Determining optimal solution in an automatic filling system with two units A and B using Big M method and Python tool

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Abstract

During the second wave of Pandemic period, there was a logistic issue in production and distribution of vaccine, remdiviser medicine and Oxygen cylinder. The issue was somehow sorted out in due course with huge loss that reflected interms of high mortality rate. This paper, an attempt is made to calculate the optimal production of two different vaccine or medicine having the same production line. The optimal value is obtained using two different method named Big M method and optimization using linear programming in Python code. The optimization study revealed that a significant scheduling could be made iun producing the two different products with respect to the demand in market and the stock in hand for the current week. The experiment is done on the table top automatic production system having a conveyor belt and two units A and B in its production line. The kit is controlled by a PLC controller having the ladder logic diagram showing the constructed based on the sequence of operation.

Keywords: Ladder logic, Big M Method, PLC controller, optimal solution, python code

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1. Introduction

An automatic filling system with two units A and B attached with conveyer belt is designed and system is run with various trials of experiment. This system would be a replica of pharmaceutical industry (processing industry) where the vaccine or medicine is the product from the production line. During the last two years of pandemic period, it was really a tough situation for pharmaceutical industry like SERUM institute of India and Bharat Bio tech in optimal production of vaccine based on the demand in the market .In this paper an attempt is made to provide an optimal solution of each products based on the market demand in the current week. The linear programming method of determining optimal solution is made using the software python code and Big M tool. Adler et al [1] proposed a method with a family of simplex variables solving a linear program in expected number of pivot steps depending on d only.H.Arsham et al [2] proposed a push –pull solution strategy. H. Arsham,[3] presented Initialization of the simplex algorithm: An artificial-free approach. H. Arsham et al[4] defined Affine Geometric Method for Linear Programs. H. Arsham [5] discussed a comprehensive simplex-like algorithm for network optimization and perturbation analysis. Barnes etm al [6] discussed on the survey of general purpose algorithm. J. Camm, A. Raturi, and A. Tsubakitani [7] presented Cutting big-M down to sizes. Dantzig et al [8] proposed in making progress during a stall in the simplex algorithm. J. Forrest, and D. Goldfarb [9] presented edge simplex algorithm for linear programming. J. More, and S. Wright [10] discussed on Optimization Software Guide. D. Myers, [11] presented a dual simplex implementation of a constraint selection algorithm for linear programming.

K.Papparrizos [12] discussed the two phase simplex without artificial variables. A. Ravindran et al [13] mentioned a comparison of the primal-simplex and complementary pivot methods for linear programming. A. Sethi, and G. Thompson et al [14] discussed the pivot and probe algorithm for solving a linear program.

T.Terlaky, et al[15] suggested pivot rules for linear programming. H. Vieira Jr., and M. Lins et al [16] mentioned an improved initial basis for the simplex algorithm. William Hart w et al[17] suggested an innovative method python optimization modeling objects (Pyomo).

Ravindran, et al [18] proposed a comparison of the primal-simplex and complementary pivot methods for linear programming. R.Arumugam et. al (2019) [19] discussed Experimental Study for Determining Switching Frequency of Inductive Sensor Using PLC. R.Rakesh et. al {2020) [20] proposed the experimental study for determining switching frequency of retro reflector sensor using PLC based on the statistical study. R.Rakesh et. al (2021) [21] discussed the Experimental investigation of Switching Frequency of magnetic sensor Using Statistical approach.

2. Methods and materials

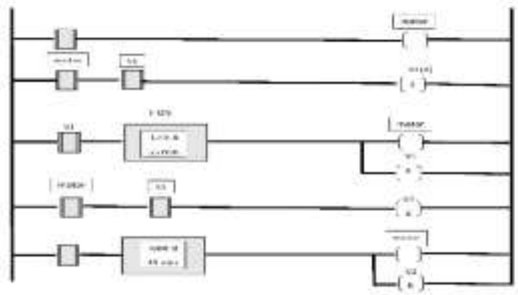
We are using PLC code for the automation of filling station through which the experiment data is collected and the analysis for optimization is done using Big M method and Python linear programming tool. This optimization will help in determining the production frequency of two different products from two different units of the automatic filling system based on the demand of the each product in market.

Automation Filling station

An automatic filling station(fig 1) is constructed which is controlled by PLC program(fig 2 &3) in the Controller. There are two sensors S1 and S2 in the conveyer belt (MHS) which is linked with tank A and tank B respectively. Initially the motor in the conveyer belt would be ON and hence the product on the belt reaches unit A which is detected by sensor S1, once S1 is ON, the motor of the conveyer belt turn OFF and the valve in Tank A opens for certain duration and the valve closes and motor turns ON, now it reaches S2 and the valve of Unit B opens ON for certain duration. This process is similar to product Y and the only difference is in the duration of valve opening in both unit A and B.

Figure 1: Automatic filling station having two units A and B

PLC code:



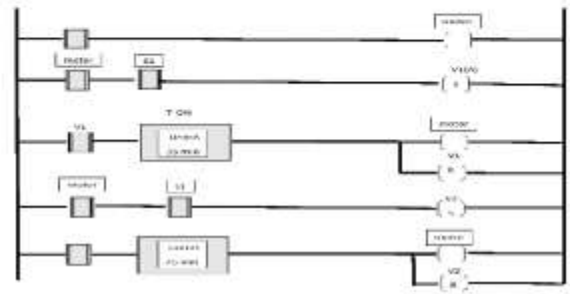


Figure 2: Product A **Figure 3: Product B**

3. Problem of the study

A company makes two products (X and Y) using two unit (A and B). Each unit of X that is produced requires 55 minutes processing time on unit A and 40 minutes processing time on unit B. Each unit of Y that is produced requires 30 minutes processing time on unit A and 43 minutes processing time on unit B.

At the start of the current week there are 60 units of X and 90 units of Y in stock. Available processing time on unit A is forecast to be 50 hours and on unit B is forecast to be 45 hours.

The demand for X in the current week is forecast to be 80 units and for Y is forecast to be 100 units. Company policy is to maximise the combined sum of the units of X and the units of Y in stock at the end of the week.

Formulate the problem of deciding how much of each product to make in the current week as a linear program. Solve this with linear program.

4. Analysis

From the experimental study ,the above problem is formulated .To do further analysis, we have to determine the number of variables in the objective equation of linear programming problem. The number of constraints and inequality condition is also determined from the above problem statement.

x = 55minA and 40minB y = 30minA and 43minB

Start 60X and 90Y

Limit A<=50hours B<=45hours

Let x be the number of units of X produced in the current week y be the number of units of Y produced in the current week then the constraints are:

55x + 30y <= 50(60) unit A time 40x + 43y <= 45(60) unit B time x >= 60 - 80 i.e. x >= 20 so production of X >= demand (80) - initial stock (60), which ensures we meet demand y >= 90 - 100 i.e. y >= 10 so production of Y >= demand (100) - initial stock (90), which ensures we meet demand (x+60-80) + (y+90-100) = (x+y-30)

4.1 Big M Method Calculator-Linear Programming

This Big M method plays a major role in the field of optimization, An online calculator for Big M linear programming method of determining optimum value is used in this experiment. Initially we need to feed the value of number of variables involved and what is the number of constraints applicable. The objective function and other constraints are defined as per the given problem. Once done, the calculator throws the optimum value based on the input given.

Big M Method
Edit Coefficients New Problem
Objective Function:
Maximize: $Z = 1X_1 + 1X_2$
Subject to:
$55X_1 + 30X_2 \leq 3000$
$40X_1 + 43X_2 \leq 2700$
$1X_1 + 0X_2 \leq 20$
$0X_1 + 1X_2 \leq 10$
$X_1, X_2 \geq 0$

The problem will be adapted to the standard linear programming model, adding the slack, surplus and / or artificial variables in each of the constraints:

- **Constraint 1:** It has a sign "≤" (less than or equal) so the slack variable will be added S_1.
- **Constraint 2:** It has a sign "≤" (less than or equal) so the slack variable will be added S_2.
- **Constraint 3:** It has a sign "≤" (less than or equal) so the slack variable will be added S_3.
- **Constraint 4:** It has a sign "≤" (less than or equal) so the slack variable will be added S_4.

The problem is shown below in standard form. The coefficient 0 (zero) will be placed where it corresponds to create our table:

Objective Function:
Maximize: $Z = 1X_1 + 1X_2 + 0S_1 + 0S_2 + 0S_3 + 0S_4$
Subject to:
$55X_1 + 30X_2 + 1S_1 + 0S_2 + 0S_3 + 0S_4 = 3000$
$40X_1 + 43X_2 + 0S_1 + 1S_2 + 0S_3 + 0S_4 = 2700$
$1X_1 + 0X_2 + 0S_1 + 0S_2 + 1S_3 + 0S_4 = 20$
$0X_1 + 1X_2 + 0S_1 + 0S_2 + 0S_3 + 1S_4 = 10$
$X_1, X_2, S_1, S_2, S_3, S_4 \geq 0$

Table 1: Initial Iteration:

Initial Table

Table 1	C_j	1	1	0	0	0	0	
C_b	Base	X_1	X_2	S_1	S_2	S_3	S_4	R
0	S_1	55	30	1	0	0	0	3000
0	S_2	40	43	0	1	0	0	2700
0	S_3		0	0	0	1	0	20
0	S_4	0	1	0	0	0	1	10
	Z	-1	-1	0	0	0	0	0

Enter the variable X_1 and the variable S_3 leaves the base. The pivot element is 1

Table 2: Iteration 1:

2	Cj	1	1	0	0	0	0	
Cb	Base	X_1	X_2	S_1	S_2	S_3	S_4	R
0	S_1	0	30	1	0	- 55	0	1900
0	S_2	0	43	0	1	- 40	0	1900
1	X_1	1	0	0	0	1	0	20
0	S_4	0		0	0	0	1	10
	Z	0	-1	0	0	1	0	20

Enter the variable **X_2** and the variable **S_4** leaves the base. The pivot element is **1**

Table 3 Iteration 2:

Iteration 2

Table 3	Cj	1	1	0	0	0	0	
Cb	Base	X_1	X_2	S_1	S_2	S_3	S_4	R
0	S_1	0	0	1	0	-55	-30	1600
0	S_2	0	0	0	1	-40	-43	1470
1	X_1	1	0	0	0	1	0	20
1	X_2	0	1	0	0	0	1	10
	Z	0	0	0	0	1	1	30

The optimal solution is Z = 30

X_1= 20, X_2= 10, S_1= 1600, S_2= 1470, S_3= 0, S_4= 0

4.2 Python Coding and Result

One of the successful tool to determine linear optimization is by using python code. The python code has various inbuilt functions which minimize the number of lines of code and also it can be easily executed with online complier.

Python Code:

```
import pulp
# Define Variables
X = pulp.LpVariable('X',lowBound=0)
Y = pulp.LpVariable('Y',lowBound=0)
# Objective Fxns
m = pulp.LpProblem("Maximum Profit",pulp.LpMaximize)
m += X+Y-30
# Constraints
m += 55*X + 30*Y <= 50*60
m += 40*X + 43*Y <= 45*60
m += X >= 80 - 60
m += Y >= 100 - 90
# Check Our Problem
print(m)
# Get the status
pulp.LpStatus[m.status]
'Not Solved'
# Solve
m.solve()
# Get the status
pulp.LpStatus[m.status]
'Optimal'
# Find the Optimal Variables/Optimal Solution Points
for var in m.variables():
print(var.name,"=>",var.varValue)
# Alternatively
print(X.varValue)
print(Y.varValue)
# What you get when you plug in the X,Y into our objective function
pulp.value(m.objective)
```


Output:-

```
Maximum_Profit:
MAXIMIZE
1*X + 1*Y + -30
SUBJECT TO
_C1: 55 X + 30 Y <= 3000

_C2: 40 X + 43 Y <= 2700

_C3: X <= 20

_C4: Y <= 10
```

```
VARIABLES
X Continuous
Y Continuous

X => 20.0
Y => 10.0
20.0
10.0
Out[2]:0.0
```


5. Discussion and Result

In both Big M method and python code method ,it is clearly illustrated that the optimal value of X product should be 20 and optimal value of Y product should be 10 in order to meet the demand in market for the current week as per the given problem. Both the method has arrived at same value and hence justified to go ahead with that number of production for the current week

6. Conclusion

This study reveals that the optimization tool using python code and Big M method can be used to determine the optimal production of two different products having the same production line .The optimization plays a vital role when there is defined demand and time as a constraint. The experiment is made with the help of an automatic filling station table top kit in lab which is completely controlled by ladder logic using PLC. Finally a comparison is made between the solution from Big M method and linear programming using Python code and it is proven that the optimal value obtained by both the method is same.

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