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Production Planning of LCDs: Optimal Linear Programming and Sensitivity Analysis

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Abstract

Aim: This research takes into the production of Flat Panel Monitor of four sizes and will point more the products that contribute the main function of profit. Methodology: For the optimization of the profit of LCDs manufacturing company, the linear programming and sensitivity analysis methods were applied. The four constraints of the LCDs production planning are (1) acquire of line space for production, (2) the assembly of products, (3) Quality control and assurance Hours (4) and packaging of material. Results: In all three scenarios the total profit is optimum and increases from scenario 1 to scenario 3. The difference between the profit of scenario 1 and scenario 2 is 257625, and gap between scenario 2 and scenario 3 is 171750. Conclusion: the three scenarios for the production of the LCDs present the varying consequences of the maximum profit for the company. However, the third scenario is the most optimal solution for the maximization of the objective function.

Keywords: Production Planning, Linear Programming, Sensitivity Analysis, Simplex Method, Operations Research, LCD Monitor.

1. Introduction

Linear programming (LP) played crucial role to solve the problem and as a tool for analysis. Various problems have been addressed by the researchers by using the linear programming. Linear programming is used both in academic institutions for students' learning and researchers to assist them in investigation of building models, problem solving and also analysing the outputs (Higle & Wallace, 2003). Linear programming is also used for the optimized allocation for the scares resources in order to get maximum profit. The linear programming has been effectively applied in diverse fields of the telecommunication, transportation, production, energy, blending, networks flows and airline crew scheduling (as cited in Khan, Bajuri and Jadoon 2011, p. 206). This research takes into the production of Flat Panel Monitor of four sizes and will point more the products that contribute the main function of profit. The method will be used to get maximum utilization of resources of the problem Flat Panel Monitor. The happening of some bottlenecks is also possible because the demand for the products may exceed from the production.

2. Literature Review

Linear programming is the hallmark emerged from the research work in management sciences and operations research. Its applications are used in various field of life i.e. production and management. Numerical data makes the base for the linear programming, which also determines the rough estimation of the values. In other ways the estimation of the rough values is difficult. Linear programming model based work also includes the post optimal solution and effects when data changes for the solution (Higle & Wallace, 2003).

Evidence from art literature showed numerous researches on the approach of linear programming and sensitivity analysis. Koltai and Terlaki (2000) observed three types of sensitivity analysis may occur through the interpretation of software results by the management decisions in the production planning. Type I sensitivity analysis arises when the form of optimal basis reflect the particular optimal basis solution in all commercial software. Type II sensitivity analysis is separated from the optimal basis solution produced. Type III sensitivity separated from Type I & II and relies on the problem data. Those three types of sensitivity arise when the LP is degenerated. So the managerial interpretation is different than mathematical interpretation and my lead to money losses and damaged plan because of the misunderstanding of shadow price. While, on the other hand, Filippi (2005) observed the tolerance approach to sensitivity analysis in linear programming. This fresh view led to introduce a geometric algorithm to have better individual tolerance that corresponding tolerance regions are maximal in regard to inclusion. This geometric, in normal manner, address the priori information on the coefficient perturbations. Ishikawa, Inoguchi, Yang and Chang (2007) also emphasized on the production of the flat panel displays and consumers attracted the new products with advance applications. They analysed the future growth and anticipation of display technologies for the production of flat panel displays. More than 98% flat display panels are manufactured in the region of East Asia with collaboration of other countries not necessarily of the same region. Taiwan, China, Republic of Korea and Japan are well known names for Flat panel display monitors while demand/supply side include North America, Europe and rest of the world. Reis, Paiva, Moutinho and Marques (2010) presented the genetic algorithm for the solution of production problem and founded that GA had given very close final value to other method of Sensitivity analysis. However, the sensitivity analysis proved to be crucial for exact problem understanding and also adjusting the algorithms of genetic algorithm. Instead of Genetic Algorithm, Khan, Bajuri and Jadoon (2011) used linear programming techniques and sensitivity analysis for the maximum profit in the products of ICI Pakistan. The linear programming was applied to different products and they predicted that Soda Ash products showed more profit upon the application of LP. The results of sensitivity analysis revealed that ICI could save the profits on the Soda Ash products. Data management for the construction of linear programming is a challenge for researchers. Uncertainty is often found in the planning of the linear programming models. Change in values, function objectives (profit) in the specified ranges are determined by the use of sensitivity analysis. Decision making also required before the removal of all uncertainties. The decision making is basically focused in production planning including as maximum profit, resource allocation, production of items, and selling of each produced items. Imam and Hassan (2009) used the model of linear programming for the production and considered that model did not tackle these issues separately. Researchers often faced the issues of uncertainty in data accuracy and used the SA to see the impacts when different data was used. Higle and Wallace (2003) used the linear programming model for maximum profit output. Valid criticism on their model for the objective function was that expected value was the linear one and hence losses and gains and cancelled each other. Demands varied as low, high and medium and it became difficult to distinguish between three alternatives. However, the linear approximation for these issues can be developed. Economic developments of counties depend upon the economic planning due to vital tools of quantification. According to Can and Ozluer (2012) the linear programming is an efficient and convenient method, which is used in the widespread manners. Economic planning includes the resources distributions, labour usage and maximum production capacity. The objective function achievement is passed through various types of restrictions such as balance between demand of labour and available labour, and also the balance between production level and production capacity.

3. Methodology

For the optimization of the profit of LCDs manufacturing company, the linear programming and Sensitivity analysis methods were applied. According to Andrea and Adrian, (2012) the linear programming is used to attain the best outcome or maximum profit. Research objective of the study include as planning of production of LCDs of 19", 20", 22" and 23". The production planning for the four sized LCDs will be achieved through meeting the customers; demands and also profit optimization for the company as prescribed by Abbasi and Sahir (2010). The methodology part of the study will also look into LCDs production variables including the constraints. According to Postolache (2007) constraints are the non negative, and only interested in the positive values. The four constraints of the LCDs production planning are too pointed in the later part of the study. However, it will be helpful to list them in the methodology part as (1) acquire of Panel Meter of LCD for production, (2) the assembly of products, (3) Quality control and assurance Hours (4) and packaging of material.

4. Discussion and Results

4. 1 Formulation of Linear Programming and Sensitivity Analysis problems for the Production Planning of Flat Screen Monitors

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Before the formulation of the linear programming problems the necessary procedures are essential as stated by Kareemm and Aderoba (2008) which include the decision variables, constraints of the problem and optimization of the objective function.

The process of production planning for FSM consists of the following three stages.

(1). Manufacturing of products (FSM)

(2). Preparation for Marketing Data & Alternatives of selling

(3). Formulation of Production plan

Model of LP is used for the optimization of the Flat Screen Monitors' production and their sale under the constraints of the manufacturing for maximization of profit.

4.2 Production planning of LCDs and formulation of Linear Programming

The linear programming concerns the optimization of the (min/ max) of the variable with linear function which are constrained by the linear relations. Linear equalities and inequalities are subject to LP optimization for the function of a linear objective. The maximization model for the production model is given as.

Maximize $Z = C1X1 + C2X2$ ....$+CnXn$ (1)

This is subject to

$a11\ X1 + a12\ X2 +$........................$+a1n\ Xn \leq r1$ (2)

$a21\ X1 + a22\ X2+$........................$a2n\ Xn \leq r2$ (3)

$am1\ X1 + am2\ X2+ +$ ……. $+ amn\ n \leq rm$ (4)

And

$xj \geq 0$ (5)

$j = 1, 2, 3$ ….n; $i = 1, 2$… m

where equation (1) is the objective function that signs for the profit of maximum selling of products, Xj shows the variable choice, Cj is the coefficient used for measurement of the selected variable for the objective function (profit).

ri is the restriction posed on the problem, aij is the coefficient used for the measurement of constraints on the given variable.

This problem will be solved by using the manual work that provides the information about linear programming.

1. Optimal value for the objective function (profit).
2. Optimal ranges for objective function. The optimal range provides information about the solution that is optimal.
3. Decision variables for optimal values and reduced costs.
4. Information about surplus or slacks, and improvement in the value of optimal solution.
5. Range in Right hand side presents the range which is for dual price. As the Right hand side increases, the value of other constraints increases and will limit the change for the objective function value.

4.3 Production Planning for Flat Panel Displays

The firm for producing the Monitors is resourceful to manufacture the electronic equipments. Now the firm is involved to produce the Flat panel monitors of sizes 19", 20", 22", and 23". Manufacturing of each size item requires the resources such as panel meter of LCD for production, and skilled labours for the assembly of components, quality assurance and packaging the product. Every resource for the production varies in cost. The constraints and demands for the production of Flat panel Monitors are given in the table 1

Resource	**Cost in US dollars**	**Requirements for LCDs Production**	

		19"	20"	22"	23"
LCD (panel meter) for production	15	1	1	1	1
Assembly	25	2	2	2.5	2.5
Quality control and assurance Hours	30	0.5	0.5	1	1
Packaging of product in Hours	15	1	1	1.5	1.5
Demand for production		10000	8000	5000	11000

Table 1: Company's data for manufacturing the Monitors

From table 1 the production estimation for each product of monitor is possible with required resources for the production of Flat panel Monitors of four sizes. The profit analysis per item is identified to be 40% of the selling price. For instance: a) the 19" LCD selling price is $120; b) the 20" LCD selling price is $150; c) the 22" LCD selling price is $180; e) and the 23" LCD selling price is $200. All sized LCD's are profitable profit in the sale of each sized product. For the maximization of profit, the firm should manufacture as many LCDs as it can sell on the production constraints. Resources required for the manufacturing of LCDs of all four sized are given in the Table 2.

Required Resources	**Manufacturing requirements for LCDs Production**				**Total Resources**	**Constraints for production resources**
	19"	**20"**	**22"**	**23"**		
LCD (panel meter) for production	10000	8000	5000	11000	34000	100%
Assembly	20000	16000	12500	27500	76000	100%
Quality control and assurance Hours	5000	4000	5000	11000	25000	100%
Packaging of product in Hours	10000	8000	7500	16000	41500	100%
Total Resources	45000	36000	30000	65500	176500	100%

Table2. Total resources for production

Total resources are as 176500, and profit anticipation for the four size LCD Monitors can be measured as following.

i. The maximum profit from selling of 10,000, 8000, 5000 and 11000 LCD is calculated in later part of the paper

4.4 Linear Programming and Sensitivity Models for Production Planning

Production planning is used to address the decisions as given in the following.

a) What is the value of the maximum profit?

b) What is the resources value it acquired?

c) What is the number of products manufactured from it?

d) What is the number of products that should sell it?

These issues cannot be considered separately as the JIT philosophy of production relates with selling and adheres that manufactured products are sold one and require the resources for the production. Thus the production of new LCD Monitors is begins automatically when stock of product has less than 10% of the items. Association between resources, production and selling of product is shown in the following figure of the decision sequence.

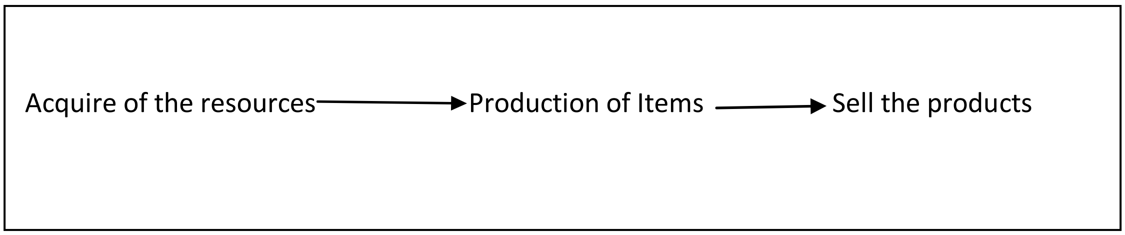

Figure 1: Decision Sequence

On the basis of this decision queue the model is also derived as following

Acquire

Produce

Sell

These correspondences between resources acquire product production and product selling shows that LCD monitors manufacturing company faces the three closely related decisions. This model show that how much resources required producing the LCD Monitors Products, and also the number of products to sell them.

4.4.1 Problem Model for Linear Programming

Structural advantages are exploited by the LP model and analysis to avoid the costly errors. Decisions are taken sequentially over the time in a real world. The production problem of LCD Monitors is straightforward.

Let consider the following variables and parameters:

$P_{19"LCD}$ = the number of 19" LCD to produce

$P_{20"LCD}$ = the number of 20" LCD to produce

$P_{22"LCD}$ = the number of 22" LCD to produce

$P_{23"LCD}$ = the number of 23" LCD to produce

LCD_{PM} = the number of Panel Meter of LCD to acquire for production

A_P = the number of labour hours for the assembly of product

QC_P = the number of labour hours for the quality control and assurance

Pg_P = the number of labour hours for the for the Packaging of product

$S_{19"LCD}$ = the number of LCD 19" to sell

$S_{20"LCD}$ = the number of LCD 20" to sell

$S_{22"LCD}$ = the number of LCD 22" to sell

$S_{23"LCD}$ = the number of LCD 23" to sell

Using these variables for the manufacturing problem is possible with following LP. Objective function is = P.0 and maximization Z is given as following.

Z = - 15LCD_{PM} – 25A_P -30QC_P – 15Pg_P + 120$S_{19"LCD}$ + 150$S_{20"LCD}$ + 80$S_{22"LCD}$+200$S_{23"LCD}$

Subject to

$P_{19"LCD}$+ $P_{20"LCD}$+ $P_{22"LCD}$+ $P_{22"LCD}$ – $LCD_{PM} \leq 0$ (Resources for LCD (Panel Meter))

2$P_{19"LCD}$ + 2$P_{20"LCD}$ +2.5$P_{22"LCD}$ + 2.5$P_{22"LCD}$ – $A_P \leq 0$ (Resources for Assembly)

0.5$P_{19"LCD}$ + 0.5$P_{20"LCD}$ + $P_{22"LCD}$+ $P_{22"LCD}$ –$QC_P \leq 0$ (Resources for Quality Control)

$P_{19"LCD}$ + $P_{20"LCD}$ +1.5$P_{22"LCD}$ + 1.5$P_{22"LCD}$ –$Pg_P \leq 0$ (Resources for Packaging)

$S_{19"LCD} \leq 10000$

$S_{20"LCD} \leq 8000$

$S_{22"LCD} \leq 5000$

$S_{23"LCD} \leq 11000$

$S_{19"LCD} - P_{19"LCD} \leq 0$

$S_{20"LCD} - P_{20"LCD} \leq 0$

$S_{22"LCD} - P_{22"LCD} \leq 0$

$S_{23"LCD} - P_{23"LCD} \leq 0$

$P_{19"LCD}, P_{20"LCD}, P_{22"LCD}, P_{23"LCD}, LCD_{PM}, A_P, QC_P, Pg_P, S_{19"LCD}\ S_{20"LCD}, S_{22"LCD}, S_{23"LCD} \geq 0$

4.4.2 Sensitivity Analysis

There is uncertainly found in the production demand of the LCDs, but low and high values are also available. Assuming as

- Low value for the 19" LCD, 20" LCD, 22" LCD and 23" LCD may occur as (75%) 7500, 6000, 3750 and 8200 respectively. Pl = 0.3
- Most likely value for the 19" LCD, 20" LCD, 22" LCD and 23" LCD may occur as (90%) 9000, 7200, 4500, and 9900 respectively. Pm = 0.4
- High value for the for 19" LCD, 20" LCD, 22" LCD and 23" LCD may occur as (100%) 10000, 8000, 5000 and 11000 respectively. Ph = 0.3.

The sensitivity analysis of the given solution expresses the decision to manufacture more LCDs of all sized, as they can be sold to produce high quantity of the LCD monitors based upon the demands of non-negative sets.

products	**Requirements for the products**		
Situation	**First Scenario**	**Second Scenario**	**Third Scenario**
19" LCD	7500	9000	10000
20" LCD	6000	7200	8000
22" LCD	3750	4500	5000
23" LCD	8200	9900	11000
LCD Panel Meter for production	25500	30600	34000
Labour hours for the assembly	57000	68400	76000
Labour hours for the QC and QA	18750	22500	25000
Labour hours for packaging	31125	37350	41500
Total Profit	1288125	1545750	1717500

Table 3: optimal Solution of profit in 3 scenarios

Table 4 shows the resources acquisitions and product quantities which increase from first scenario to 3rd scenario. In the all three scenarios, the LCD monitors manufacturing company needs the resources for the production of the LCD Monitors.

Stability in structure of solution, and association between the given solution shows that expected demand is an adequate answer for the LCDs producing company. If company produces the 7500, 6000, 3750 and 8200 for 19" LCD, 20" LCD, 22" LCD and 23" LCD respectively, then it has demand of 75% for all four sized LCDs. When demand increases to 90%, the number of 19" LCD, 20" LCD, 22" LCD and 23" LCD are 9000, 7200, 4500, and 9900 respectively. Finally, the demand becomes 100% for 19" LCD, 20" LCD, 22" LCD and 23" the number of LCDs for each category are as 10000, 8000, 5000 and 11000. In the first scenario low number of all sized LCDs is produced and company's profit remains lower as $1288125 shown in the table. In the second scenario the number of product is larger than first scenario and profit also increase to $1545750. In the third scenario the number of products is largest and also the profit is maximum in all three scenarios as $1717500. In all three scenarios the demand for the 23" LCDs remained maximum and net gain was also high. This sensitivity analysis also can be achieved by using software packages like EXCEL, MATLAB, WINQSB and LINDO.

4.5. Use of Linear Programming Model to Make Decision for Production and Selling of LCDs

The need of a power approach for the model development is required in the face of products' demand. The relationship between time of decision and demand is required in the specific demand scenarios. Three scenarios show the change towards the optimization of objective function. It is not useful to make decision before the demand is not known. Uncertainty in demand requires the revealing it by the decision makers. The Linear programming model provides the needful mechanism to determine the expected revenue from the sale of LCDs.

The LP model can be traced back three scenarios in sensitivity analysis. In all three scenarios the total profit is optimum and increases from scenario 1 to scenario 3. The difference between the profit of scenario 1 and scenario 2 is 257625, and gap between scenario 2 and scenario 3 is 171750. The data output in all three scenario is optimal, but scenario 3 is the most optimal solution as it is the highest in all scenarios.

5. Conclusion

It is challenging to construct the linear programming model from the data provided. The production planning of the LCDs for the company requires the models to address the decisions in the future. Uncertainty clouds with the data used in the construction of linear programming model. The post optimal analysis (sensitivity analysis) is used to know the changes in right hand side, specific ranges and coefficients of objective function by the optimal solution. Today's decision for the production of LCDs will balance the condition which can occur in the future. In the current case, the three scenarios for the production of the LCDs present the varying consequences of the maximum profit for the company. However, the third scenario is the most optimal solution for the maximization of the objective function. So in this regards, the authors' intention is to support decision-maker with heuristics procedures to do better decision based on well-understand information in an efficient computational way.

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Appendix 1

1) The profit calculation for first scenario is given as

$$Z = -15LCD_{PM} - 25A_P - 30QC_P - 15Pg_P + 120S_{19"LCD} + 150S_{20"LCD} + 80S_{22"LCD} + 200S_{23"LCD}$$

Subject to

$P_{19"LCD} + P_{20"LCD} + P_{22"LCD} + P_{22"LCD} - LCD_{PM} \leq 0$

$2P_{19"LCD} + 2P_{20"LCD} + 2.5P_{22"LCD} + 2.5P_{22"LCD} - A_P \leq 0$

$0.5P_{19"LCD} + 0.5P_{20"LCD} + P_{22"LCD} + P_{22"LCD} - QC_P \leq 0$

$P_{19"LCD} + P_{20"LCD} + 1.5P_{22"LCD} + 1.5P_{22"LCD} - Pg_P \leq 0$

$S_{19"LCD} \leq 7500$

$S_{20"LCD} \leq 6000$

$S_{22"LCD} \leq 3750$

$S_{23"LCD} \leq 8250$

$S_{19"LCD} - P_{19"LCD} \leq 0$

$S_{20"LCD} - P_{20"LCD} \leq 0$

$S_{22"LCD} - P_{22"LCD} \leq 0$

$S_{23"LCD} - P_{23"LCD} \leq 0$

= -15*25500 -25*57000 -30*18750 -15*31125 + 120*7500 +150*6000 +180*3750 +200*8250

= - 382500 – 1425000 – 562500 - 466874 + 900000 + 900000 + 675000 + 1650000

= - 2836875 + 4125000

= 1288125

2) The profit calculation for second scenario is given as

Z = - $15LCD_{PM} - 25A_P - 30QC_P - 15Pg_P + 120S_{19"LCD} + 150S_{20"LCD} + 80S_{22"LCD} + 200S_{23"LCD}$

Subject to

$P_{19"LCD} + P_{20"LCD} + P_{22"LCD} + P_{22"LCD} - LCD_{PM} \leq 0$

$2P_{19"LCD} + 2P_{20"LCD} + 2.5P_{22"LCD} + 2.5P_{22"LCD} - A_P \leq 0$

$0.5P_{19"LCD} + 0.5P_{20"LCD} + P_{22"LCD} + P_{22"LCD} - QC_P \leq 0$

$P_{19"LCD} + P_{20"LCD} + 1.5P_{22"LCD} + 1.5P_{22"LCD} - Pg_P \leq 0$

$S_{19"LCD} \leq 9000$

$S_{20"LCD} \leq 7200$

$S_{22"LCD} \leq 4500$

$S_{23"LCD} \leq 9900$

$S_{19"LCD} - P_{19"LCD} \leq 0$

$S_{20"LCD} - P_{20"LCD} \leq 0$

$S_{22"LCD} - P_{22"LCD} \leq 0$

$S_{23"LCD} - P_{23"LCD} \leq 0$

= -15*30600 -25*68400 -30*22500 -15*37350 +120*9000 +150*7200 +180*4500 +200*9900

= -459000 – 1710000 – 675000 – 560250 +1080000 +1080000 +810000 +1980000

= - 3404250 +4950000

= 1545750

3) The profit calculation for third scenario has been given in the following.

Z = - $15LCD_{PM} - 25A_P$ -$30QC_P - 15Pg_P + 120S_{19"LCD} + 150S_{20"LCD} + 80S_{22"LCD} + 200S_{23"LCD}$

Subject to

$P_{19"LCD} + P_{20"LCD} + P_{22"LCD} + P_{22"LCD} - LCD_{PM} \leq 0$

$2P_{19"LCD} + 2P_{20"LCD} + 2.5P_{22"LCD} + 2.5P_{22"LCD} - A_P \leq 0$

$0.5P_{19"LCD} + 0.5P_{20"LCD} + P_{22"LCD} + P_{22"LCD} - QC_P \leq 0$

$P_{19"LCD} + P_{20"LCD} + 1.5P_{22"LCD} + 1.5P_{22"LCD} - Pg_P \leq 0$

$S_{19"LCD} \leq 10000$

$S_{20"LCD} \leq 8000$

$S_{22"LCD} \leq 5000$

$S_{23"LCD} \leq 11000$

$S_{19"LCD} - P_{19"LCD} \leq 0$

$S_{20"LCD} - P_{20"LCD} \leq 0$

$S_{22"LCD} - P_{22"LCD} \leq 0$

$S_{23"LCD} - P_{23"LCD} \leq 0$

= -15*34000 -25*76000 -30*25000 -15*41500 +120*10000+150*8000+ 180*5000+ +200*11000

= - 510000 - 1900000- 750000-622500 + 1200000 + 1200000 + 900000 + 2200000

= - 3782500 + 5500000

= **1717500**