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RESEARCH ARTICLE

OPTIMIZING THE PRODUCT MIXINGS AND MACHINE PROCESSING TIME OF A FAST FOOD RESTAURANT USING A LINEAR PROGRAMMING MODEL: CASE STUDY OF OSTRICH BAKERY

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ABSTRACT

When it comes to staying on top of the fast food industry, food innovation is one of the most important elements (Fastfood Restaurant , 2002). We regularly see our favourite fast food brands competing for our attention by introducing new and increasingly more exciting menu options either as limited editions or as new regulars on their menus. They do this bearing in mind to minimize cost. A case study of Ostrich Bakery fast food restaurant is considered using Linear Programming models as a management tool. The Linear Programming models comprise of the Product Mixing model and Machine Processing time model. These models produce optimal solutions from the data based on the four major products and the related machines. This paper aims at using Linear Programming as a management tool to minimize the processing time of products in the Product mixing model and to utilize the production capacity of the machines in the Machine processing time model. Results show that the total sum of all the objective value contributions gives the Product mixing model value and the Machine processing time model value respectively. One of the main limitations of this study is the use of data from fast food restaurant branches of the Ostrich Bakery in Nigeria (Kaduna). The main contribution of the paper is to get the optimal solutions from the objective value contributions of the Product mixing model and the Machine processing time model in the Ostrich Bakery (Headquarters in Kaduna).

INTRODUCTION

Preamble

Linear programming is a management tool that is used in most organizations, big or small that have limited supply of their resources (John et al., 2002). It deals with the optimization of a function of variables known as well-defined objective function, subject to a set of linear equations and/or inequalities known as constraints. In the Ostrich Bakery, Linear programming focuses on the Product mixing model and the Machine processing time model which is applied to find the best allocation of its resources in order to minimize the processing time of the products and utilize the production capacity of the machines. Ostrich Bakery produces several kinds of products but the four which are generally in demand will be considered which are: Bread, Meat Pie, Hamburger and Cake. The 6 machines with respect to the products are: Mixer, Molder, Rotate Oven, Flat Oven, Slicing Machine and Grinder. The Product mixing model focuses on the product mixings which lay a total emphasis on the time spent by each machine in processing the product with its unit electricity cost. In the Product model, the variables are based on the 6 machines and the constraints are based on the 4 products.

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The Machine processing time model focuses on the utility of the machines which emphasize on the processing time for each product. In the Machine processing time model the variables are based on the 4 products and the constraints are based on the 6 machines. In each case of the Product mixing model and the Machine processing time model, the variables obey the law of proportionality and additivity. The TORA programming software handles data related to the Product mixing model and Machine processing time model in order to obtain the objective values respectively.

Linear programming based on the Product mixing model and the Machine processing time model in the Ostrich Bakery will help in attaining the optimum use of productive factors, give a clear picture of the relationships within the basic equations, inequalities or constraints which give a better idea and highlighting about the problem and its solution. Linear programming models are examples of prescriptive models. Prescriptive models are used to prescribe a course of action that, in some sense, is optimal (Hillier and Lieberman, 2001). The Machine processing time model and Product mixing model of the Ostrich Bakery represent the real system, thus its objective is to obtain best solutions. The processing time of the product mixing and utilization of machines in the Ostrich Bakery are considered under the TORA programming software with respect to Linear Programming.

The general linear programming problem is applied in the Product mixing model and Machine processing time model in order to obtain the objective functions respectively. Considering the Product mixing model, the objective function is the production process of each material (mixer, moulder, rotate oven, flat oven, slicing machine and grinder) which is to be obtained in the optimal manner while the constraints are the products (bread, meatpie, hamburger and cake). Considering the Machine processing time model, the objective function is the production capacity of each material (bread, meatpie, hamburger and cake) which is to be obtained in the optimal manner while the constraints are the machines (mixer, moulder, rotate oven, flat oven, slicing machine and grinder).The variables obey the properties of proportionality and additivity. Linear programming is a quantitative method that can serve as a management tool to the Product mixing model and Machine processing time model derived from the Ostrich Bakery.

Reason for the Research Work

One of the reasons for the popularity of fast food restaurants to customers has been that through economies of scale in purchasing and producing food, the companies can deliver food to consumers at a very low cost. Despite this, many of the operators are not realizing optimal efficiencies that would result from high capacity utilization of machines that produce their products. Analyzing food equipment vis-à-vis the daily productions is hardly done, but when done will result into more effectiveness. This research will proffer some solutions based on our case study of Ostrich Bakery, Kaduna which can be useful to other similar organizations.

Scope and Limitations of Study

The study focuses on the operations in a fast food restaurant, using the Ostrich Bakery along Ahmadu Bello way in Kaduna as the case study since that is its Headquarters. The operations are based on the Product mixing model and the Machine processing time model. The products and the machines under observation are analyzed based on the daily processing time of each machine for the four major products considered in the Ostrich Bakery.

Literature Review

Generally speaking, linear programming can be used for optimization problems if the following conditions are satisfied:

1. There must be a well-defined objective function which is to be either maximized or minimized and which can be expressed as a linear function of decision variables.
2. There must be constraints on the amount or extent of attainment of the objective and these constraints must be capable of being expressed as linear equations or inequalities in terms of variables.
3. There must be alternative courses of action.
4. Decision variables should be inter-related and non-negative.
5. The resources must be in limited supply (Hillier and Lieberman, 2001).

The Ostrich Bakery fast food restaurant which, is the case study, operates in a building where customers come to receive services. It has branches all over the country (Nigeria). Its location in Kaduna, along Ahmadu Bello Way, is the case study. It has a daily quantity demand. Employees run a shift of 24hrs daily. The company has a slogan "*Eat and tell others about it*" which has made an effective publicity on its own. It has also been known for its low-cost charges of products and transparency in food preparations which have attracted high demand by customers. Many fast food restaurants build on the principles, system and practices of their fellow fast food restaurants in order to remedy their flaws and introduce better standards.

Chris Adedipe, Managing Director, Mr. Bigg's, while assessing the fast food industry in Nigeria in an exclusive interview with BUSINESSDAY admitted that the Nigerian fast food industry has shown remarkable growth particularly in the past 20 years (Sharma, 2011). Adedipe said the industry has developed from the mobile vans to premises-based restaurants, adding that with globalization it would mature along the lines of what obtains in the developed world with operators specializing in areas such as ethnic meals, chicken and pastries segments. He maintained that though there are companies operating with franchises, given the way the industry is growing, some of the major operators would come into the country.

Already, some major South African fast food outlets are operating in Nigeria under franchise while others have indicated interest in coming into the country directly. He, however, disclosed that what may be keeping the major fast foods back from Nigeria is the absence of a food processing industry in the country (Sharma, 2011). In Nigeria, the term "fast food" is been carried out directly in fast casual restaurants like Mr Biggs, Tantalizers, Bakers Delight, Big Treat, Yummylicious, Ostrich Bakery and many others and indirectly like Canteens and 'Mama Put' where normally the food seller packages the food in large food flasks and could be seated just outside work sites. Despite the simplicity of the situation, the food sellers still face challenges when customers are many like congestion or days when customers are scarce like idle servers. Electricity supply challenges also have a great effect on the capacity of food equipment related to its products.

Methodology and data

Model Consideration

Data from the Ostrich Bakery was classified into the Product Mixing and the Machine Operation/ Processing Times in order to establish a standard linear program.

Product Mixing Constraints

Considering the Product Mixing model, the variables are the 6 machines which are: Mixer (y_1), Moulder (y_2), Rotate Oven (y_3), Flat Oven (y_4), Slicing Machine (y_5) and Grinder (y_6).The constraints are the 4 products which are: Bread, Meatpie, Hamburger and Cake. They are with respect to their processing time in daily operations.

The Objective function is to minimize the processing time of the product mix.

Minimize $Z = \sum_{i=1}^{6} c_i y_i$

C_i is how many hours each machine spends *unit cost of each product.

Note: NEPA Tariff per month (30days) is #400,000.

To find the unit cost for each product; Bill for each product / produce in 30days.

The linear function of the variables are subject to the constraints

$a_{11}x_1 + a_{12}x_2 + \ldots + a_{1n}x_n (\leq, =, \geq) b_1,$
$a_{21}x_1 + a_{22}x_2 + \ldots + a_{2n}x_n(\leq,=,\geq)b_2,$
$a_{m1}x_1 + a_{m2}x_2 + \ldots + a_{mn}x_n(\leq,=,\geq)b_m,$

and meet the non-negativity restrictions

$x_1, x_2, \ldots, x_n \geq 0.$

By linearity is meant a mathematical expression in which the expressions among the variables are linear. The variables obey the properties of proportionality and additivity.

The data obtained from Ostrich Bakery in Table 3.1 were subjected into a linear programming model to Optimize the Production. These models were solved by the TORA programming package as shown below.

Rotate oven (C_3) y_3 = ((10 * 4.12) + (10 * 2.78))y_3 = 69y_3
Flat oven (C_4) y_4 = ((10 * 4.12) + (10 * 4.45) + (10 * 19.44))y_4= 280.10y_4

Slicing machine (C_5) y_5 = (10 * 2.78)y_5 =27.80y_5

Grinder (C_6) y_6 = (4 * 4.45)y_6= 17.8y_6

Minimize $Z = 246.32y_1 + 55.2y_2 + 69y_3 + 280.10y_4 + 27.80y_5 + 17.8y_6$

subject to

Bread: $15y_1 + 5y_2 + 20y_3 + 30y_4 \geq 70$

Meatpie: $15y_1 + 30y_4 + 15y_6 \geq 60$

Hamburger: $15y_1 + 5y_2 + 20y_3 + 15y_5 \geq 55$

Cake: $15y_1 + 20y_4 \geq 35$

Subjecting the above models into TORA a computer package, the following results were obtained as presented in the next section.

Machine Processing time Constraints

Considering the Machine processing time model, the variables are the 4 products which are: Bread (x_1), Meatpie (x_2), Hamburger (x_3) and Cake (x_4).

Table 3.1. Shows the daily processing time of each machine for each product

Time per unit (mins)					
Machine	Bread	Meatpie	Hamburger	Cake	Capacity (hours/day)
Mixer	15	15	15	15	8
Moulder	5	__	5	__	8
Rotate oven	20	__	20	__	10
Flat oven	30	30	__	20	10
Slicing machine	__	__	15	__	10
Grinder	__	15	__	__	4
Processing Time	70	60	55	35	

Product Mixing Model: Optimal Production of Material

Objective function: To optimize the processing time of the product mix.

Minimize $Z = \sum_{i=1}^{6} C_i y_i$

Bread: 160,000 / (1,296 * 30) = 4.12 unit cost

Meatpie: 40,000 / (300*30) = 4.45unit cost

Hamburger: 25,000 / (300 * 30) = 2.78 unit cost

Cake: 175,000 / (300 * 30) = 19.44 unit cost

Minmize $Z = C_1y_1 + C_2y_2 + C_3y_3 + C_4y_4 + C_5y_5 + C_6y_6$

Mixer (C_1) y_1 = ((8 * 4.12) + (8 * 4.45) + (8* 2.78) + (8 * 19.44))y_1=246.32y_1

Moulder (C_2) y_2 = ((8 * 4.12) + (8 * 2.78))y_2=55.2y_2

The constraints are the 6 machines which are Mixer, Moulder, Rotate Oven, Flat Oven, Slicing Machine and Grinder. They are with respect to their capacity in daily operations.

The Objective function is to optimize the utilization of machines.

Minimize $W = \sum_{i=1}^{4} D_i X_i$

D_i is the processing time for each product.

The linear function of the variables is subject to the constraints

$a_{11}x_1 + a_{12}x_2 + \ldots + a_{1n}x_n (\leq, =, \geq) b_1,$
$a_{21}x_1 + a_{22}x_2 + \ldots + a_{2n}x_n(\leq,=,\geq)b_2,$
$a_{m1}x_1 + a_{m2}x_2 + \ldots + a_{mn}x_n(\leq,=\geq)b_m,$

and meet the non-negativity restrictions

$x_1, x_2, \ldots, x_n \geq 0.$

Machine Model: Optimal Utilization of Machines
Objective function:

Minimize W= $\sum_{i=1}^{4} D_i X_i$
D_i is the processing time for each product.

From table 3.1 above, the objective function of the Machine Model is:

Minimize W = $70x_1 + 60x_2 + 55x_3 + 35x_4$

Subject to:

Mixer: $15x_1 + 15x_2 + 15x_3 + 15x_4 \geq 480$

Moulder: $5x_1 + 5x_3 \geq 480$

Rotate Oven: $20x_1 + 20x_3 \geq 600$

Flat Oven: $30x_1 + 30x_2 + 20x_4 \geq 600$

Slicing Machine: $15x_3 \geq 600$

Grinder: $15x_2 \geq 240$

Also subjecting the above models into TORA a computer package, the following results were obtained as presented in the next section.

RESULTS

Product Mixing Model

The values of the variables are;

$x_1 = y_1 = 0$
$x_2 = y_2 = 0$
$x_3 = y_3 = 0.88$
$x_4 = y_4 = 1.75$
$x_5 = y_5 = 2.50$
$x_6 = y_6 = 0.50$

The objective coefficients of the variables are;

$x_1 = y_1$ is 246.32
$x_2 = y_2$ is 55.20
$x_3 = y_3$ is 69.00
$x_4 = y_4$ is 280.10
$x_5 = y_5$ is 27.80
$x_6 = y_6$ is 17.80

The values of the variables y_i, i=1,2,3,…6 above are the optimal values that makes the objective function optimal. Therefore, the value of the objective function is obtained by multiplying each value of the variable with each value of the objective coefficient respectively. This gives the objective value contribution for each of the variables. Thus the total sum of all the objective value contributions gives the Product Mixing Model Value.

For $x_i = y_i = \sum_{i=1}^{6}((Value) * (Objective\ Coefficient))$

Objective function = (246.32 * 0) + (55.20 * 0) + (69.00 * 0.88) + (280.10 * 1.75) + (27.80 * 2.50) + (17.80 * 0.50)

= 0 + 0 + 60.72 + 490.175 + 69.5 + 8.9

= 629.295
Therefore the Product Mixing Model Value from the objective function is 629.295

Machine Processing Model

The values of the variables are;

$x_1 = 4.00$
$x_2 = 16.00$
$x_3 = 92.00$
$x_4 = 0.00$

The values of the variables x_i, i=1,2,3,4 above are the optimal values that makes the objective function optimal. The value of the objective function is obtained by multiplying each value of the variables with each value of the objective coefficient respectively. This gives the objective contribution for each of the variables. Thus the total sum of all the objective value contributions gives the Machine Processing model value.

$x_i = \sum_{i=1}^{4}(\text{(Value)} * \text{(Objective Coefficient)})$

Objective function = (4.00 *70.00) + (16.00 * 60.00) + (92.00 * 55.00)
+ (0.00 * 35.00)
= 280.00 + 960.00 + 5060 + 0.00
= 6300.00

Therefore the Machine Processing Time Model Value from the objective function is 6300 .00

Conclusion

Optimizing the formulated Linear Programming model of Ostrich Bakery gave optimal solutions for the Product mixing model and Machine processing time model as:

Minimum Z_i (product mixing) = x_i = y_i (i = 1,2,3,4,5,6) = 629.295

Minimum W_i (machine processing time) = x_i (i= 1,2,3,4) = 6300

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