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Optimization of Production and Inventory Systems in Manufacturing for Higher Productivity

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ABSTRACT.

The coordination of production and inventory systems in manufacturing is of critical importance. This research work integrates the production and inventory systems of Nigeria bottling company Owerri plant. Data were collected through structured questionnaire from the production, inventory and sales department of the company. Two models were developed from the data collected which integrate the production and inventory systems of the company for a six month production planning horizon. The models were solved using a computer software called TORA. Both models depict the optimum production and inventory schedules within the specified planning horizon. Model one makes a productivity improvement of 15.7%, while model two makes an improvement of 15.0% when compared with the existing model. The results from the models were analyzed and compared using sensitivity analysis vis-à-vis dual price and reduced cost analysis. The percentage level of productivity improvement and reduction on the optimum solution was determined through dual price and reduced cost on both models respectively. Model one makes an improvement of 0.0028% and a reduction of 0.0031%,while model two makes an improvement of 0.0021% and a reduction of 0.0037% when a unit input is added.

Key words: Production, Optimization, Inventory systems, Manufacturing, Productivity.

Introduction

Selection of the right manufacturing strategy is a critical decision for production managers in the increasingly competitive manufacturing arena. To be more competitive in today's business environment, companies are striving to improve their manufacturing processes. Increasing labor productivity , eliminating waste from operations and responding more efficiently are major targets to achieve. These are aimed at meeting customers expectation through reduction in production costs and necessary parameters.

According to Adeyemi e'tal (2010), Optimum production scheduling of multi-product plant has been an intricate issue.

This motivated the researcher after discovering an escalated increase in holding cost due to excess production, as a result of seasonal demand for soft drink every last quarter month of the year. There was no guideline as how much to produce. Secondly, inventory and production are being managed independently with little or no integration among them.

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Objectives

To develop models that will integrate and co-ordinate production and inventory systems of the company.

To determine the optimum inventory and production schedules with a minimum total cost of production using the developed models for higher productivity.

Methodology

The instruments that were used in this project are, development and administration of structured questionnaires which aided in data collection. Literature reviews/ libraries for data collection; data analysis, soft ware applications, modeling.

Direct interaction and interview with some key personnel in the store, purchasing, accounting, production and inventory department were used . Data were made available by some of the key personnel mentioned in the departments above by providing the past records in their departments. Company's journals were also made available which aided In providing data.

Model Parameters

The parameters, variables and constraints are defined as follows:

j =No of raw materials, **t** =No of periods, **i** = No of products.

H_{cj} =Unit holding/carrying cost of the raw material in the plant.

H_{ci} =unit holding/carrying cost of the product (finished goods)

C_i =Production cost per unit product

A_j =Maximum storage capacity of the raw materials at the

Plant

A_i =Maximum storage capacity of the finished goods (products) at the plant.

U_i =Unit production time (cycle time) of product i at the Plant.

T =Maximum available production time at the plant

D_i =Periodic/forecasted demand for each of the products(i)

C_P =Purchasing cost of raw materials

Decision Variables.

Q_{it} =Quantity of product I produced in period t.

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INV_{it} =Inventory level of product I kept in period t

I_{Rjt} =Inventory level of raw materials j in period t .

Assumptions

A. Demand for each product in each period is estimated and known.

B. Initial inventory at the beginning of the period is zero.

C. Enough personnel and good standard of operation

Model Formulation

Total Cost Of Production(Tcp) =Total Production Cost (Tpc)+Total Inventory Cost (TIC)

TC P = TPC + TIC---------------------A

TPC = $\sum\sum Cit \times Qit$------------------------B

TIC = Sum of average inventories of finished goods and raw materials

Finished goods inventory=Ave Sum of initial and final inventory , but initial inventory is assumed to be zero (Brown, 2002).

Final Inventory = $H_{cit} \times INV_{it}$. This means that

Ave Sum Of Inventory = $0.5\ (0+H_{cit} \times INV_{it})$-------------C

For Raw Materials, Inventory cost of raw material = Ave SUM of starting and ending inventory.
Cost of starting = unit purchasing cost x inventory level. = $Cp \times I_{Rit}$

Cost of ending inventory =unit holding/carrying cost × inventory level. =$H_{cjt} \times I_{Rit}$

AVE SUM = $0.5\ (Cp \times I_{Rit} + H_{cjt} \times I_{Rit})$------------------------------D

Combining eqn (C) and (D)

I have $0.5(Cp \times I_{Rit} + H_{cjt} \times I_{Rit} + H_{cjt} \times INV_{it}$

Total Inventory Cost = $0.5[\ (H_{cit} + Cp) \sum\sum I_{Rit} + (H_{cit}) \sum\sum INV_{it}$------------F

TCP =$\sum\sum C_{it} \times Q_{it} + 0.5[\ (H_{cjt} + Cp) \sum\sum I_{Rit} + (H_{Cit}) \sum\sum INV_{it}$-------------G

Model One,(The Linear Programming Model)

Minimize TCP =$\sum\sum C_{it} \times Q_{it} + 0.5[\ (H_{cjt} + Cp) \sum\sum I_{Rit} + (H_{Cit}) \sum\sum INVit$

$i\ \varepsilon\ (1,2,3)$, $t\ \varepsilon\ (1\text{-----}6)$, $j\ \varepsilon\ (1,2,3)$

subject to

A. Periodic capacity restriction on production

$\sum\sum U_{it} \times Q_{it} \leq T_i$

i ε (1,2,3), t ε (1—6)

B. Production demand inventory balance

$\sum\sum (INV_{it} + Q_{it}) \leq Ai$

i ε (1,2,3), and t ε (1----6)

C. Production demand inventory balance. Using inventory continuity equations (Chandra, 2004), ie initial inventory + quantity produced –final inventory ≤ DEMAND. That is,

$\sum\sum (INVit + Qit - INVit) \leq Di$

I ε (1,2,3), t ε (1- - -6)

D, Material inventory facility balance

, $\sum\sum I_{Rjt} \leq A_{jt}$

J **ε (1,2,3) t ε (1---6)**

Model Two, (Integer Programming Model)

Minimize $TCP = \sum\sum C_{it} \times Q_{it} + [(H_{cjt} + Cp) \sum\sum I_{Rit} + (INVit)$

i ε (1,2,3), t ε (1-----6), j ε (1,2,3)

Recall That Q_{it} **=Quantity of product i produced in period t**

Therefore Y_{it} **=[1 if product i is produced at period t]**

=[0 otherwise]

Y is a binary decision variable which can be 1 or 0

subject to

A , $Q_{it} \leq My_{it}$

i ε (1,2,3), t ε (1-----6)

Y_{it} **ε (0, 1)**

B, $M = Max \sum D_{it}$

C, $Q_{it} \geq 0$

D $\sum\sum U_{it} \times Q_{it} \leq M_{it}$

$i\ \varepsilon\ (1,2,3)$, **and** $t\ \varepsilon\ (1{-}{-}{-}{-}6)$

E, $\sum\sum (INV_{it} + Q_{it}) \leq A$

$i\ \varepsilon\ (1,2,3)$, **and** $t\ \varepsilon\ (1{-}{-}{-}6)$

F, $\sum\sum (INV_{it} + Q_{it} - INV_{it}) \leq D_i$

$i\ \varepsilon\ (1,2,3)$, **and** $t\ \varepsilon\ (1{-}{-}{-}6)$

G, $\sum\sum I_{Rit} \leq A_j$

$i\ \varepsilon\ (1,2,3)$, **and** $t\ \varepsilon\ (1{-}{-}{-}6)$

Model description model two

The first constraint A, implies that decision y_{it} depends on the amount of $Q_{it,}$ it means that when there is production in period t, yit is certainly equal to one and to satisfy the relation between yit and Qit, a very large positive number M is needed.

The second constraint B , suggests one of the feasible values for M. this value must be set sufficiently large to ensure that it is greater than Qit. This amount can be set as the maximum summation of demand for each product over a planning horizon.

The third constraint C, is used to define the non negativity of the decision variable Qit (Du & Evans, 2008).

The fourth constraint D is the period capacity restriction on production . This entails the maximum production time irrespective the number of shift the company may run in a period. This must satisfy the quantity of product I produced at that period multiply by the unit production time .

The fifth constraint E ,is the production facility inventory balance , this tries to satisfy the storage capacity of the plant with respect to the production volume in a period.

The sixth constraint F, is the production demand inventory balance .This equation entails that demand in the current month can be met from goods produced at that month (Kozan, 2001).

The seventh constraint G is the material inventory facility balance.

This tries to satisfy the inventory level of raw materials with the storage capacity.

Data Presentation.

For ease of identification and simplification, the variables used in the model are redefined as follows.

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Table 1. Quantity Of Product i, produced in period t.

Where Q1 is the Quantity of product One produce in Period one,Q2 is

The quantity of product two produced in period two.Q4 is the quantity of one produced in period two.

Qit	i	T
Q1	1	1
Q2	2	1
Q3	3	1
Q4	4	2

- **RAW MATERIAL INVENTORY**
- The plant has the following raw materials ,concentrates, sugar, and cork/bottle, with the estimated periodic holding cost as depicted on the table below. TABLE 4.2

Periods/Raw Materials	Concentrate invRaw1 in Naira	Sugar Inv Raw2 in Naira	Cork/bottles Inv Raw3 in Naira
1	5000	3000	500
2	5000	3000	500
3	6000	3000	500
4	5500	3200	600
5	6000	3200	600
6	6000	3200	600

Products Or Finished Goods Inventory.

The company has the followings three products, **coca cola** (coke, fanta,sprite etc) , **CSD**, and **bottle water**, with the **estimated periodic** holding/lnventory carrying cost shown on the table below. Table 4.3

Sensitivity Analysis: This shows how the input parameters of the models can change within certain limits without causing the optimum solution to change..

Reduced Cost. This is the amount (penalty) to be paid for producing /introducing a unit quantity of a product that is not recommended by optimal solution.

Dual Price(Shadow Price).

This is the amount or gain by which the objective could be improved or changed, given a unit increase / decrease in the RHS of the constraints.

Conclusion/Recommendation

At this point, it is very clear that the dual price made an improvement while the reduced cost made a reduction in the optimal value. This implies that both parameters help in determining the performance level of production and consequently variables for productivity increase..

Going by these, the NBC Owerri Plant, should look critically on the constraints that have the greater values of dual price and try as much as possible to focus on them by increasing the input resources in such area for higher productivity. Also the company should try as much as possible to avoid keeping inventory of the finished goods (INVs),especially those ones that have greater values of reduced cost for them to avoid incurring cost. If they should abide by these, they will attain a greater optimal level production and inventory·

The use of computer software In solving mathematical programming problems have in a remarkable way proven to be highly effective in making improvement in manufacturing industries. Consequently, the integration and coordination of production and inventory systems through good model formulation in manufacturing industries have paved way for optimum production of goods and services. This was proved in the models formulated in this research work.

$$\text{Minimize} \quad TCP = \sum\sum C_{it} \times Q_{it} + [\,(H_{cjt} + Cp) \sum\sum I_{Rit} + (INVit)$$

$$i\ \varepsilon\ (1,2,3), \quad t\ \varepsilon\ (1\text{-----}6), \quad j\ \varepsilon\ (1,2,3).$$

The models integrated the production and inventory systems of NBC owerri plant.

This implies that manufacturing companies that have the same system of operation like NBC owerri will find this work very useful as guide to achieving higher productivity.

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