, weight, lb., up)

%% Start with the default options

options = optimoptions('fgoalattain');

%% Modify options settings

options = optimoptions (options, 'Display', 'off'); % Suppress output display

options = optimoptions (options, 'SpecifyConstraintGradient', true); % Use analytical gradients if available

%% Call the fgoalattain solver

[x, fval, attainfactor, exitflag, output, lambda] = ...

fgoalattain (@fgoalattainobj, x0, goal, weight, [], [], [], [], lb., up, [], options);

### *5.3. Objective Function*

function f = fgoalattainobj(x)

% Objective functions for goal attainment

% x (1): x Operating days for Factory X

% x (2): y Operating days for Factory Y

f(1) = 180 * x(1) + 160 * x(2); % Total production cost

f(2) = 6 * x(1) + 1 * x(2); % Dining  products

f(3) = 3 * x(1) + 1 * x(2); % Folding products

```
f(4) = 4 * x(1) + 6 * x(2); % Fittings products
end
```

### 5.4. Constraint Function

```
function [c, ceq] = fgoalattaincon(x)
% Inequality constraints (c <= 0):
% Factory X and Y should not operate more than 5 days
c = [x (1) - 5;
    x (2) - 5]; % Limits for x and y (<= 5)
ceq = []; % No equality constraints
end
```

### 5.5. Goal Function

```
clc;
clear all;
% Initial guess for decision variables [x, y]
x0 = [0.1, 0.1];
% Goal values for: [Cost, Dining, Folding, Fittings]
goal = [800, 12, 8, 24];
% Weights for each goal (absolute values)
weight = abs(goal);
% Lower and upper bounds for x and ylb. = [1.28, 3.5];
up = [5, 5];
% Solve using fgoalattain
[x, fval, attainfactor, exitflag, output, lambda] = fgoalattain (...@fgoalattainobj, x0, goal, weight, ... [], [], [], [], lb., up, @fgoalattaincon, options);
```

## 6. Conclusion

This study investigated the application of Goal Programming (GP) to optimize Material Requirement Planning (MRP) for three furniture products. The selection of these things was based on their industry importance. The GP model concentrated on striking a balance between important production objectives and quality, social, and economic factors. The model, which was solved with MATLAB and Microsoft Excel Solver, was successful in tackling problems, including lowering the cost of reverse logistics and enhancing quality through improved material segregation. The findings indicate that the GP strategy facilitates improved decision-making in inventory and production management, particularly for large-scale issues where it shortens processing times. When weighted goal programming was used instead of worst-case scenarios, more realistic results were obtained.

Decision-makers can create a Multi-Choice Probabilistic Goal Programming (MCPGP) model by setting several ambition levels to increase flexibility. The speedy delivery of ideal outcomes by the solver validated the effectiveness and resilience of the approach. GP also helps to improve overall production efficiency by reducing waste from materials and by-products. MATLAB is more appropriate for managing intricate models and huge datasets, whereas Excel Solver is more straightforward and easier to use for minor issues. All things considered, goal programming in MATLAB is a useful and effective technique for material planning in the furniture sector.

## Conflicts of Interest

The authors declare that there are no conflicts of interest related to the research or publication of this paper titled "Material Planning with Goal Programming in MATLAB." The work was conducted independently as part of academic requirements.

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Both authors contributed equally to this work.

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