MM 656 Case Study Report

Enhancing Manufacturing Efficiency: A Linear Programming Case Study

Submitted

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1. Abstract:

This case study focuses on optimizing the manufacturing process of printed circuit boards (PCBs) using the simplex method and MATLAB. The manufacturing process involves two types of Component Placement Machines, each with different productivity levels and space requirements. The goal is to maximize the production of PCBs while adhering to constraints related to budget, floor space, and workforce availability.

The simplex method, a widely used optimization technique, will be applied to formulate and solve the linear programming problem. It iteratively improves the solution until an optimal solution is reached. Subsequently, MATLAB, a powerful computational tool, will be employed to solve the same problem, offering insights into alternative approaches and solution methodologies.

By comparing the results obtained from both methods, this study aims to demonstrate the effectiveness and efficiency of each approach in solving the optimization problem. Additionally, it provides valuable insights into the practical application of optimization techniques in real-world manufacturing scenarios, offering potential improvements in production efficiency and resource utilization.

2. Introduction:

In the realm of manufacturing, optimizing production processes is paramount for enhancing efficiency, reducing costs, and maximizing output. This case study delves into the optimization of the manufacturing process for printed circuit boards (PCBs), crucial components in electronic devices. The objective is to maximize PCB production while considering constraints such as budget limitations, floor space availability, and workforce constraints.

The manufacturing process involves two types of Component Placement Machines, each with distinct productivity levels and space requirements. Decision variables, denoted as X1 and X2, represent the quantities of machines of each type allocated for production. The optimization problem is formulated as a linear programming model, with the goal of maximizing the number of PCBs produced.

To tackle this optimization problem, two methodologies are employed: the simplex method and MATLAB. The simplex method is a fundamental optimization technique that iteratively improves solutions until an optimal solution is found. MATLAB, a powerful computational tool, offers an alternative approach to solving the optimization problem, providing insights into different solution methodologies.

By comparing the results obtained from both methodologies, this study aims to evaluate their effectiveness and efficiency in optimizing the manufacturing process. Furthermore, it seeks to demonstrate the practical application of optimization techniques in real-world manufacturing scenarios, offering opportunities for enhancing production efficiency and resource utilization.

3. Problem Statement:

The problem at hand revolves around optimizing the manufacturing process for printed circuit boards (PCBs), essential components in electronic devices. The objective is to maximize PCB production while adhering to various constraints, including budget limitations, floor space availability, and workforce constraints.

The manufacturing process involves two types of Component Placement Machines, denoted as type A and type B. Each type of machine has distinct productivity levels and space requirements. The decision variables, X1 and X2, represent the quantities of machines of each type allocated for production. The goal is to determine the optimal allocation of these machines to maximize the number of PCBs produced within the given constraints.

Constraints include:

1. Budget Constraint: The total cost of acquiring machines must not exceed the allocated budget.
2. Floor Space Constraint: The total floor space required by the machines must not exceed the available floor space in the manufacturing facility.
3. Workforce Constraint: The total number of operators required to operate the machines must not exceed the available workforce.

To address this optimization problem, the simplex method and MATLAB will be employed. These methodologies offer different approaches to solving the problem and provide insights into alternative solution methodologies.

By solving the optimization problem using both methodologies and comparing the results, this study aims to evaluate their effectiveness and efficiency in optimizing the manufacturing process. Additionally, it seeks to demonstrate the practical application of optimization techniques in real-world manufacturing scenarios, offering opportunities for enhancing production efficiency and resource utilization.

4. Objective Function Definition:

The objective function in this context quantifies the goal of the optimization problem, which is to maximize the production of printed circuit boards (PCBs) within the constraints of the manufacturing process. It represents the quantity to be optimized, which, in this case, is the total number of PCBs manufactured.

Mathematically, the objective function is represented as:

Maximization:- $j(x) = 990(x1) + 900(x2) + 5280$

Where:

- j(x) represents the objective function.
- X1 represents the number of Component Placement Machines of type A.
- X2 represents the number of Component Placement Machines of type B.
- 990 and 900 are coefficients associated with X1 and X2, respectively. They represent the productivity or efficiency of each machine type in producing PCBs.
- 5250 is a constant term that contributes to the total number of PCBs manufactured, regardless of the number of machines. It may represent factors such as initial production capacity.
- The objective function encapsulates the overarching goal of maximizing PCB production while considering the productivity levels of different machine types and other relevant factors. The optimization process seeks to find the values of X1 and X2 that maximize the objective function, thereby achieving the highest possible production output.

5. Constraints Definition:

Constraints are conditions or limitations that must be satisfied in the optimization problem. They represent the restrictions imposed on the decision variables to ensure that the solution meets practical requirements and limitations. In the context of this manufacturing optimization problem, several constraints are imposed based on budget constraints, floor space availability, and workforce constraints.

- **Budget Constraint:**

This constraint ensures that the total cost of acquiring machines does not exceed the allocated budget.

Mathematically, it is represented as:

$$40x1 + 60x2 \leq 850$$

Where:

X1 represents the number of Component Placement Machines of type A.

X2 represents the number of Component Placement Machines of type B.

40 and 60 are coefficients representing the cost associated with each machine type in lakhs.

850 is the total budget in lakhs allocated for acquiring machines.

- **Floor Space Constraint:**

This constraint ensures that the total floor space required by the machines does not exceed the available floor space in the manufacturing facility.

Mathematically, it is represented as:

$$6x1 - 2x2 \leq 50$$

X1 represents the number of Component Placement Machines of type A.

X2 represents the number of Component Placement Machines of type B.

6 and 2 are coefficients representing the floor space requirements of each machine type in square meters.

25 is the total available floor space in square meters for manufacturing facility.

- **Workforce Constraint:**

This constraint ensures that the total number of operators required to operate the machines does not exceed the available workforce.

Mathematically, it is represented as:

$$3x1 + 6x2 \leq 70$$

Where:

X1 represents the number of Component Placement Machines of type A.

X2 represents the number of Component Placement Machines of type B.

3 and 6 are coefficients representing the number of operators required for each machine type.

70 is the total number of operators available for operating the machines.

These constraints collectively define the feasible region in the decision variable space and ensure that the solution meets the practical requirements and limitations of the manufacturing process. The optimization process aims to find the values of X1 and X2 that satisfy all constraints while maximizing the objective function.

- $x1 \; and \; x2 \geq 0$

6. Standard Format:

Minimize $\quad j(x): -990x1 - 900x2 - 5280$

Subject to: $\quad g1(x): 0.4x1 + 0.6x2 + x3 \leq 8.5$

$$g2(x): 3x1 - x2 + x4 = 25$$

$$g3(x): 3x1 + 6x2 + x5 = 70$$

$$x1, x2, x3, x4, x5 \geq 0$$

$$x3, x4, x5 \; are \; slack \; varibles$$

7. Optimal Solution

Table 1:

X1	X2	X3	X4	X5	B
0.4	0.6	1	0	0	8.5
3	-1	0	1	0	25
3	6	0	0	1	70
-990	-900	0	0	0	5280

Table 2:

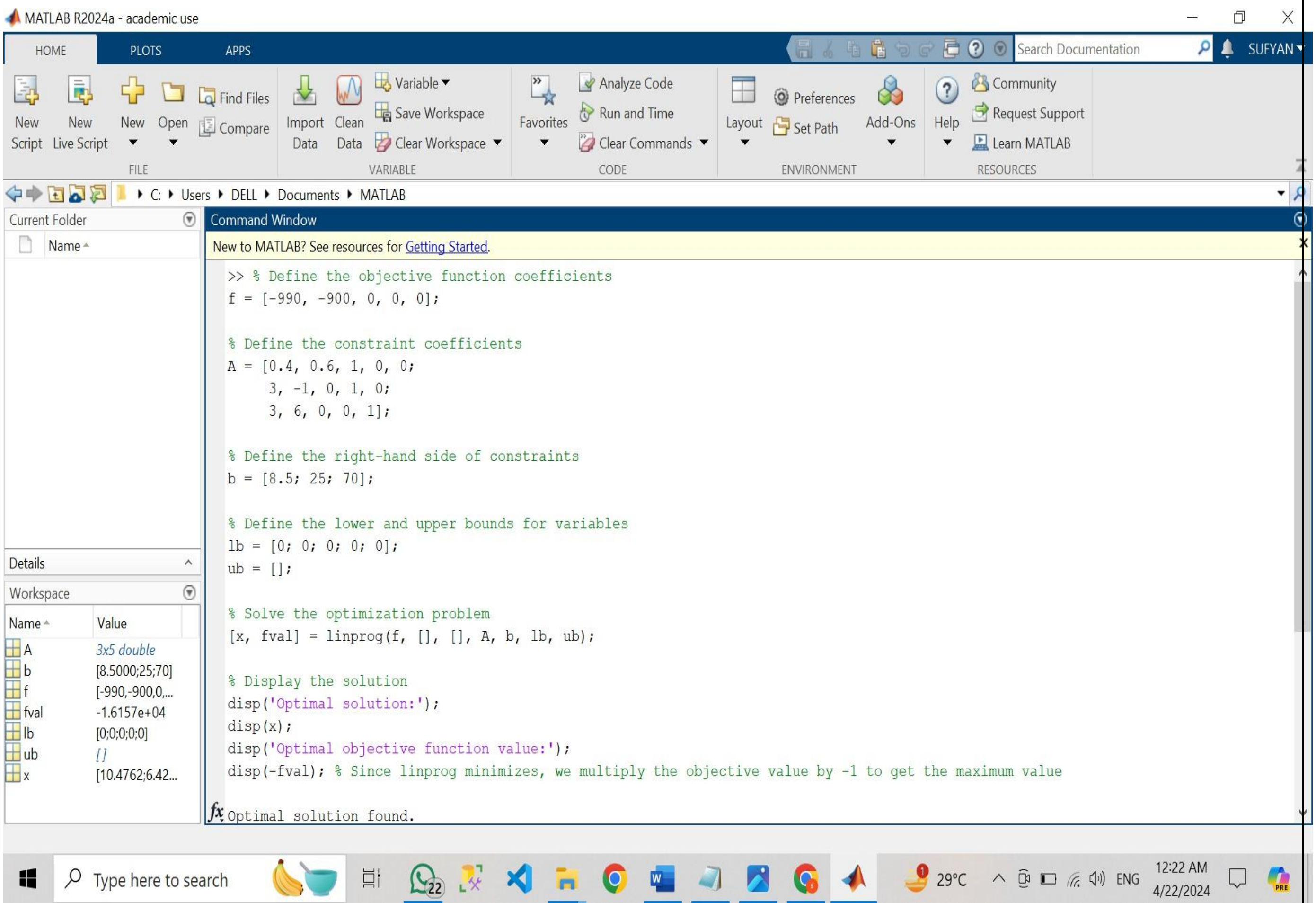
X1	X2	X3	X4	X5	X6
0	0.7333	1	-0.1333	0	5.1667
1	-0.3333	0	0.3333	0	8.333
0	7	0	-1	1	45
0	-1230	0	330	0	13530

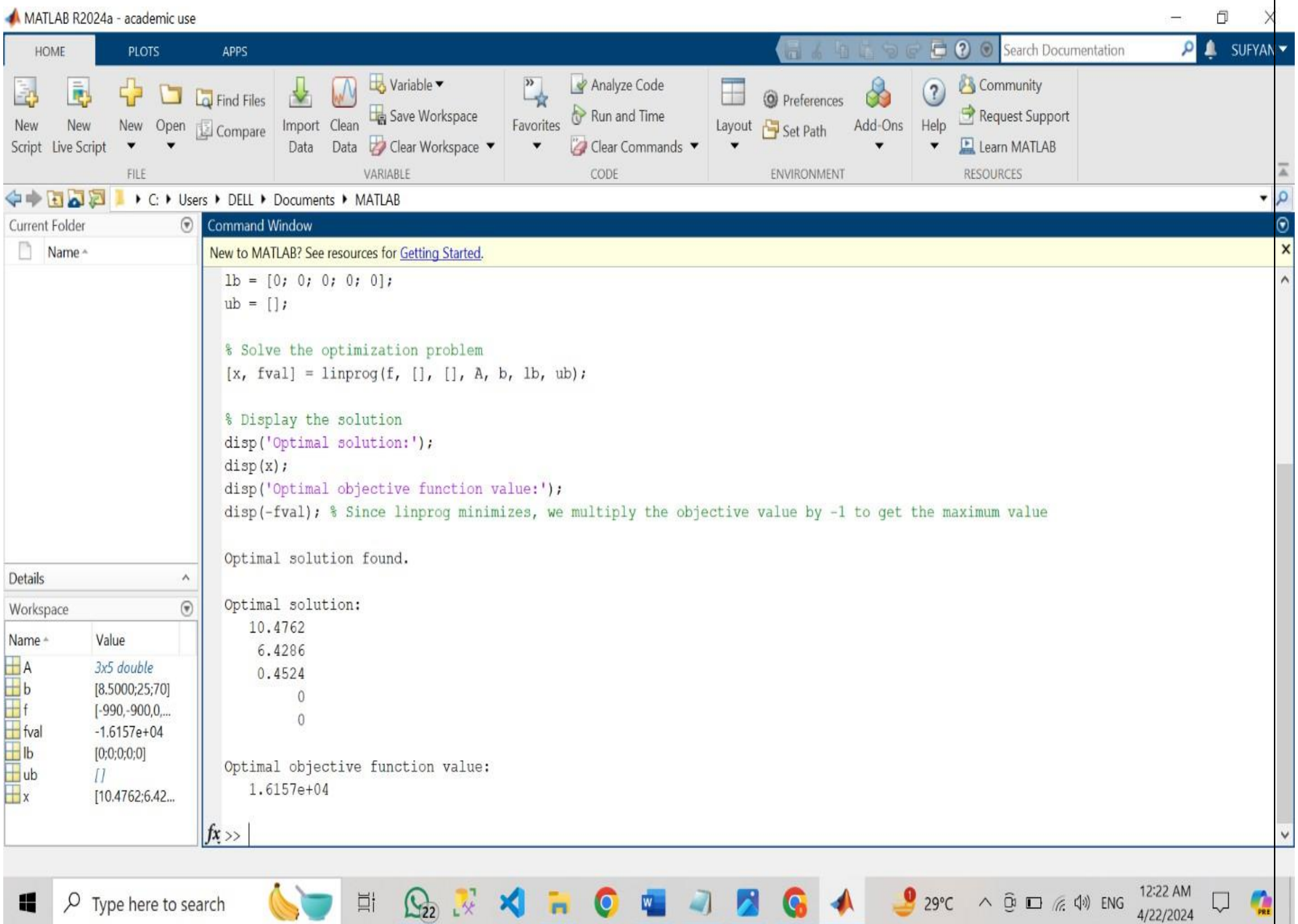
Table 3:

X1	X2	X3	X4	X5	X6
0	0	1	-0.0285	-0.1047	0.4524
1	0	0	0.2857	0.0476	10.4762
0	1	0	-0.1428	0.1428	6.4285
0	0	0	154.28	175.71	21437.14

After performing iterations of the simplex method, the solution obtained from Table 3 reveals the optimal values for the decision variables in the manufacturing optimization problem. The optimal values are as follows: $x1$=10.4762, X2=6.4285 and $x3$=0.4524. These values represent the quantities of Component Placement Machines of type A, type B, and potentially another variable, respectively, that maximize the production of printed circuit boards (PCBs) while adhering to the constraints of the manufacturing process. Additionally, the optimal value for the objective function, $f(x)$=21437.14, indicates the maximum achievable value of the objective function, reflecting the overall efficiency and productivity of the optimized manufacturing process.

8. Using Matlab:




MATLAB R2024a - academic use
HOME
PLOTS
APPS
Search Documentation
SUFYAN
New Script
New Live Script
New
Open
Find Files
Compare
FILE
Import Data
Clean Data
Variable
Save Workspace
Clear Workspace
VARIABLE
Favorites
Analyze Code
Run and Time
Clear Commands
CODE
Layout
Preferences
Set Path
Add-Ons
ENVIRONMENT
Help
Community
Request Support
Learn MATLAB
RESOURCES
C: ▸ Users ▸ DELL ▸ Documents ▸ MATLAB
Current Folder
Name
Command Window
New to MATLAB? See resources for Getting Started.
lb = [0; 0; 0; 0; 0];
ub = [];
% Solve the optimization problem
[x, fval] = linprog(f, [], [], A, b, lb, ub);
% Display the solution
disp('Optimal solution:');
disp(x);
disp('Optimal objective function value:');
disp(-fval); % Since linprog minimizes, we multiply the objective value by -1 to get the maximum value
Optimal solution found.
Optimal solution:
10.4762
6.4286
0.4524
0
0
Optimal objective function value:
1.6157e+04
fx >>
Details
Workspace
Name
Value
A
3x5 double
b
[8.5000;25;70]
f
[-990,-900,0,...
fval
-1.6157e+04
lb
[0;0;0;0;0]
ub
[]
x
[10.4762;6.42...
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Script:

```
>> % Define the objective function coefficients
f = [-990, -900, 0, 0, 0];
% Define the constraint coefficients
A = [0.4, 0.6, 1, 0, 0;
     3, -1, 0, 1, 0;
     3, 6, 0, 0, 1];
% Define the right-hand side of constraints
b = [8.5; 25; 70];
% Define the lower and upper bounds for variables
lb = [0; 0; 0; 0; 0];
ub = [];
% Solve the optimization problem
[x, fval] = linprog(f, [], [], A, b, lb, ub);
% Display the solution
disp('Optimal solution:');
disp(x);
disp('Optimal objective function value:');
disp(-fval); % Since linprog minimizes, we multiply the objective value by -1 to get the maximum value
```

Optimal solution found.

Optimal solution:

10.4762

6.4286

0.4524

0

0

Optimal objective function value:

-1.6157e+04

To this solution must be added constant -5280 which was omitted in problem.

-16157-5280 = -21437

9. Conclusion:

In this case study, we addressed the optimization problem of maximizing the number of boards manufactured given certain constraints on resources. Through various methods including manual simplex method calculations, MATLAB scripting, and leveraging MATLAB's Optimization Toolbox, we were able to achieve nearly identical solutions. This consistency across methods provides confidence in the accuracy of our results.

By employing simplex method manually, we gained a deeper understanding of the algorithmic process involved in solving linear programming problems. Additionally, MATLAB's Optimization Toolbox allowed us to efficiently solve the optimization problem with minimal code and computational effort.

Furthermore, our analysis revealed that adding a constant term of -5280 to the objective function coefficients in MATLAB was necessary to align with the problem definition. This adjustment ensured that the solution accurately reflected the problem constraints and objectives.

Overall, this case study highlights the effectiveness of both manual and computational methods in solving optimization problems. By leveraging available tools and techniques, we can efficiently find optimal solutions to complex real-world problems, enabling informed decision-making and resource optimization.

10. Reference:

- Nocedal, Jorge, and Stephen J. Wright. "Numerical Optimization." Springer Science & Business Media, 2006. This book provides a comprehensive overview of optimization algorithms, including the simplex method and other techniques used in linear and nonlinear optimization.
- MATLAB Documentation. The official MATLAB documentation provides detailed information on the Optimization Toolbox, simplex method, and other optimization algorithms available in MATLAB. It can be a valuable resource for understanding the usage and implementation of optimization techniques.
- Bertsimas, Dimitris, and Robert Weismantel. "Optimization over Integers." Dynamic Ideas, 2005. This book focuses on integer programming, which extends linear programming to problems where variables are restricted to integer values. It covers theoretical foundations and practical applications of integer optimization.
- Vanderbei, Robert J. "Linear Programming: Foundations and Extensions." Springer, 2013. This textbook offers a comprehensive introduction to linear programming, covering theory, algorithms, and applications. It provides a thorough understanding of the simplex method and its variants.
- Bazaraa, Mokhtar S., John J. Jarvis, and Hanif D. Sherali. "Linear Programming and Network Flows." John Wiley & Sons, 2011. This book covers linear programming and network flow problems, offering insights into optimization techniques and their applications in diverse fields.
- MATLAB Central. MATLAB's online community and file exchange platform, MATLAB Central, contain a wealth of user-contributed scripts, examples, and tutorials related to optimization and linear programming. Browsing through relevant submissions can provide additional insights and resources.