Title: Optimization Profit of the Shenandoah Valley Textile Mill Case

Course:
Year: 1990
Author(s): A. Pagliero, P. Wibowo and M. Inceoglu

Report No: P90008

Abstract: We examined the problem of optimizing profit for production of 7 different cotton cloth styles. The process of operation was divided into 12 processes. Those are desizing, boiling, dyeing, calendaring, etc. which then are formulated as Linear Programming Model to generate optimum profit. Several constraints are applied, such as demand constraint, and machine capacity in terms of process hours, and cost.

OPTIMIZATION PROFIT OF THE SHENANDOAH
VALLEY TEXTILE MILLE CASE

A. Pagliero, P. Wibowo, and M. Inceoglu

EMP - P9008

OPTIMIZATION PROFIT OF THE SHENANDOAH VALLEY TEXTILE MILL CASE

EMGT 543 - SPRING 1990

by.

Agnes Pagliero
Philipus G. Wibowo
Murat Inceoglu

PORTLAND STATE UNIVERSITY
June 4, 1990

ABSTRACT

This project has examined the problem of optimization profit for production of 7 different cotton cloth styles. The process of operation will be divided into 12 processes. Those are desizing, boiling, dyeing, calendering, etc. which then will be formulated as a Linear Programming to generate optimum profit. Several constraints will be applied such as demand constraint which will be set, machine capacity in term of process hours, and cost.

TABLE OF CONTENTS

I. INTRODUCTION

To produce a finished cloth from rough and an unfinished cotton cloth, many processes should be used. This finishing phase operations may be divided into three major groups; preparatory, color and finishing. Preparatory operations include laying out, singeing, desizing, kier boiling, bleaching and drying. In coloring operations include printing and dyeing, while finishing operations include starching, shrinking, calendering and napping process.

In this project, seven different styles of cotton cloth are recommended to be produced as suggested by the Marketing research department of The Shenandoah Valley Textile Mill. Those are Bleached style, four styles of Printed cloth and two Dyed styles, blue and red. The company is also committed by a contract to produce at least 5,000 yards of each printed styles. but the sale department has estimated that the maximum possible sales of two printed styles will be 100,000 yards and 50,000 yards.

There are some assumptions and limitation involved here, in the modeling process. If the mill produces at its maximum capacity, it is certain that there will be excess capacity in at least 6 of its operations; laying out, napping, shrinking, putting-up, shading and packing. Hence, these operations are assumed to be neither restrictive nor critical and therefore may be omitted from further consideration. Only eleven processes will be considered in the operation to produce all types of products. Those are; Singeing, Desizing, Kier Boiling, Bleaching, Drying, Mercerizing, Printing, Ageing, Dyeing, Starching and Calendering.

Printing and Ageing processes will be applied only to printed styles cloth. The process of Mercerizing is separated for each type of cloths. For Dyed cloths, Dyeing process is needed but for others is not. All processes are in term of process-hours capacity due to each process machine. Breakdown, maintenance, cleaning, etc. are assumed have been included in the machine process-hours.

II. MODEL DESCRIPTION

In defining a model for this problem, 7 variables are used as defined in the beginning. They are bleached style, 4 printed styles and 2 dyed styles (blue and red).

The constraints are divided into 2 groups; demand restraints, and process restraints. The demand restraints/constraints are represented by 6 equations while the process restraints/constraints are represented by 14 equations.

Seven types of finished cloth:

$x1$ - number of yards of bleached style produced

$x2$ - number of yards of printed style #1 produced

$x3$ - number of yards of printed style #2 produced

$x4$ - number of yards of printed style #3 produced

$x5$ - number of yards of printed style #4 produced

$x6$ - number of yards of blue dyed style produced

$x7$ - number of yards of red dyed style produced

The management of Shenandoah Valley Textile Mill assigned a task to maximize profit. To determine the most profitable production schedule, the management has set the contributions to profit and overhead per yard for each style as follows:

Style	Profitability
x1	$0.40
x2	0.60
x3	0.80
x4	1.00
x5	1.25
x6	1.20
x7	1.30

The process restraints for productions consist of 11 restrictions. These rates of production are expressed in yard per hour. Those restrictions are:

Process	styles						
	x1	x2	x3	x4	x5	x6	x7
Singeing	9,000	6,000	9,000	7,000	8,000	9,000	8,000
Desizing	13,000	10,000	9,000	11,000	8,000	13,000	12,000
Kier Boiling	1,500	900	1,000	800	900	1,300	1,200
Bleaching	1,000	1,100	1,050	1,100	1,100	1,100	1,200
Drying	13,000	10,000	10,000	12,000	11,000	11,000	12,000
Mercerizing	800	550	600	650	700	700	800
Printing	--	300	300	200	250	--	--
Ageing	--	5,000	4,000	4,000	6,000	--	--
Dyeing (blue)	--	--	--	--	--	4,000	--
Dyeing (red)	--	--	--	--	--	--	3,500
Starching	2,000	1,800	1,800	1,600	1,500	2,000	1,500
Calendering	4,000	5,000	3,000	2,500	4,000	3,200	3,500

The maximum number of process-hours that will be available for each critical operations above are shown below. All process-hours have been made for breakdowns, maintenance, cleaning, etc.

Process	Capacity (process-hours)
Singeing	150
Desizing	150
Kier Boiling	900
Bleaching	1,500
Drying	140
Mercerizing	
(bleached)	830
(printed)	830
(dyed)	830
Printing	1,800
Ageing	150
Dyeing	
(blue)	150
(red)	140
Starching	500
Calendering	450

III. MODEL FORMULATION

* Objective function

MAX (z): 0.4x1 + 0.6x2 + 0.8x3 + 1.0x4 + 1.25x5 + 1.2x6 + 1.3x7

* Constraints

There are twenty constraints can be generated for this model. Fourteen constraints are process restraints and six constraints are demand restraints. constraints

\- Process constraints:

1. 0.11x1 + 0.17x2 + 0.11x3 + 0.14X4 + 0.13x5 + 0.11x6 + 0.13x7 <= 150,000

2. 0.08x1 + 0.10x2 + 0.11x3 + 0.09x4 + 0.13x5 + 0.08x6 + 0.08x7 <= 150,000

3. 0.67x1 + 1.11x2 + 1.00x3 + 1.25x4 + 1.11x5 + 0.77x6 + 0.83x7 <= 900,000

4. 1.00x1 + 0.91x2 + 0.95x3 + 0.91x4 + 0.91x5 + 0.91x6 + 0.83x7 <= 1,500,000

5. 0.08x1 + 0.10x2 + 0.10x3 + 0.08x4 + 0.09x5 + 0.09x6 + 0.08x7 <= 140,000

6. 1.25x1 <=830,000

7. 1.82x2 + 1.67x3 + 1.54x4 + 1.43x5 <= 830,000

8. 1.43x6 + 1.25x7 <= 830,000

9. 3.33x2 + 3.33x3 + 5.00x4 + 4.00x5 <=1,800,000

10. 0.20x2 + 0.25x3 + 0.25x4 + 0.17x5 <= 150,000

11. 0.25x6 <= 150,000

12. 0.29x7 <= 140,000

13. 0.50x1 + 0.56x2 + 0.56x3 + 0.63x4 + 0.67x5 + 0.5x6 + 0.67x7 <= 500,000

14. 0.25x1 + 0.20x2 + 0.33x3 + 0.40x4 + 0.25x5 + 0.31x6 + 0.29x7 <= 450,000

- Demand constraints:

1. x2 >= 5,000
2. x3 >= 5,000
3. x4 >= 5,000
4. x5 >= 5,000
5. x4 <= 100,000
6. x5 <= 50,000

IV. SENSITIVITY ANALYSIS

Optimal Solution: (changes in Cj not in the basic solution, x1 and x7). We see that two variables are equal to zero (they are not in the basic solution); x1 (bleached style) and x7 (red dyed style). We also see from the reduced cost that 1 yard of x1 introduced in this optimal solution would reduce the profit by \$0.314286 and 1 yard of x7 would reduce the profit by \$0.081718 .

We know from the sensitivity analysis performed by LINDO that ΔC1 can be as: -INFINITY <= Δc1 <= 0.314286

or c1: -INFINITY <= c1 <= 0.714286

without a change in the basic solution.

For x7, we have: -INFINITY <= Δc7 <= 0.081718

or c7: -INFINITY <= c7 <= 1.381718

For those two variables, we can decrease the profit by an infinite amount without changing the basic solution. This is understandable since we try to maximize profit; therefore, decreasing those two profits (c1 and c7) will not increase the total profit, or the contrary. That's why x1 and x7 are still not being produced.

Let's see the impact of a change above those interval on the solution and on the profit. We changed c1 from 0.4 to 0.8 (double), then the number of unit (yard) of x1 produced is not longer equal to zero, but 335080.4 . The profit is now equal to 1039068.00 which is a 1.9% increase in profit for a 100% increase in c1.

Let's consider the example of x7. Changes in c7 from 1.3 to 1.4 (increase of 7.7%), the number of x7 produced is no more equal to zero and the profit increases to 1,028,299.00 (0.8% increase). If we try to change c7 to 1.5 (15% increase), the profit will be 1,076,192.00 (5.5% increase) and if we increase c7 to 1.6 or 23% increase, the profit will increase to 1,124,468.00 (or 10.25% increase).

Conclusion: we saw that for x1, the increase on the profit (c1) should be extremely important to have an impact on the total profit. Under the given constraints, the production of x1 should therefore not be considered.

For x7, the sensitivity of the total profit about a change in c7 is very high (i.e. a small change in c7 gives a noticeable increase in the profit). Therefore, if the company has the possibility to renegotiate the price of x7 with his customer, it could be very profitable.

Change of Cj in the basic solution (x2, x3, x4, x5, x6)
From the LINDO sensitivity analysis, we have:

INFINITY $\leq \Delta c2 \leq$ 0.2	INFINITY $\leq c2 \leq$ 0.8
0.196458 $\leq \Delta c3 \leq$ 0.88889	0.88889 $\leq c3 \leq$ 0.996458
0.1 $\leq \Delta c4 \leq$ INFINITY	1.1 $\leq c4 \leq$ INFINITY
0.292857 $\leq \Delta c5 \leq$ INFINITY	2.542857 $\leq c5 \leq$ INFINITY
0.093486 $\leq \Delta c6 \leq$ INFINITY	1.293486 $\leq c6 \leq$ INFINITY

For variable x2, we can decrease c2 of an infinite amount without changing its production number. This is understandable since, with the actual profit (c2=0.6) we already produce the minimum amount required by the constraint. If we increase c2 by an amount more than 0.2, we will change the production number. The basic solution will stay the same even we change c2 from 0.6 to 0.85 (Δc2=0.25), but the value of x2 will increase to 197,303.9 against 5,000. The profit will also increase by 1% that is 1,030,712.00 . If c2 is changed to 0.9 (5% increase), x2 value become 304,178 and the profit will be 1,041,765.00 (21% increase), basic solution is not changed. The conclusion is, profit is not very sensitive on the production of x2.

For variable x3, if we changed the coefficient c3 from 0.8 to 0.6 (Δc3=-25%), basic solution is changed (x7 are now produced). The production of x3 is reduced to its strict required minimum, which is 5,000 because its no more very interesting to produce it. The profit itself, if we do this changes, it will be 981,067.10 or 3.8% decrease. Changes of c3 from 0.8 to 0.9 (12.5% increase), the basic solution is not changed, the profit will be 1,040,765 , which is 2% increased. The change of c3 from 0.8 to 1.0 (25% increase) and basic solution is not changed, the profit will be 1,071,183 or 5% increase.

Conclusion for c3 and x3: sensitivity much higher for an increase than a decrease. A decrease in profit is harmful for the total profit because we are still required to produce a minimal amount of 5,000 x3, therefore, we can't totally eliminate it from the solution.

For coefficient c4 for variable x4, we can increase it by an infinite amount without changing the basic solution. This is understandable since we already produce the maximum amount demanded by customers (100,000 units). We can decrease the profit by 0.1

without changing the basic solution.

If we change c4 to 0.8 (Δc4=-0.2 or 20% decrease), the basic solution is not modified, the production of x4 is reduced to 5,000 (minimum requirement) and the production of x3 is increased. The profit will be 1,009,347 or 1% decrease.

For variable x5, we can increase c5 by an infinite amount since the production of x5 is already maximum according to the demand (50,000). A decrease in c5 from 1.25 to 0.95 (24% decrease), the basic solution isn't changed; the amount of x5 will be reduced to 5,000 (minimum requirement) and the production of x3 increases by 27%. Profit is not very sensitive to these changes (profit will be 1,005,168.00 or decrease by 1.44%).

Variable x6, we can increase the profit of x6 by an infinite amount without changing the basic solution. This is understandable since we already produce in amount close to 600,000 or maximum requirement, but we see that a very small decrease (0.093406) will make the basis vary.

The change of c6 to 1.1 (Δc6=9% decrease), doesn't change the basic solution, production of x6 decreases by 69% and production of x7 increases from 0 to 462,314.60 . Profit will be 964,437.30 or 5.4% decrease.

Conclusion: for the basic variables, we saw that the most sensitive coefficient is the profit made on x6 (blue dyed style), therefore, the profit on x6 must be watched carefully by managers and should not decrease by a large amount.

V. RIGHT-HAND SIDES (RHS)

For all the 20 constraints, LINDO Right-Hand Side ranges give the interval in which the RHS can be without a change. The highest dual price is for constraint #14 (1.428571), this means that the total profit will decrease of 1.428571 if one unit of the available resource is not available anymore.

Constraint #14 corresponds to the limitation in process-hours for starching. From the data concerning product rate, we can see that the two fabrics using the most hours for this process are x5 (printed style #4) and x7 (red dyed style) with 1/1,500 hr/yard, then comes x4 (printed style #3), x3 (printed style #2) and x2 (printed style #1), and follow by x1 (bleached style) and x7 (blue dyed style).

From the LINDO Sensitive Analysis, we have:

39,044.88 >= ΔRhS >= 107,690.20 or

392,309.00 <= RhS <= 539,044.88

without a change in the basis.

V.1. CHANGES IN THE RIGHT-HAND SIDES

From 500,000 to 540,000 (increase in process-hours), when we increase the number of hours by 40 hr/week, the basis is changed (introducing x7), the profit is $1,076,452.00 (5.5%) increase and the reduced cost is now 0.865230 which is understandable since we made more hours available, therefore, the constraint is less critical.

If RHS is equal to 550,000, the profit will be $1,085,104.00

or 6.6% increase. The dual price is still $0.865230. If RHS is changed to 392,230 (108 hours/week less), the basis is unchanged. The dual cost is increased because less hours are available (1.587302). Profit will be 865,876.9 or 15% decrease.

If RHS is 450,000 (decrease of 50 hr/week), basis is unchanged, reduced cost will also unchange but profit will be decreasing by 7% or $948,418.00 . If RHS is changed to 480,000 or 20 hr/week decrease), the profit will be $991,275.3 or 3% decrease and the rest is unchanged.

The second most critical constraint to study is constraint #9 with a dual price 0.339660 .

$205,047.1 <= \Delta RHS <= 27,999.97$

We can increase it by 28 hr/week and decrease it by 205 hr/week without changing the basic solution. Constraint #9 corresponds to the dyed process, therefore, it limits the product of x6 and x7 (most profitable fabrics).

If RHS is decrease to 820,000 , the profit will be $1,016,450.00 or 0.3% decrease and the basis is unchanged. If RHS is 600,000, the profit will be $938,664 or 8% decrease and x7 will be introduced in the basic solution, dual prices are changed.

VI. CONCLUSION

The use of Linear Programming is a powerful way to allocate resources. Although this model may not be used as an absolute solution ~~but~~, it can provide the decision makers with valuable information as to know how the optimal solution can change, given a change in the coefficients of the problems.

Obviously, the model do not represent the real world situation. The calculation and the resulting conclusions of this problem are obtained based on the assumption only. All the constraints are set by using the management instuition to reach their targets, but the ability of LINDO program to change the coefficient is greatly helpful to the managers for making a decision in order to optimize their targets.

Sensitivity analysis can also be used to determine how critical estimates of coefficient are in the formulation of linear programming. By changing the coefficient of each variable, we can test the model to find the optimal solution. The trend of the objective function can be analyzed by playing around the number of the coefficient, but reliable and logical estimations are necessary.

Another aspect of sensitivity analysis is concerned with changes in the Right-Hand Side values of the constraints. The change of Right-Hand Side value may affect the feasible region and perhaps cause a change in the optimal solution. This is understandable, since the change of RHS value may decrease or increase the resource availability, which may affect the optimal solution of the problem although it depends on the level of critical constraints.