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OPTIMAL PRODUCTION SCHEDULING FOR A MANUFACTURING COMPANY: A CASE OF ADAMA BEVERAGES LTD. (FARO), ADAMAWA STATE NIGERIA

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Abstract

Scheduling production process in manufacturing and service industries required an informed decision to achieve optimal and efficient service delivery and optimized cost of production. In this paper, we presents an optimal solution of products scheduling from their sources to destinations in form of transportation problem in a manufacturing company of Adama Beverages Ltd. (FARO), Adamawa state Nigeria. The paper established an efficient scheduling that minimizes the total cost of production in the company. A twelve month capacity data (2017) of the company was collected, transformed and modeled using the concept of transportation algorithm. Optimality solutions were attained using Quality Management software package for Windows. The results revealed that the production cost of ***N54,398,112*** *for that year could be reduced by the firm and still meets its demands. The recommendation was made to the management of Adama Beverages Ltd. (FARO) to adopt our model to achieve its objective of satisfying her customer's demands at a reduced cost of production.*

Key words: Optimality, Production cost, QM Software, Scheduling, Transportation model

1. Introduction

Profit making, cost minimization and customer satisfaction are the ultimate goals for any production company. Many factors must be considered and incorporated in other to realize these goals and to guarantee the running of the company. These factors are satisfaction of customer demands, timely and optimum delivery of services, and qualitative products for healthy market competition among others. The company needs competent hands and technical experts to achieve these inclusively. A clear cut, scientifically based production plan will guide the management of the company as to the direction of their production process in the long run. These will assist the manager together with his team to optimize both the profit and the production cost of the company. At the closure of every financial year, most manufacturing firm do prepare a subsequent year production plan to enable them know the quantity of raw materials required, quantity of products required to be produced for each production period in order to satisfy the demand for each period which can be estimated based on the previous year demand information.

According to Amponsah *et al* [1], "The production plan can be executed weekly, monthly, quarterly or even yearly depending on the products of the company. Production scheduling is the allocation of available production resources over time to best satisfy some criteria such as quality, delivery time, demand and supply. An optimum production schedule is the production schedule, which efficiently allocates resources over time to best satisfy some set criteria i.e. the plan which allocates the optimum level of production resources necessary to meet a given demand at a minimum cost".

Adama Beverages Ltd FARO is a manufacturing company located along Numan Road in Jimeta-Yola of Adamawa State. They produce juice, table water, sachet pure water and lots more. They have Departments such as marketing, production, accounts and ICT, they all perform different functions to achieved a given objective or goal. This work focuses only on production Department and explores the Juice production sector (FARO juice). This is resulted because of the juice constant scarcity and excesses in some period. In order to seek a balance between over production and under production, this study is to help the management solve this problem. The goal of every production firm is to make profit and satisfy its customers demand but lack of optimal production scheduling leads to the goal not been achieved. The Production Department of Adama Beverages is currently faced with the challenge of over production and sometimes under production of customer's demand for FARO juice supplied to their customers. This study establishes an efficient production scheduling that helps to minimize cost of production and meet their customers demand to establish an efficient schedule that minimizes total production cost of the company.

This Study provides an optimum production of FARO juice at minimum cost. It seeks to address the issue of efficiency in the production Department of Adama Beverages FARO Adamawa state Nigeria. The result of this research will help the company to know when to produce, when not to produce and what quantity to produce.

2. **Literature Review**

Many researchers had conducted investigations in a scheduling related problem. For example Mouli *et al.* [2], uses Optimal Production Planning under Resource Constraints. Modibbo *et al.* [3], uses genetic Algorithm approach to allocate courses to lectures and classes as a university timetabling problem. Amponsah *et al.* [1], conducted a study on "production scheduling problem for a beverage firm based in Accra, in an attempt to cut down manufacturing cost and increase efficiency". According to them, optimum scheduling problem requires the transportation model to be balanced before the solution process is started. Their model showed that the firm should allocate the available stocks monthly to reduce production cost. Also overtime or subcontracting is not necessary in reducing the cost of production according to them. They therefore recommended the usage of the model to determine the optimum level of production to meet a given demand at a minimum cost. Production scheduling is also documented in Roubellat & Lopez [4]; Herrmann [5]; Javanmard & Kianehkandi [6]; Kumral [7]; Benkherouf & Boushehri [8] among others. Santos *et al.* [9] see production scheduling as a task that is difficult to accomplish especially in an uncertain environment of complexity where resources are scarce. The authors presented and analyzed scheduling problem of a shop-floor using Ant Colony Optimization (ACO) approach in a manufacturing scenario with parallel resources, and flexible routings and single-stage processing. They concluded that ACO is an efficient technique in branch-and-bound, and executes faster than many algorithms. Muhammad *et al.* [10], used linear Programming Approach to resource allocation problem in foam manufacturing industry.

Transportation problem therefore is a special case of the linear programming, it arises when there is a demand of goods and services from manufacturers or service providers which require a shipment from the sink (source) to destination (demand areas). The overall objective of this model is satisfying the customers demand considering the resources available at a minimum possible cost of transportation. The model assumes that the demand can be met from any source(s) where more than one source exists and it considered a unit cost of shipment. These imply that there is proportionality in the number of units shipped on a particular route with its cost. According to Hassan [11], the transportation model can be extended to areas such as inventory control, employment scheduling, machine and personnel assignment among others.

3. **Methodology**

Transportation problem model was used to analyze the data for production collected from the company for 2017 financial year. We modeled the data as a balanced transportation problem satisfying the rim condition. We considered the periodic production as our sources $S_1, S_2, \ldots, S_n$ and Periodic shipment of products as our destinations $W_1, W_2, \ldots, W_m$. The quantity produced a_i at source S_i and the demands d_j at the destination W_j are regarded as the capacities for period i *and* j respectively. The problem is to optimize a production schedule that will satisfy all demands at each destination at minimum possible cost, while the production capacity is not violated. We defined c_{ij} to be the unit cost of producing x_{ij} units from sink i time period to the destination j time period. Since the number of units produced cannot be negative, $x_{ij} \geq 0$.

Mathematically, the transportation problem, in general, may be stated as follows:

$$\text{Minimize } Z = \sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij} X_{ij}, \qquad (1)$$

$$\text{Subject to } \sum_{j=1}^{n} x_{ij} \leq a_i,\ j = 1,2,\ldots,n \text{ (Supply constraints)} \qquad (2)$$

$$\sum_{i=1}^{m} xij \geq d_j, i = 1,2,\ldots,m \text{ (Demand constraints)} \qquad (3)$$

$$x_{ij} \geq 0. \qquad \text{(Non-negativity constraints)} \qquad (4)$$

We used VAM method to obtain the starting basic feasible solution because it provides an improved basic feasible solution and better solution.

3.1 Model Assumptions

i. Allocation can be done only after production of goods

ii. Every month production can be allocated only to present and future months demand only.

iii. Availability of raw materials: Raw materials should be made available

iv. Customer Requirement: Only customers in need of the product will be supplied to.

v. Availability of labour force: There should be workers or man powers that are ready to work in the production Department.

3.2. Model Formulation

The problem is formulated as follows:

Minimize Z = $\sum_{i=1}^{12}\sum_{j=1}^{12} C_{ij} X_{ij}$,

Subject to $\sum_{j=1}^{12} x_{ij} \leq a_i, j = 1,2,...,n$ (Supply or capacity constraints)

$\sum_{i=1}^{12} xij \geq d_j, i = 1,2,...,m$ (Destination or demand constraints)

The objective seek to determine the optimal amount of products Xij to be produce from source *i* to a destination *j* that will minimize the overall cost of production $\sum_{i=1}^{12}\sum_{j=1}^{12} C_{ij} X_{ij}$,.

Thus, we have:

Minimize $\sum_{i=1}^{12}\sum_{j=1}^{12} 960 X_{ij}$,

Subject to:

Supply constraints

$\sum_{j=1}^{12} X_{1j} \leq 49735$, $\sum_{j=1}^{12} X_{2j} \leq 59300$,

$\sum_{j=1}^{12} X_{3j} \leq 54010$, $\sum_{j=1}^{12} X_{4j} \leq 59570$, $\sum_{j=1}^{12} X_{5j} \leq 65240$,

$\sum_{j=1}^{12} X_{6j} \leq 53059$, $\sum_{j=1}^{12} X_{7j} \leq 54023$, $\sum_{j=1}^{12} X_{8j} \leq 55730$, $\sum_{j=1}^{12} X_{9j} \leq 59292$,
$\sum_{j=1}^{12} X_{10j} \leq 59350$, $\sum_{j=1}^{12} X_{11j} \leq 65750$, $\sum_{j=1}^{12} X_{12j} \leq 54060$.

Demand constraints

$\sum_{j=1}^{12} X_{1j} \leq 53420$, $\sum_{j=1}^{12} X_{2j} \leq 49735$, $\sum_{j=1}^{12} X_{3j} \leq 54195$, $\sum_{j=1}^{12} X_{4j} \leq 59115$,
$\sum_{i=1}^{12} X_{5j} \leq 50670$,, $\sum_{i=1}^{12} X_{6j} \leq 50150$, $\sum_{i=1}^{12} X_{7j} \leq 58732$, $\sum_{i=1}^{12} X_{8j} \leq 49450$,
$\sum_{i=1}^{12} X_{9j} \leq 49150$, $\sum_{i=1}^{12} X_{10j} \geq 48750$, $\sum_{i=1}^{12} X_{11j} \geq 60350$, $\sum_{i=1}^{12} X_{12j} \geq 52340$,

The solution to the above model was obtained using QM packages which employed MODI method in solving the problem.

4. Result Discussion

Table 1 gives the company's financial year (2017) production plan in cartons. A carton contains twenty-four pieces of the product. Inventory at the beginning of January, 2017 was 55,340 cartons. The cost of production per carton is ₦960.00 and the unit cost of storage per month is ₦16.00.

Table 1: Capacity data for the company (in cartons)

S/N	Months	Demand	Supply
	Inventory at the beginning of 2017		55,340
1	January	53,420	49,735
2	February	49,735	59,300
3	March	54,195	54,010
4	April	59,115	59,570
5	May	50,670	65,240
6	June	50,150	53,059
7	July	58,732	54,023
8	August	49,450	55,730
9	September	49,150	59,292
10	October	48,750	59,350
11	November	60,350	65,750
12	December	52,340	54,060
	Total	**631,137**	**639,384**

(FARO, 2018)

4.1 The Initial Feasible Table

Table 2 shows the production cost per carton plus the storage cost in each cell. For example, in cell C22 (Jan, Feb) the cost is ₦960 whereas in the next cell C2,3 (Jan, March) the cost is ₦976. Where production is not feasible, we assigned high cost of ₦10000. For example in cell C4,1 (Feb, Jan), the cost is N10000. This is because the company cannot produce in the month of February and satisfy a January demand the same year.

Table 3 gives the optimal solution to the problem solved by the QM software. It gives the allocations with minimum total production cost. The company's production plan for the 2017 financial year would have incurred a total of Six hundred and fourteen million, Six-hundred and Ninety four thousand eighty naira (N614,694,080) for producing a total of Six-hundred and Ninety four thousand, seven hundred and twenty four cartons of the product. The optimal solution from table 3 is Five hundred and sixty million, two hundred and ninety five thousand and nine hundred and sixty eight naira (₦560, 295,968). The company could have reduced total production cost by ₦54,398,112 if the above optimal schedule was used.

Table 4 gives the summary of the optimum solution. From the summary, from the inventory last year all the demand in January was met. The allocation of Dummy demands is not counted. They are introduced to satisfy the rim condition of transportation model.

Table 2: Initial Table the QM Software uses to Generate Results

Sol.	January	Februray	March	April	May	June	July	August	September	October	November	December	**Supply**
Inventory	16	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	**55340**
January	10000	960	976	992	1008	1024	1040	1056	1072	1088	1104	1120	**49735**
Feburary	10000	10000	960	976	992	1008	1024	1040	1056	1072	1088	1104	**59300**
March	10000	10000	10000	960	976	992	1008	1024	1040	1056	1072	1088	**54010**
April	10000	10000	10000	10000	960	976	992	1008	1024	1040	1056	1072	**59570**
May	10000	10000	10000	10000	10000	960	976	992	1008	1024	1040	1056	**65240**
June	10000	10000	10000	10000	10000	10000	960	976	992	1008	1024	1040	**53059**
July	10000	10000	10000	10000	10000	10000	10000	960	976	992	1008	1040	**54023**
August	10000	10000	10000	10000	10000	10000	10000	10000	425	960	976	992	**55730**
Sept.	10000	10000	10000	10000	10000	10000	10000	10000	10000	960	976	1008	**59292**
October	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	960	976	**65750**
November	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	960	**65750**
December	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	**54060**
Demand	**53420**	**49735**	**54195**	**59115**	**50670**	**50150**	**58732**	**49450**	**49150**	**48750**	**60350**	**52340**	

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Table 3. Optimal Solution to the Production Scheduling Problem extracted from the QM Software

Sol.	January	Februray	March	April	May	June	July	August	September	October	November	December	Dummy
Inventory	53420												1920
January		49735											0
Feburary			54195	5105									0
March				54010									
April					50670								8900
May						50150	5673						9417
June							53059						
July								49450					4573
August									49150				6580
Sept.										48750	1000		9542
October											59350		
November												52340	13410
December													54060

Table 4 Summary of the Optimum Production Schedule Generated by the QM Software

From	To	Production Unit	Cost per Unit (₦)	Production Cost (₦)
Inventory	January	53420	16	854,720
January	February	49735	960	47,745,600
February	March	54195	960	52,027,200
February	April	5105	976	4,982,480
March	April	54010	960	51,849,600
April	May	50670	960	48,643,200
May	June	50150	960	48,144,000
May	July	5673	976	5,536,848
June	July	53059	960	50,936,640
July	August	49450	960	47,472,000
August	September	49150	960	47,184,000
September	October	48750	960	46,800,000
September	November	1000	976	976,000
October	November	59350	960	56,976,000
November	December	52340	960	50,246,400

POM-QM software, 2018

The optimal scheduling as presented in Table 4 gives the required product amount to be allocated for demands during each production period of the year. The optimal allocation reflected the objective of minimizing the total cost of production. Some of the inventory at the beginning of the financial year that is 53420 cartons were used to meet the demands in January with a total production (inventory) cost of 854,720 naira, the production in January (49735 cartons) will be used to meet the demand in February with a production cost of 47,745,600 naira, February production will be used to meet the demand in March and Some demand in April with 52,027,200 and 4,982,480 naira respectively. Production in March will be used to meet demand in April with a production cost of 51,849,600 Naira; production in April will be used to meet demand in May with a cost of 48,643,200. Production in May will be used to meet demand in June and some demand in July with a cost of 48,144,000 and 5,536,848 respectively. Production in June will be used to meet demand in July with a cost of 50,936,640. Production in July will be used to meet demand in August with a cost of 47,472,000. Production in August will be used to meet demand in September with a cost of 47,184,000. Production in September will be used to meet demands in October and November with a cost of 46,800,000 and 976,000 respectively. Production in October will be used to meet demand in November with a cost of 56,976,000 and Production in November will be used to meet demand in December with a cost of 50,246,400.

The aim of the study was achieved which the production schedule has been minimized. The reduced total cost of production is ₦560,295,968.00 using our model as against a total cost of production of ₦614,694,080.00 used by the company, this difference of ₦54,398,112.00 in the cost is very significant to organization. Also the objectives were all achieved.

5. Conclusion

The modeling of the real life production problem as a transportation problem has been demonstrated in this study. The theoretical methods of solving transportation models as special cases of linear programming developed by Dantzig and Wolfe (1951), such

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as VAM, North West Corner and least square methods have been proven to be acceptable in addressing similar problems of scheduling. The computer package QM was used to analyze the scheduling model. The optimal result shows an improvement over the existing production plan of the company with reduced cost of **₦54,398,112**. A systematic monthly allocation plan was presented with the respective amount to satisfy the demand of the company's customers at a reduced production cost. Hence, our model is recommended to the production manager of Adama Beverages Limited (FARO) for implementation.

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