NIPES Journal of Science and Technology Research 3(4) 2021 pp.119 – 124 pISSN-2682-5821, eISSN-2682-5821

NIPES

Journal of Science and Technology Research

Journal homepage: www.nipesjournals.org.ng

Optimization of the Production Capacity of a Manufacturing Company as Linear Programming Model

Amosun, S.T[a] and Muhammed, M.A[b]

[a]Department of Mechanical and Mechatronic Engineering, Federal University Otuoke, Bayelsa, Nigeria

[b]Department of Mathematics, Yaba College of Technology, Lagos

amosunts@fuotuoke.edu.ng

Article Info

Keywords:
Optimization, linear, programming, software, production, mathematical

Received 24 October 2021
Revised 12 November 2021
Accepted 16 November 2021
Available online 12 December 2021

https://doi.org/10.37933/nipes/3.4.2021.12

https://nipesjournals.org.ng

Abstract

Optimization of production capacity can be a major factor on increasing production rates and reducing production cost. Most industrial processes and products are not sufficiently utilized and the use of simple, accessible mathematical technology opens that latent capacity which is of significant value. The determination of the best operational setting for the products or process is usually accomplished through single-objective function optimization routines. This work attempts to use an existing database obtained from the records of a manufacturing company to optimize her production capacity. Ten types of plastic products are produced in the company that include medium mug, 350cl.container, big chamber pot, small mug, flower bowl, big mug, fuji reggae container, 1-litre container, paint container, food plate. A problem of this nature was identified as a linear programming problem, formulated in mathematical terms and solved using LINDO software. The solution obtained revealed that to optimize the production activities of Haskem Plastic Manufacturing Company (Nigeria) Limited, the company should produce approximately 978 units of Flower bowl and approximately 747 units of 1-litre container while other types should be less produced since their values are turning to zero in order to achieve a maximum monthly profit of #1704400.

1.Introduction

Production optimization is the practice of making changes or adjustments to a product to make it more desirable. The main objective of any production optimization is to improve utilization of the production capacity of a production plant to get higher throughput. Optimization problems are often classified according to the mathematical characteristics of the objective function, the constraints, and the controllable decision variables. There are many optimization algorithms available. However, some methods are only appropriate for certain types of problems. It is important to be able to recognize the characteristics of a problem and identify an appropriate solution technique. Within each class of problems, there are different minimization methods, which vary in computational requirements, convergence properties, and so on. Linear programming, LP is a mathematical technique used in operations research to solve specific problems. LP systems also provide a variety of extensions that fall under the general heading of stochastic and robust optimization. These include classic recourse problems given distributions or scenario trees for data, explicit chance constraints and other formulations that seek a solution that is robust in the face of uncertainty. Implementations vary considerably due to the great variety of problem types. Various kinds of optimization problems can also be formulated as LP problemssuch as resource allocation, transportation, production planning, schedulingand assignment problems that permits a choice or choices between alternative courses of action. All the production optimization solutions work actually either in synergy or coordinating with base control loops. No fancy software or clever strategy can really unleash its full potential if applied on top of poorly tuned control loops. So taking care of the basic control layer is of paramount importance and can deliver substantial and sometimes even surprising economic returns by itself. Linear Interactive and Discrete Optimizer (LINDO) is a convenient, but powerful tool for solving linear, integer and quadratic programming problems. These problems occur in areas of business, industry, research and government [1, 2, 3]. Since optimization models are usually developed in the context of some larger scheme or application (or both), the ability of LP software to be embedded is often a key consideration. Many production optimization techniques have been introduced into the manufacturing process in order to improve the production capacity by various researchers in the field of production optimization. For instance, a very important class of production scheduling problems and the main methods employed to solve them were presented by [4]. Another research was also conducted by [5] on optimal production scheduling for the dairy industry. [6] also proposed an integrated solution in which a production plan that was feasible with respect to this plan was sought. [7] applied optimization principle in optimizing profits of a production industry using linear programming to examine the production cost and determine its optimal profit. [8] presented a model and algorithms for optimizing the production capacity of an intangible flow production system with the given network structure. [9] discussed an optimization modeling for the capacity planning of production facilities and alternative facilities with consumable capacity. [10] analyzed the balance between the actual production capability of a production company's targets in the coming periods. [11] also established a six-tier attribute index system evaluation model for the optimization of production planning scheme set of mass customization enterprises in cloud manufacturing environment. The objective of this research work is to determine the optimal production capacity through the application of linear programming algorithm.

2. Methodology

Optimization is a quantitative procedure that requires the application of discipline and serious multivariable mathematical technology. There are three main optimization technologies used: (1) first principle (2) sequential empirical optimization, and (3) neural network. In general, they have these in common:

- They depend on the good performance of the regulatory control system
- Each application requires the formulation of a scope to drive the software
- For each output there is a prediction model as a function of all the inputs
- There is an optimization engine to search the prediction models for the best combination of adjustment decisions that result in the best predicted performance metrics, given the values of the uncontrolled inputs (if any).

The task in this case study is to maximize the total profit after satisfying a set of constraints. Table1 below presents ten different types of plastic products produced by Haskem plastic manufacturing company, their production cost, selling price and profit. Table 2 is the allocation table that shows the basic constraints. Linear Interactive and Discrete Optimizer (LINDO) is used for this work. It has also been used by thousands of companies worldwide to maximize profit and minimize cost. The system requirement of the computer implementation of this problem using LINDO required ten (10) variables as decision variables and three (3) constraints. The first set of constraints provides a series of material balances on the inventories. The raw materials used are divided under these categories: High Density Poly Ethylene (HDPE) and Low Density Poly Ethylene (LDPE). Both HDPE and LDPE are types of plastics made from ethylene. Finally, there are capacity constraints on the amount that can be produced on regular time. There exist various other constraints as the available resources can be categorized. These are the total labour hours available per production period and machine hours availability. All variables are non-negative.

Table 1: Types of plastic products, production cost, selling price with the profits

S/N	Name of Product	Production cost per product (#)	Selling price per product (#)	Profit (#)
1	Medium mug (x_{1t})	850	1100	250
2	350cl. Container (x_{2t})	1500	1800	300
3	Big Chamber Pot (x_{3t})	1200	1400	200
4	Small Mug (x_{4t})	700	900	200
5	Flower Bowl (x_{5t})	900	1200	300
6	Big Mug (x_{6t})	1500	1900	400
7	Fuji Reggae (x_{7t})	2000	2300	300
8	1-Litre Container (x_{8t})	950	1250	300
9	Paint Container. (x_{9t})	1350	1700	350
10	Food Plate (x_{10t})	650	900	250

Table 2: Allocation Table

Products	X_{1t}	X_{2t}	X_{3t}	X_{4t}	X_{5t}	X_{6t}	X_{7t}	X_{8t}	X_{9t}	X_{10t}	Maximum Available Resources
Raw Materials	650	50	190	160	30	70	35	290	50	200	295000
Labour hour requirement	35	20	40	45	30	30	22	35	40	40	163200
Machine hour requirement	18	10	20	22	14	16	11	17	19	21	26400
Product contribution	7	8	10	7	13	10	4	40	6	25	

Source: Haskem Plastic Manufacturing Company records

2.1 Formulation of Linear Programming

Mathematical models were constructed for the production of various types of plastics produced by Haskem Plastic Manufacturing Company. The objective of the model was to maximize the total profit after satisfying a set of constraints. These constraints were mainly raw materials, labour hour and machine hours.

The specified linear programming model for the attainment of the objective function will be to maximize the total profit given by:

$$\text{Max TC} = C_1X_{1t} + C_2X_{2t} + C_3X_{3t} + C_4X_{4t} + C_5X_{5t} + C_6X_{6t} + C_7X_{7t} + C_8X_{8t} + C_9X_{9t} + C_{10}X_{10t} \quad (1)$$

Both the objective function and the constraints values were inserted into the linear programming model from the allocation and can be stated thus:

$$\text{MAXIMIZE } Z = 7X_{1t} + 8X_{2t} + 10X_{3t} + 7X_{4t} + 13X_{5t} + 10X_{6t} + 4X_{7t} + 40X_{8t} + 6X_{9t} + 25X_{10t} \quad (2)$$

Subject to:

Raw Material Constraint

$$650X_{1t} + 50X_{2t} + 190X_{3t} + 160X_{4t} + 80X_{5t} + 70X_{6t} + 35X_{7t} + 290X_{8t} + 50X_{9t} + 200X_{10t} \leq 295000 \quad (3)$$

Labour Hours Constraint

$$35X_{1t} + 20X_{2t} + 40X_{3t} + 45X_{4t} + 30X_{5t} + 30X_{6t} + 22X_{7t} + 35X_{8t} + 40X_{9t} + 40X_{10t} \leq 163200 \quad (4)$$

Machines Hours Constraint

$$18X_{1t} + 10X_{2t} + 20X_{3t} + 22X_{4t} + 14X_{5t} + 16X_{6t} + 11X_{7t} + 17X_{8t} + 19X_{9t} + 21X_{10t} \leq 26400 \quad (5)$$

$$X_{1t}, X_{2t}, X_{3t}, X_{4t}, X_{5t}, X_{6t}, X_{7t}, X_{8t}, X_{9t}, X_{10t} \geq 0 \quad (6)$$

3. Results and Discussion

3.1 Optimal Solution from Lindo Software

In the area of discrete optimization, the ideas underlying branch-and-bound search for integer programming are sufficiently powerful to handle broader classes of constraint types. The problem of optimization is sufficiently generic and there are several commercially available software programmers with fairly broad applicability. Specific application areas where LINDO has proven to be of great use include product distribution, ingredient blending, production and personnel scheduling, inventory management etc. The guiding design philosophy for LINDO is that there should not be a large setup cost to learn the necessary features of LINDO. The results, taken in order, show that LINDO took two iterations to solve the model, second, that the maximum profit attainable from the ten variables as we have constrained them is 426100.22253, and third, the variables X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9 and X_{10} take the values 0.00, 0.00, 0.00, 0.00, 97.814812, 0.00, 0.00, 74.74075, 0.00, 0.00 respectively.

The results of this analysis as shown in Tables 3 and 4 revealed that to optimize the production activities of Haskem Plastic Manufacturing Company (Nigeria) Limited, the company should produce approximately 978 units of Mug 4 and approximately 747 units of Fuji Reggae in order to maximize its revenue. The weekly optimal turnover of ₦426100.2, in thousands, is same as ₦1704400.89 average monthly revenue, in thousands, for Haskem Plastic Manufacturing Company (Nigeria) Limited.

Table 3: LP Optimum at Step2 in which the objective function (4261.22) changed

Variable Coeff.	**Value**	**Reduced Cost**
X1	0.000000	78.411110
X2	0.000000	0.388889
X3	0.000000	18.077778
X4	0.000000	17.733334
X5	97.814812	0.000000
X6	0.000000	2.166667
X7	0.000000	2.716667
X8	74.740738	0.000000
X9	0.000000	4.288889

X10	0.000000	4.5444445
ROW	SLACK.OR SURPLUS	DUAL PRICES
2	0.000000	0.125556
3	10769.629883	0.000000
4	0.000000	0.211

Note: number of iterations= 2

Table 4: Ranges in which the basis is unchanged (Objective Coefficient Range)

Variable Coeff.	**Current Increase**	**Allowable**	**Decrease Allowable**
X1	7.000000	78.411118	INFINITY
X2	8.000000	0.388889	INFINITY
X3	10.000000	18.077778	INFINITY
X4	7.000000	17.733334	INFINITY
X5	13.814812	19.941177	0.512196
X6	10.000000	2.1666676	INFINITY
X7	4.000000	2.7166671	INFINITY
X8	40.000000	7.125000	10.955357
X9	6.000000	4.288889	INFINITY
X10	25.000000	4.544446	INFINITY
ROW RHS	Current Increase	Allowable	Decrease Allowable
2	29500.000000	15535.29393945	14414.286133
3	16320.629883	0.000000	10769.629883
4	2640.000000	0.211	910.689636

Note: number of iterations=2

4. Conclusion

This study addressed the problem of optimizing the production capacity of a plastic manufacturing company. In this research, we developed linear programming model and used LINDO software program to maximize profit and reduce cost. It can be concluded that to optimize the production activities of Haskem Plastic Manufacturing Company (Nigeria) Limited, the company should produce approximately 978 units of Mug 4 and approximately 747 units of Fuji Reggae in order to maximize its revenue. The weekly optimal turnover of ₦426100.2, in thousands, is also same as ₦1704400.89 average monthly revenue. This result is similar to the results obtained by other researchers mentioned above on production optimization of manufacturing companies. Further, management decision should therefore be to intensify effort in increasing the profit by minimizing total cost of production.

References

[1] C. W. Moreno (2006); Optimization in Production Operations Optimal “LeanOperations” in Manufacturing. Advanced Process Management, Ultramax corporation, 110Boggs, Ohio, USA.
[2] N. Bonavita, J.C. Bovero, R. Martini, (2004). Control loops: performance and Diagnostics, Proceedings. of 48th ANIPLA Conference, Milano, Italy.

[3] H.P.Bieker,SPE,NTNU;O.Slupphaug,T.A.Johansen,(2007).Real time production optimizattion of offshore oil and gas production systems. Technology Survey, SPE Production and Operations, 22(4): 382-391.
[4] G.I. Zobola, C.D. Tarantilis, G. Loannou (2008). Production Scheduling Problems. Published by Springer, 28, 1-4.
[5] H.S.Dogaris (2008). Annals of operations research, Publisher:" Springer Science + Business Media", USA, pp315-331.
[6] Y. Hong-Sen, X. Qi-Feng, L. Xia-Ling (2003). Integrated production planning and scheduling on automobile assembly lines, 35(8), 711-725.
[7] N.K, .Oladejo, A. Bolarinwa, S.O., Salawu, A.F. Lukmon and H.I. Bukari (2006).Optimization principle and its application in optimizing Landmark University bakeryproduction using linear programming. "International Journal of Civil Engineering andTechnology", 10(02), 183-190.
[8] P. Korytkowski (2006). Optimization of production capacity of an intangible flow production system with the given network structure. Elsivier: IFAC proceedings, 39(03), 627-632.
[9] B.W. Baetz and E.I. Pas (1988). Optimization modeling for capacity planning of production facilities and Alternative facilities with consumable capacity. Elsevier: "Mathematical and computer modeling", volume II, 1069-1072.
[10] M. Sugarindra and R. Nurdiansyah (2020). Production Capacity Optimization with rough cut Capacity Planning (RCCP). IOP Conference series; "Materials Science and Engineering", IOPPublishing,722.
[11] Z. Weixu, H. Shi. Q. Zhang, H. Fengyi (2019). Multiobjective optimization model of production planning in Cloud manufacturing based on TOPSIS method with combinedweights."Hindawi Complexity Journal of Optimization" 1-15.doi.org/10.1155/2019/7503176.