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Research Article

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An Optimal Warehouse Management for Production Companies

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Abstract To assist production planning decisions, a mixed integer linear programming for a variant of the homogenous-vehicle, multi-product production routing problem model is developed which took into account the production, the delivery requirements, multiple products, and different inventory levels. The objective is to minimize the sum of the production, transportation, and inventory costs. The proposed framework is validated with case studies in a rice milling company (Shaman Concept Nig. Ltd) which was analysed using Quantitative Methods (QM), Production and Operations Management (POM) for Windows V5.2 Build 128. The results show that significant savings can be obtained by using this scientific integrated approach with respect to the current company practice and were recommended to the case company for optimum use in scheduling there monthly production output.

Keywords Optimal Production, Inventory, integer programming, Scheduling

Introduction

Production planning is important in a manufacturing facility to ensure efficient, and effective utilization of resources. It typically involves sequencing and scheduling the production batches, determining the optimal batch quantities and prioritizing the batches. In reality, the planning of the production processes is often conducted under a variety of uncertainties, such as demand, machine availability, worker efficiency, etc. Therefore, it is important to take the uncertainties into consideration when making the production decisions [1].

Production planning plays an important role in improving overall manufacturing system performance, especially when a system operates in an uncertain environment. Uncertainty in product demand, processing time, and quality of raw materials are among the common types of uncertainties that characterize production environment. Scheduling is the process of arranging, controlling and optimizing work and workloads in a production or manufacturing process. It is used to allocate plant and machinery resources, plan human resources, plan production processes and purchase materials [2].

Despite the benefits of increased foreign trade and investment for companies including access to more customers and cheaper resources, globalization increases competition. Companies need to have long-term plans and manage their operations and logistics efficiently to remain competitive in a global marketplace. As a result, coordination between production and transportation scheduling and distribution planning has received increased attention in global companies [3]. To minimize the total cost, manufacturing firms should integrate their production and logistics decisions, especially when considering the rising costs of transportation and distribution of finished products. Emerging global competition has made it possible for logistics companies to improve their warehousing and distribution services. Most organizations have made it clear by designing and operating a customized warehousing and distribution service that deliver great benefits. There has been more focus on operational excellence which implies you must consistently deliver quality service across all operations. Many manufacturing companies are now outsourcing their outbound logistics, because they cannot do it themselves and remain competitive. They began to look to third party specialist to perform activities that were not a part of their core competency [4].

Literature Review

Many researchers had investigations planning and scheduling related problem. For example Mouli *et al.* [5], uses Optimal Production Planning under Resource Constraints. Mijinyawa *et al.* [6], uses special case of linear programming (LP) and presented an efficient scheduling that minimizes the total cost of production in a manufacturing industry. Amponsah *et al.* [7] conducted a similar research on "production scheduling" using a case study of beverage manufacturing company in Accra. Their model reduces the production cost and suggested optimal level of production monthly. Many optimization techniques were employed in the management of productions as well as warehouses in an attempt to efficiently utilize the limited resources. For instance Muhammad *et al.* [8] applied LPP to address resource allocation problem in foam manufacturing industry. Ant Colony Optimization (ACO) approaches was used by Santos *et al.* [9] in a manufacturing scenario with parallel resources. Other researchers include but not limited to Roubellat & Lopez [10]; Herrmann [11]; Javanmard & Kianehkandi [12]; Kumral [13]; Benkherouf & Boushehri [14] among others.

According to Hassan [15], the transportation model can be extended to areas such as inventory control, warehouse management, and employment scheduling, machine and personnel assignment among others. Therefore, this research seek to incorporate the costs of production, inventory and transportation using a mixed integer programming to develop a framework that ultimately minimize the total cost and guarantee the optimal management of warehouse in the production company.

Materials and Method

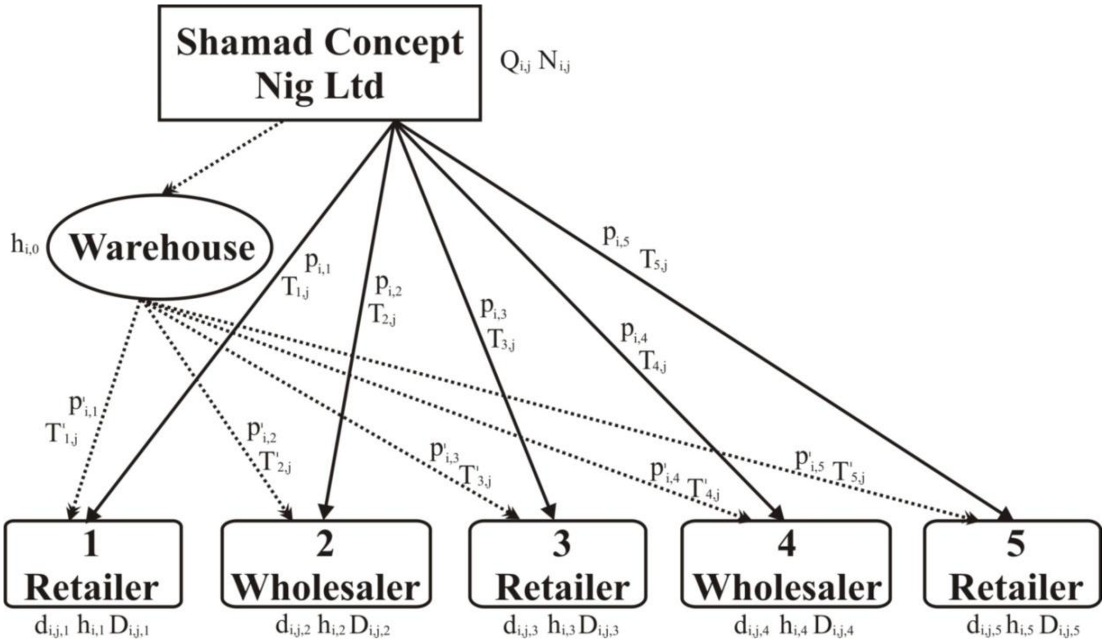

Figure 1: Flow of Products and Decision Variables at each location

Shamad Concept Nig. Ltd relies on traditional methods of production planning and inventory with production, inventory and distribution planned separately. In order to minimize the total costs of production, a mixed integer linear programming model of the problem was formulated by integrating production, inventory and transportation (see fig.1).

Asingle production line (Shamad'sYola Factory) is considered such that the line is characterized by capacity *C*, setup cost *k* and setup time *t*, expressed in terms of kilograms (bags) of rice, all requests are delivered in direct shipments and usually full truckloads. In this case, even if routing is allowed, it is convenient to serve each retailer directly, with almost-full-load vehicles every time instant. The set of locations for products di is$l$ = {0, 1, 2, 3, 4, 5} where *location 0* denotes the plant's location and locations for the customers to range from 1 to

5.The number of products produced in the production line was denoted by $i = 1, 2$.Also Y defined a set of homogenous vehicles (for distribution) and H the planning horizon.

Minimize:

$$\sum_{i=1}^{m}\sum_{j=1}^{n} N_{ij}\,k + \sum_{i=1}^{m}\sum_{j=1}^{n} e_i Q_{ij} + \sum_{l=0}^{z}\sum_{i=1}^{m}\sum_{j=1}^{n} h_l I_{ijl} + \sum_{l=0}^{z}\sum_{j=1}^{n} p_l T_{lj} \tag{1}$$

Subjectto:

$$I_{ij0} = I_{i(j-1)l} + \left(Q_{ij} - \sum_{i=1}^{z} D_{ijl}\right) \tag{2}$$

$$I_{ijl} = I_{i(j-1)l} + \left(D_{ijl} - d_{ijl}\right) \tag{3}$$

$$\sum_{i=1}^{m} I_{ijl} \le g_l \tag{4}$$

$$I_{ij0} \ge u_{ij} \tag{5}$$

$$\sum_{i=1}^{m} D_{ijl} \le v \times T_{jl} \tag{6}$$

$$Q_{ij} \le C \times N_{ij} \tag{7}$$

$$\sum_{i=1}^{m} Q_{ij} \le C + \left(1 - \sum_{i=1}^{m} N_{ij}\right) \times t \tag{8}$$

$$\sum_{l=1}^{z} T_{jl} \le |Y| \tag{9}$$

$$\sum_{i=1}^{m} N_{ij} \ge 1 \tag{10}$$

$$Q_{ij} \ge q \times N_{ij} \tag{11}$$

$$D_{ijl} \ge 0 \tag{12}$$

$$I_{ijl} \in \mathbb{N} \tag{13}$$

$$Q_{ij} \ge 0 \tag{14}$$

$$T_{jl} \in \mathbb{N} \tag{15}$$

$$N_{ij} \in \begin{cases}1\\0\end{cases} \tag{16}$$

Where,

i : An index representing a product

j : An index representing a period (i.e. months);

l : An index representing a location (i.e. the plant, regional depots and wholesalers);

C: A parameter representing the production capacity of the line;

k : A parameter representing the setup cost of the production line;

q : A parameter representing the minimal production lot of the production line;

t : A parameter denoting the setup time of the production line;

e_i : A parameter representing the unit (i.e., per bag) production cost associated with product i

$u_{i,j}$: A parameter denoting the safety stock of product i at each period that must be ensured by the plant;

$r_{i,l}$: A parameter representing the starting inventory level of product i at location l;

$h_{i,l}$: A parameter denoting the inventory holding cost for each product i in each location l;

g_l : A parameter denoting the global inventory-holding capacity (i.e. for all products) for each location l;

$d_{i,j,l}$: A parameter representing the demand of product i in period j at location l;

p_l : A parameter representing the transportation cost for location l (except location 0 because location 0 is the plant's location, also this takes into account the cost of empty return to the plant);

v : A parameter denoting the vehicle capacity expressed in terms of bags;

$Q_{i,j}$: Real variable representing production quantity (in bags) produced in the production line of product i in period j;

$I_{i,j,l}$: Integer variable representing inventory of product i (in bags) at location l (including location 0) in period j;

$N_{i,j}$: Binary variable equal to 1 if product i is produced in period j, and 0 otherwise;

$T_{l,j}$: Integer variable representing the number of trucks sent to location l in period j ;

$D_{i,j,l}$: Real variable representing the quantity of product i delivered to location l (Except location 0 because it is plant's location) in period j.

The objective function (1) minimized the total cost which consists of three components; the cost of production, the cost of inventory and the cost of distribution. Constraints (2) and (3) defined the inventory conservation at the supplier and customers respectively, indeed almost in the plant and customers, the inventory at each day is equal to the inventory of the last day increased by the inputs and decreased by the outputs. Constraint (4) imposed a maximal inventory level at the supplier and at the customers, as our case is from real-life, each location has a maximal inventory capacity which must not be exceeded. Constraint (5) ensured that a safety stock of each product is held in the plant. Indeed, to avoid stock-out and ensure the continuity of shipping products to customers especially in the high season, a safety stock by products must be held at the plant. Constraint (6) ensured that the vehicle capacities are respected. In this case, we use a homogeneous fleet of vehicles with a fixed capacity. Constraint (7) ensured that the production capacity is respected. The production line has a production capacity which depends on the bottleneck machine line. Constraint (8) ensured that a setup time, measured in bags. Constraint (9) ensured that a vehicle can deliver, in the same period. Constraint (10) ensured that at least one product is produced for the line in each time period; at least one product must be produced each time period. Constraint (11) ensured the minimum process lot size. The production scheduler can't change the product on the machine if a minimal quantity of this product is not produced. Constraints (12) to (16) imposed integrality and non-negativity conditions on the variables.The data collected was analysed using QM for Windows V5.2 Build 128 software application in obtaining the optimality value for the production, inventory and transportation costs.

Result and Discussion

There is one plant (factory) that produces two different brand of rice (Parboiled and White) and cannot exceed 300 bags of rice (both brands) per day.

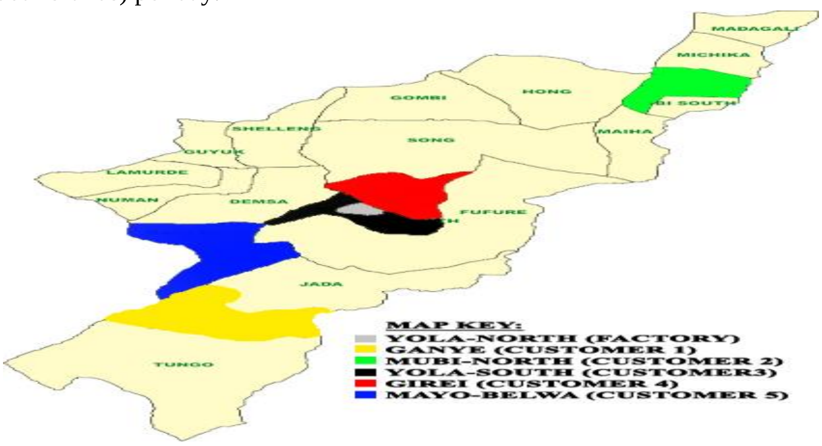

Figure 2: Location of Plant (Factory) and Customers

The unit production costs (per bag) are N13,000.00 and N14,000.00 for parboiled and white respectively. Changing the production type in the factory has a setup cost of N2,000.00 and a consistent safety stock of 30 bags and 40 bags of parboiled and white rice respectively. The products can be stored in the factory or plant warehouse, which has a storage capacity of 2,000 bags and 70,000 bags respectively (both parboiled and white rice), or products shipped to a sample of 5 customers within Adamawa State (Ganye, Mubi, Yola, Girei and

Mayo-Belwa). The daily inventory holding cost for each bag is on average equal to N7.00 (for warehouse and factory), and N16.00 per bag for each warehouse in wholesaler and retailers locations however the wholesalers support themselves with their inventory holding costs.

The storage capacity at the customers ranges from 100 to 500 bags. The transportation is fully outsourced by3 available trucks .Each vehicle can carry up to 150 bags of rice. Finally, for each period (i.e., one day) of the planning horizon the total daily demand for each location: Ganye, Mubi, Yola, Girei and Mayo-Belwa is (60, 90, 42, 30, 30) for parboiled rice and (40, 60, 28, 20, 20) for white rice respectively daily.

Table 1: Table of Result Obtained

RESULT	**LOCATION (l)**						
	Period	**Factory**	**Ganye**	**Mubi**	**Yola**	**Girei**	**Mayo-Belwa**
Inventory (I_{1jl})	1 month	30 bags	3 bags	0 bags	3 bags	6 bags	6 bags
Inventory (I_{2jl})	1 month	110 bags	2 bags	0 bags	2 bags	4 bags	4 bags
Number of trucks delivery (T_{jl})	1 month	–	7trucks	10trucks	5 trucks	4 trucks	4 trucks

$N_{11} = 1$; $N_{21} = 1$; $Q_{11} = 190$ bags; $Q_{21} = 90$ bags.

We decomposed the total cost into three components; production, transportation and inventory costs. Figure 3 shows the results; it was observed that the cost of production far exceeds other costs.

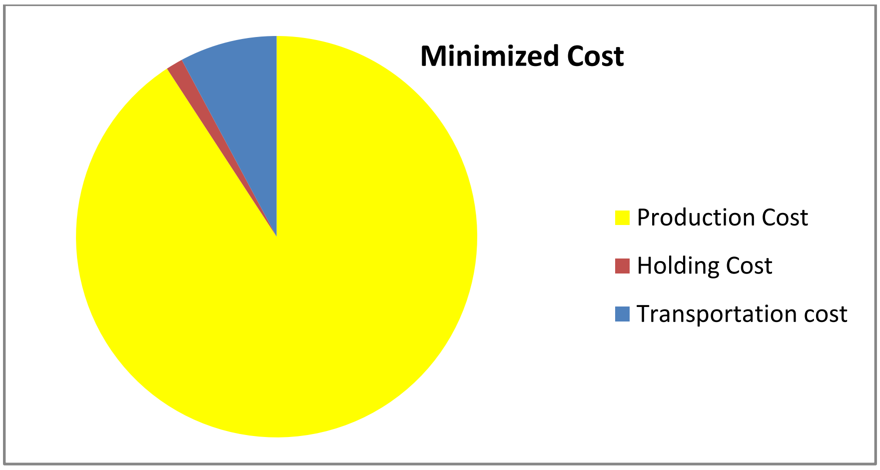

Figure 3: Pie Chart representing the decomposed cost components

The result of the analysis shows a reduction of 10.97%in the overall cost (actual cost = N4,194,000.00) of production, holding and transportation. The company's current strategy is to move product to warehouse and distribute to customers in order to minimize holding cost costs. Therefore, in the company's solution, transportation costs are higher and storage costs are lower, however, a global view will reduce the total cost and thus make the company more competitive. By producing a lesser amount of white rice compared to parboiled rice but the constraints are respected for each case of production, inventory and transportation costs.

Conclusion

Production planning is the process of the effective allocation and use of resources such as materials and production capacities to meet the requirements of customers. Due to the significance of the different production related costs, the planning of production lot-sizing and scheduling activities plays an essential role in optimizing the costs. In this paper we presented a study of a manufacturing system with a single production line of two products. Our objective was to determine the optimal production plan, which includes the production, inventory and transportation costs of each product. A mathematical model (mixed integer linear programming model) was developed in order to determine the optimal plan that maximises the total cost. Data was collected for every parameter of the model and was substituted into the model, which was read-in and solved using Quantitative Methods (QM), Production and Operations Management (POM) for Windows V5.2 Build 128.From the analysis of the result, it shows that the optimum production of the two products at every month runs at the optimal quantity 280 bags per day (190 bags parboiled rice, 90 bags of white rice approximately), yielding a reduction of 10.97% in the total cost (production, holding and transportation). The initial total cost of production of the two products are N4, 230 000.00 as against the minimized cost (N3,766,801.00). The results were recommended to the aforementioned case Company.

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