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Optimization of Production Scheduling in a Production Company Using Transportation Model

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Abstract

Transportation model is one of the most predominantly used technique in the field of Operational Research, it is widely used as a decision-making tool in industries and organizations to help managers make better decisions. The performance of any industry/organization depends on both its technological expertise and managerial and organizational effectiveness. In this paper, a production scheduling problem of 1500 ml of packaged Faro water produced by Adama Beverages Limited (ABL), Yola, is modelled as a transportation model and analyzed using Production and Operations Management (POM) Software. The result of the analysis shows that the Company would minimize its yearly cost of production by ₦85, 424,780:00 (46.25%), if proper production scheduling is being adhered to.

Keywords: EOQ; Transportation model; Inventory Control; production scheduling; Demand; Capacity

Introduction

Adama Beverages Limited (ABL) Yola, Adamawa State is a manufacturing industry engaged in the production of different categories of Bottled water, Bottled Juice, Sachet water, Jar water and sachet Juice. This study concentrated on only one product whose production and demand was regular throughout the year and its data were available. The product considered is 1500 milliliters of Faro bottled water.

A well planned work schedule is very essential to the progress of any firm; it will achieve reduced production cost and meet customers demand. Unplanned work schedule leads to overlap between the different shift and hence high cost of production (Stephen, Yue, & Lai, 2003). As a result of this, the study used the transportation modeling technique with dynamic Economic Order Quantity involving production in order to establish an optimal production scheduling for the product under study. Presently, the company carries out overtime production throughout the year which leads to maintaining a high labour force, but with this production plan the company need not to carry out overtime production throughout the year unless it is to meet specific orders. This will enable the company to reduce its labour force and to considerably reduce the overall production cost which could be re invested in other aspects of the business.

The aim of this research is to design a master production schedule (MPS) in order to have a well-planned production scheduling to help ABL reduce cost of producing 1500ml of Faro bottled water. However, the specific objectives of the study are to:

- Find optimal solution to the transportation problem.
- Minimize production cost.

The Transportation Model

Transportation problem is one of the most interesting linear programming problems concerning with the distribution of products or services. The main objective of the model is to determine the amount of products that will be shifted from each source to each destination that will minimize the total cost of transportation while satisfying the demand of each destination. If the transportation costs from every source to all destinations are known, then transportation problem will determine the routes in such a way that the minimum possible transportation cost incurs (Kavitha & Vinoba, 2015). The problem was first formalized by French Mathematician G. Monge in 1781. A Russian mathematician L. V. Kantorovich made some major advancement in this field during and after the World War II to solve the post war problems. This is why the problem is sometimes stated as Monge-Kantorovich problem (Abdulsattar, Gurudeo, & Ghulam, 2014). Hitchcock (1941) gave the mathematical description of the transportation problem and was further developed by Koopman (1947) and Dantzig (1963) (Reena & Bhatwala, 2015).

The problem is stated in two forms; the balanced and the unbalanced transportation problems (Ahmed, 2012). In balanced transportation problem the total quantity of demand of all the destinations is equal to the total quantity to be supplied by all the sources. Whereas, in the unbalanced problem, total supply from all sources is not equal to the total demand of all the destinations. The unbalanced transportation problem is converted into the balanced one by adding dummy source or dummy demand. Figure 1 below provides a schematic overview of transportation problem with m sources (S_1, S_2, … S_m) and n destinations (D_1, D_2, …, D_n).

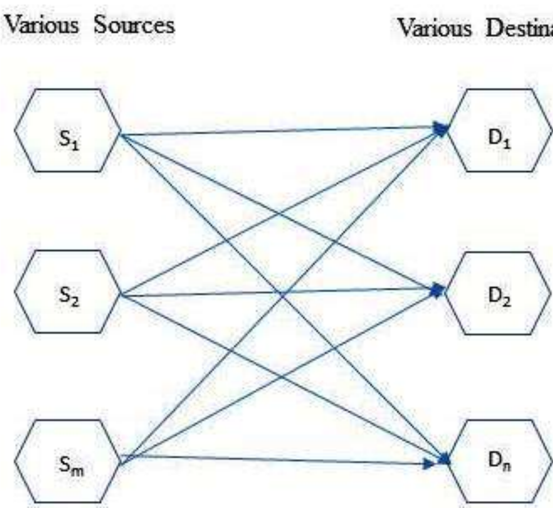

Figure 1: Transportation of goods from m sources to n destinations (Purnima & Gyan, 2014)

Mathematical Formulation of Transportation Problem

Let X_{ij} = Quantity of product supplied C_{ij} = Cost of transportation of unit quantity from ith source to jth destination, a_i = amount of quantity of the product available at ith source, b_j = amount of quantity of the product required at jth destination

The objective of the model is to minimize total cost of transportation which is formulated as:

$$Minimize\ Z = \sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij} x_{ij}$$

Subject to:
$$\sum_{j=1}^{n} x_{ij} = a_i, \quad i = 1, 2, \dots, m$$
$$\sum_{i=1}^{m} x_{ij} = b_j, \quad j = 1, 2, \dots, n$$
$$x_{ij} \geq 0 \qquad \forall\ i, j$$

A necessary and sufficient condition for the existence of a feasible solution for the transportation problem is that the total supply is equal to the total demand, i.e.

$$\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j$$ (Purnima & Gyan, 2014).

The Production Problem

Production problem is similar to the transportation problem except that in the production problem, it is possible to both ships into and out of the same node (point). It is an extension of the transportation problem in which intermediate nodes, referred to as trans-shipment nodes, are added to account for locations such as warehouses. The general linear programming model of a production problem is:

Minimize: $Z = \sum_{allarcs} c_{ij} x_{ij}$

Subject to: $\sum_{arcout} x_{ij} = \sum_{arcin} x_{ij} \leq s_i$ Monthly Production levels …………………… (1)

$\sum_{arcout} x_{ij} - \sum_{arcin} x_{ij} = 0$ Production nodes ………………. (2)

$\sum_{arcin} x_{ij} - \sum_{arcout} x_{ij} = d_j$ Monthly demands to be met ………….... (3)

Where

x_{ij} = number of units shipped from a production level to a demand point.

c_{ij} = Cost per unit of shipping from a production level to a demand point.

s_i = Supply at each production level.

d_{ij} = Demand at each demand point (Purnima & Gyan, 2014)

Materials and Methods

The data used in this study is a secondary data collected from the company, for the year 2014. The data include the regular production capacity, overtime production capacity and the monthly demand of the 1500ml of Faro bottled water.

The data were collected through interview with some operators in the production unit, stores and operations manager in the company. The production capacities (regular and overtime) and the monthly demand of the products were obtained from the operations department while the initial inventory as at July 2013 of the product was obtained from the store's manager. The production cost and the unit holding cost were obtained from the finance department. The unit holding cost and the production cost were collected per carton. The cost per bottle was calculated by dividing each cost per carton by the number of bottles in the carton.

Time periods during which production can take place are the regular shifts and overtime shifts for each of the twelve months. Since each of these twelve months periods becomes a source, we then added a thirteenth source, the initial inventory, since it can also supply goods. Time periods during which products will be required or demanded are the twelve months. These become the destinations, with a total demand of 2,790,000 bottles. Costs associated with the initial inventory are future carrying cost only, since production costs and past carrying charges have already been incurred and cannot be minimized. The remaining cost entries are simply the production cost plus storage charges.

Any unused overtime capacity will be shipped to the dummy demand point. To ensure that no goods are used to meet demand during a month prior to their production, a prohibitively large cost (say ₦ 10,000) is assigned to any cell that corresponds to using regular production to meet demand for a current or an earlier (or previous) month. In the same way, since units produced during overtime shifts must be used to meet demands in the same month as produced, a prohibitively large cost is also assigned to a cell that corresponds to using overtime production to meet next month's demand. Combining these observations yields the balanced production problem and its optimal solution in Figures 2 and 3 respectively.

Table 1 provides the product information, Table 2 shows that the total regular capacity was 3,314,000 units and total overtime capacity was 1,657,000 which gives a total supply of 4,971,000 and the total demand was 2,790,000 units. The total supply exceeds total demand by 2,301,000. This shows that a dummy demand of 2,301,000 was created to balance the transportation model. Table 3 shows that the non-optimal production cost was ₦184, 292,000:00.

Table 1: Production Information

Production category	Number of bottles/ carton	Regular prodctn. cost (in ₦)	Overtime prodctn. cost (in ₦)	Unit holding cost/bottle (in ₦)	Inventory as at July, 2013
1500 ml	12	37	37.22	0.25	120,000

Source: Adama Beverages Limited (ABL)

Table 2: Production capacity of 1500ml Faro Bottled Water (in thousands of bottles)

Months	Regular capacity (‘000)	Overtime capacity (‘000)	Demand (‘000)
July	206	103	155
August	270	135	314
September	234	117	143
October	320	160	320
November	280	140	286
December	220	110	181
January	300	150	351
February	280	140	204
March	322	161	306
April	240	120	188
May	320	160	129
June	322	161	213
Total	3,314	1,657	2,790

Source: Production Unit, Adama Beverages Limited (ABL).

Table 3: Non-Optimal Production cost for 1500ml Faro Bottled Water

Production Schedule	Production Capacity (₦) (A)	Unit Cost (₦) (B)	Production Cost (₦) (A X B)
Regular Time	3,314,000	37.00	122,618,000
Overtime	1,657,000	37.22	61,673,540
Total	**4,971,000**		**184,291,540**

Method of Data Analysis

The data collected in this study were modeled as a transportation problem and was analyzed using Production and Operations Management (POM) for windows software. The production cost of Faro bottled water is made up of treated distilled water, packaging materials and utilities. Production is carried out in three shifts of 8 hours per shift. At the beginning of each month, the company decides how many products should be produced during the subsequent month. The productions are in two phases namely regular and overtime where the first two shifts are considered to be regular production period (i.e. from 7:00 AM to 10:00 PM) and the last shift is considered to be overtime production period (i.e. from 11:00 PM to 6:00 AM).

Results and Discussions

Figure 3 shows the breakdown of the optimal production schedule that minimize the cost of producing 1500ml of Faro Bottled Water. The minimized cost of production is ₦98,867,220:00. The regular production of 35,000 units produced in June, 2013; and the inventory of 120,000 units were used to supply the demand for July, 2013. The regular production 206,000 from July, 2013 plus overtime production of 108,000 units from August will be used to supply demand in August, 2013. The regular production of 143,000 units from August, 2013 was fully used to serve the demand for September 2013. The demand for October, 2013 was met by 234,000 units produced during regular production in September, 2013 plus 86,000 units from overtime production in October 2013. The demand for November, 2013 was met by 286,000 units from the regular production in October, 2013 while the demand for December, 2013 was met by 181,000 units from regular production in November, 2013. The demand in January, 2014 was met by regular production of 220,000 units from December, 2013 plus overtime production of 131,000 units from January, 2013. The demand in February, 2014 was met by 204,000 units from the regular production in January, 2014. All 280,000 units produced during regular production in February, 2014 and 26,000 units from overtime production in March are used to satisfy demand in March, 2014. The regular production of 188,000 units from March, 2014 was used to satisfy demand in April, 2014. The regular production of 129,000 units from April, 2014 was used to satisfy demand in May, 2014. The regular production of 213,000 units from May, 2014 was used to satisfy demand in June, 2014. From the results, it is clear that, the overtime production for July, 2013, September 2013, November 2013, December 2013, February 2014, April 2014, May 2014 and June 2014 are not necessary that the management can do away with them to save cost. Table 4 shows that the company will save a cost of ₦85, 424,780 (i.e. 46.35% of the total production cost) from the production of 1500ml Faro bottled water if this production schedule is followed.

Table 4: Saved Cost for the Production of 1500ml

Bottle type	Non-optimal cost (A)	Optimal cost (B)	Saved cost (A-B)	Percentage saved cost
1500 ml	184,291,540	98,867,220	85,424,320	46.35%

Conclusion

The fact that companies can use efficient scheduling system to reduce production cost and inventory cost simultaneously while satisfying their customer's demand is justified in the analysis of the data. With efficient scheduling, the company was able to reduce the production cost of 1500ml of Faro bottled water by 46.35% as shown in Table 4 above. The study also revealed that efficient scheduling system and control can facilitate the production processes in a number of ways. First and foremost, scheduling system can result in optimum utilization of capacity. Thus companies, with the help of good production scheduling system, can schedule their task and production in a way to ensure that production capacities i.e., employees and machinery do not remain idle, they should be fully utilized and that there is no undue queuing up of task since there is proper allocation of task to the production facilities.

	July 2013	Aug 2013	Sep 2013	Oct 2013	Nov 2013	Dec 2013	Jan 2014	Feb 2014	Mar 2014	Apr 2014	May 2014	June 2014	SUPPLY
Initial Inv. June 2013	0	.25	.5	.75	1	1.25	1.5	1.75	2	2.25	2.5	2.75	120
Regular July	10000	37	37.25	37.5	37.75	38	38.25	38.5	38.75	39	39.25	39.5	206
Regular Aug	10000	10000	37	37.25	37.5	37.75	38	38.25	38.5	38.75	39	39.25	270
Regular Sep	10000	10000	10000	37	37.25	37.5	37.75	38	38.25	38.5	38.75	39	234
Regular Oct	10000	10000	10000	10000	37	37.25	37.5	37.75	38	38.25	38.5	38.75	320
Regular Nov	10000	10000	10000	10000	10000	37	37.25	37.5	37.75	38	38.25	38.5	280
Regular Dec	10000	10000	10000	10000	10000	10000	37	37.25	37.5	37.75	38	38.25	220
Regular Jan	10000	10000	10000	10000	10000	10000	10000	37	37.25	37.5	37.75	38	300
Regular Feb	10000	10000	10000	10000	10000	10000	10000	10000	37	37.25	37.5	37.75	280
Regular Mar	10000	10000	10000	10000	10000	10000	10000	10000	10000	37	37.25	37.5	322
Regular Apr	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	37	37.25	240
Regular May	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	37	320
Regular Jun	37	37.25	37.5	37.75	38	38.25	38.5	38.75	39	39.25	39.5	10000	322
Overtime Jul	37.22	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	103
Overtime Aug	10000	37.22	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	135
Overtime Sep	10000	10000	37.22	10000	10000	10000	10000	10000	10000	10000	10000	10000	117
Overtime Oct	10000	10000	10000	37.22	10000	10000	10000	10000	10000	10000	10000	10000	160
Overtime Nov	10000	10000	10000	10000	37.22	10000	10000	10000	10000	10000	10000	10000	140
Overtime Dec	10000	10000	10000	10000	10000	37.22	10000	10000	10000	10000	10000	10000	110
Overtime Jan	10000	10000	10000	10000	10000	10000	37.22	10000	10000	10000	10000	10000	150
Overtime Feb	10000	10000	10000	10000	10000	10000	10000	37.22	10000	10000	10000	10000	140
Overtime Mar	10000	10000	10000	10000	10000	10000	10000	10000	37.22	10000	10000	10000	161
Overtime Apr	10000	10000	10000	10000	10000	10000	10000	10000	10000	37.22	10000	10000	120
Overtime May	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	37.22	10000	160
Overtime Jun	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	37.22	161
DEMAND	155	314	143	320	286	181	351	204	306	188	129	213	

Figure 2: Production Modelling of 1500ml of Faro Bottled Water

Optimal cost = $98867.22	July 2013	Aug 2013	Sep 2013	Oct 2013	Nov 2013	Dec 2013	Jan 2014	Feb 2014	Mar 2014	Apr 2014	May 2014	June 2014	Dummy
Initial Inv. June 2013	120												
Regular July		206											
Regular Aug			143										127
Regular Sep				234									
Regular Oct					286								34
Regular Nov						181							99
Regular Dec							220						
Regular Jan								204					96
Regular Feb									280				
Regular Mar										188			134
Regular Apr											129		111
Regular May												213	107
Regular Jun	35												287
Overtime Jul													103
Overtime Aug		108											27
Overtime Sep													117
Overtime Oct				86									74
Overtime Nov													140
Overtime Dec													110
Overtime Jan							131						19
Overtime Feb													140
Overtime Mar									26				135
Overtime Apr													120
Overtime May													160
Overtime Jun													161

Figure 3: Optimal Production Schedule for 1500ml of Faro Bottled Water

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