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Proposal of Product-Replenishment Policy Determination on Multi-Source Problems to Minimize Over Stock in DC PT. XYZ Area Bandung Using Mixed-Integer Programming Method

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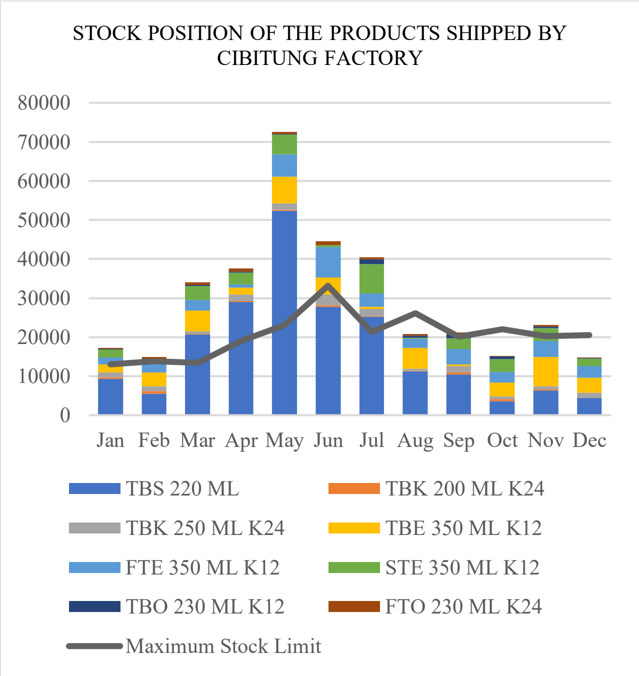
***Abstract*—** PT. XYZ is one of the companies engaging in fast moving consumer goods (FMCG) sector and produce soft drinks as its main product. In supporting the product distribution to its customers, PT XYZ has several administrative offices and distribution centers (DC) which spread across each region. The DC has main function as the warehouse which has storage activity before the products are distributed. One of the DC is located in Bandung, West Java. DC Bandung itself received product shipments from three factories, such as Cibitung, Cakung and Tambun. Related to the product shipment, DC Bandung has not determined the replenishment policy, and this condition results over stock at some periods, due to the unscheduled delivery time and undetermined product quantity. This condition gives a big impact to the total inventory cost that has to be borne by DC Bandung. This research was conducted to give the proposal of product replenishment policy using mathematical model with mixed-integer programming method as one of the linear programming types, which aimed to minimize over stock and total holding cost in DC Bandung with several constraints. Mathematical modeling is involved in this research as an approximation to the real replenishment system in the DC. The results of application of the proposed method are in the form of analytical solution, such as order quantity, and reorder point of each product that will give an impact to the total unit inventory and the total holding cost in the DC. The results calculation of replenishment policy provide savings on total inventory costs as much as IDR 23,800,981.20

***Keywords*—**Mixed-Integer Programming, Order Quantity, Over Stock, Replenishment Policy.

I. INTRODUCTION

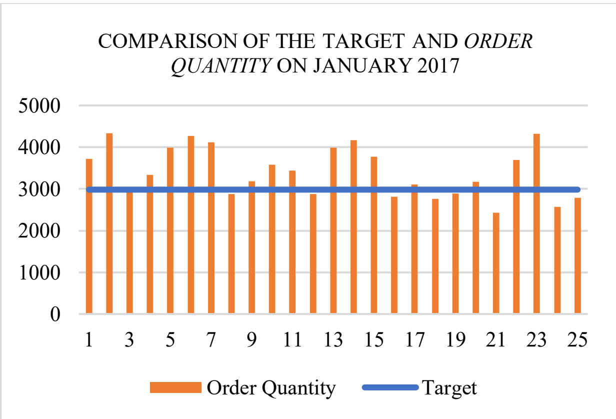
PT. XYZ is one of the companies which produce packaged soft drink in Indonesia. The company structure of PT. XYZ consists of factories, administration office, and distribution center. In supporting the distribution activity to its customers, PT. XYZ has 12 administration offices, and several distribution centers which spread across all regions in Indonesia. One of them is located in Bandung, West Java. DC Bandung is received product shipment from three factories, which is located in Cibitung, Cakung, and Tambun.

One of the supporting aspects of distribution activity is inventory. According to [1] inventory has an important role in company's performance because it exists in all steps of supply chain. The amount of excess inventory (over stock) will cause waste and will affect the high cost of inventory. In contrast, if the amount of inventory is too small, it will cause stock out so that the company could not fulfill customer demand [2]. Thus, inventory management is one aspect which can be used to measure the performance of PT. XYZ. Graph-1 shows the inventory position of products from the Cibitung factory.



Graph-1 Stock Posisiton of the Products Shipped by Cibitung Factory

Graph-1 shows that the number of stock position is above the maximum stock limit in DC on several periods and this condition known as over stock. The cause of over stock on DC may vary depending on the regulation on the DC itself. In this case, one of the causes of over stock is unscheduled replenishment time and quantity, so that the product accumulates in several periods as shown in graph-2



Graph-2 Comparison of the Target and Order Quantity on January 2017

Based on this problem, the solution needed is the proposed policy of replenishment schedule from the factory to DC Bandung to reduce the over stock occurred in DC.

II. LITERATURE REVIEW

2.1. Supply Chain Management

Supply chain [3] consists of all parties involved either directly or indirectly, in meeting customer demands. Supply chain does not only include producers and suppliers, but also transporters, warehouses, retailers, and customers. Supply chain includes all functions involved in receiving and charging customer requests. The supply chain involves various stages, such as [3]:

1. Customers
2. Retailers
3. Wholesaler / distributor
4. Manufacturer
5. Supplier of raw materials

2.2. Inventory

Inventory [4] is a stock of goods or resources used in an organization. According to [5] inventory is an item that is stored for future use or sale. Manufacturing inventory types include [4]:

1. Raw Material
2. Work-in-Process inventory
3. Finished products inventory

Based on the accumulated reasons, inventories can be classified as follows [6]:

1. Cycle Stock
   Cycle stock is an inventory that arises in the supply chain as the result of fulfilling inventory sold or used in production. Cycle stock is needed to meet the demand under certain conditions, that is, when a company can predict demand and lead time.

2. In-transit Inventory
   These are items that are traveling from one location to another. In-transit inventory is also considered to be part of the cycle stock even though this type of inventory is not available for sale or sent until after arriving at the destination. request function during lead time. The in-transit inventory provides security during supply delivery times.

3. Safety or Buffer Stock
   Safety or buffer stock is an inventory that occurs because of uncertainty in demand and lead time. Safety stock also serves to deal with

fluctuations and uncertainties in demand, supply, and lead time.

4. Speculative Stock
   Speculative stock is an inventory held for reasons other than to fulfill the demand. For example, the reason for purchasing a material with a larger volume than is needed because material prices are predicted to be increase or material gaps occur

5. Seasonal Stock
   Seasonal stock is a form of speculative stock which is included as an accumulation of inventory before the seasonal period begins. This often happens in agricultural products and other seasonal products.

6. Dead Stock
   Dead stock refers to existing items but do not have requests for certain periods of time. Dead stock has the possibility of experiencing obsolescence in storage.

2.3. Dynamic Lot sizing

In the scope of inventory management, dynamic lot sizing is defined as generalization of the EOQ model where the demand is varies for each product [7]. There are three aspects that influence decisions in procurement, such as [8]:

1. Minimize costs
2. Strategy (fulfillment of demand), and
3. Other limiting factors (warehouse capacity, etc.)

2.4. Integer Programming

In general, the linear programming (LP) model is used in determining solutions to problems to achieve several objectives and has several limitations, such as limited resources, etc. [9]

Components of the LP model include decision variables, objective functions, and model limitations that consist of decision variables and parameters [9]:

1. The decision variable is a mathematical symbol that represents the level of activity carried out by the company.
2. Objective function is a linear mathematical relationship that describes the company's objectives in the form of decision variables. Objective functions always maximize or minimize some values, such as profit maximization, or minimizing production costs
3. Limitation of the model is also alinear relationship of decision variables. The limit represents restrictions that exist in the operating environment. Like limited resources, etc.

In practice, the solution of LP can be either fractions or real numbers (non-integers). This prompts to find the optimal solution with integers. The types of integer programming models are [9]:

1. Total integer model where all decision variables have solution values in integer form
2. 0-1 integer model where all decision variables have zero or one solution, and
3. Mixed integer programming where decision variables have integer solution values, and non-integers (non-integers)

IV. DATA CALCULATION

3.1. Total Holding Cost Calculation (Existing)

In this case, calculation would be conducted by two sample products. Such as TBS 220 ml and TBE 350 ml k12

1. Demand

   Demand is defined as sales target which is determined by the factory. Table-1 shows the demand for January 2018

TABLE 1
DATA OF DEMAND FOR JANUARY 2018 (a)

Product	Days-									
	1	2	3	4	5	6	7	8	9	10
TBS 220 ML	1028	1028	1028	1028	1028	1028	1028	1028	1028	1028
TBE 350 K12	312	312	312	312	312	312	312	312	312	312

TABLE 1
DATA OF DEMAND FOR JANUARY 2018 (b)

Product	Days-									
	11	12	13	14	15	16	17	18	19	20
TBS 220 ML	1028	1028	1028	1028	1028	1028	1028	1028	1028	1028
TBE 350 K12	312	312	312	312	312	312	312	312	312	312

TABLE 1
DATA OF DEMAND FOR JANUARY 2018 (c)

No	Product	Days-				
		21	22	23	24	25
1	TBS 220 ML	1028	1028	1028	1028	1028
2	TBE 350 K12	312	312	312	312	312

2. Order Cost

   Order cost is the cost due to an order made from DC to the factory. This cost is fixed for each item order [10]. The order cost is calculated based on the order frequency, and the cost of procurement message which is determined by the company. The order cost for PT. XYZ is IDR 432.20/order. The following is the example of order cost calculation for a month period:

   TBS 220 ml

   O_p = f x A

   O_p = 9 x IDR 423.20

   O_p = IDR 3,808.80 per month

   TBE 350 ml K12

   O_p = f x A

   O_p = 8 x IDR 423.20

   O_p = IDR 3,385.60 per month

3. Holding Cost

   Holding cost is the cost due to storage activity in the DC. Holding cost is calculated based on amount of the products which is stored, and the holding cost for each unit. The holding cost in PT. XYZ is IDR 1.78/unit. The following is the example of holding cost calculation for a month period:

   TBS 220 ml

   O_s = m x h

   O_s = 208818 x IDR 53.08

   O_s = IDR 11,084,059.44 per month

   TBE 350 ml K12

   O_s = m x h

O_s = 77136 x IDR 53.08
O_s = IDR 4,094,378.88 per month

4. Total Holding Cost (Existing)
Total holding cost is the sum of order cost and holding cost. Table-2 shows the calculation of total holding cost during a month period:

TABLE 2
CALCULATION OF TOTAL HOLDING COST (OT)

Product	O_p	O_s	OT
TBS 220 ml	IDR 3,808.80	IDR 11,084,059.44	IDR 11,087,868.24
TBE 350 ml K12	IDR 3,385.60	IDR 4,094,378.88	IDR 4,097,764.48

5. Warehouse Capacity
The calculation of warehouse capacity is conducted by calculating the maximum limit (St) of each product and summed based on the product source factory. The following table is an example of calculation the maximum stock limit of products from the Cibitung factory for January 2018:

TABLE 3
MAXIMUM STOCK LIMIT (CARTON)

Source	Product	Maximum Stock Limit (carton)
Cibitung Factory	TBS 220 ML	13022
	TBK 200 ML K24	
	TBK 250 ML K24	
	TBE 350 K12	
	FTE AP 350 ML K12	
	STE 350 ML K12	
	TBO 230 ML K12	
	FTO AP 230 ML K24	

3.2. Optimal Order Quantity & Shipping Time Calculation

In this problem, the proposed solution method is by using mathematical model with mixed-integer programming. Mathematical modeling is the methodology proposed by Daellenbach which starts from system modeling and ends with mathematical modeling along with verification and validation [11]. While mixed integer programming is used to calculate the optimal reorder point and order quantity.

The mathematical model used in this research was first proposed by previous research about multi-item dynamic lot sizing which conducted by J. Gutierrez, M. Colebrook B. Abdul-Jabar and J. Sicilia [8]. This mathematical model aims to determine the optimal quantity and time of products that must be shipped from the factory to the DC. The notation used in this study is shown as follows [8]:

$d_{n,t}$: Demand of product *n* on periods *t*
$f_{n,t}$: Fixed setup cost of product *n* on period *t*
$p_{n,t}$: Production cost of product *n* on period *t*
$h_{n,t}$: Holding cost of product *n* on period *t*
$D_{n,t}$: Accumulated demand of product *n* on period *t*
S_t : Total dynamic inventory in the DC on period *t*
w_n : Unit capacity (volume) of product *n*
$x_{n,t}$: Order quantity of product *n* on the beginning of period *t*
$I_{n,t}$: Inventory quantity of product *n* on the end of period *t*

The objective function of this problem is shown as follows:

$$Z = Min \sum_{n=1}^{N} \sum_{t=1}^{T} f_{n,t}y_{n,t} + p_{n,t}x_{n,t} + h_{n,t}I_{n,t} \quad (1)$$

And the constrains are as follows:

$$I_{n,0} = I_{n,T} = 0, n = 1 \dots, N \quad (2)$$

$$\sum_{n=1}^{N} w_n\left(I_{n,t-1} + x_{n,t}\right) \le S_t, t = 1, \dots, T \quad (3)$$

$$I_{n,t-1} - I_{n,t} + x_{n,t} = d_{n,t}, n = 1, \dots, N; t = 1, \dots, T \quad (4)$$

$$x_{n,t} \le y_{n,t}D_{n,t}, n = 1, \dots, N; t = 1, \dots, T \quad (5)$$

$$x_{n,t}, I_{n,t} \in \mathbb{N}_0 = \mathbb{N} \cup 0; y_{n,t} \in \{0,1\}, n = 1, \dots, N; t = 1 \dots, T \quad (6)$$

The calculation process is done by using MATLAB R2016A application. The output of this calculation is the number of inventory and order quantity of products per day. Table-4 shows the output of order quantity calculation with suggested method for January 2018:

TABLE 4
OUTPUT OF ORDER QUANTITY WITH SUGGESTED METHOD

Order Quantity (x)	Product (carton)	
Days-	TBS 220 ML	TBE 350 ML K12
1	1112	1025
2	1175	311
3	1310	68
4	636	14
5	1102	608
6	1306	658
7	923	300
8	884	145
9	1128	186
10	1187	80
11	616	333
12	992	361
13	1064	593
14	1295	291
15	745	349
16	1310	232
17	1367	710
18	734	282
19	1188	181
20	1091	412
21	644	223
22	1274	260
23	676	186
24	1119	92
25	1002	139

V. CONCLUSION

In this paper, we proposed the replenishment policy by using mathematical modeling as a model approaching the real replenishment system, and mixed integer programming as a solution method to calculate the optimal reorder point and the order quantity.

The results of using this method gives an impact on holding cost and order cost. The holding cost borne by the company at the existing condition was IDR 43,884,228.08. While the holding cost with proposed method is IDR 19,908,078.64. This case indicates that by using the proposed method, the number of inventory in DC is pressed not to exceed the DC capacity, but still able to fulfill customer demand.

The order cost that was borne by the company at the existing condition was IDR 74,060.00. While the order cost with proposed method is IDR 265,769,60. This shows that by using the proposed method, the order frequency is more than the existing condition, because the order is made when total inventory in the DC is less than customer demand. So that, with the reduced amount of inventory from existing conditions, resulting in the frequency of orders increasing in order to maintain inventory to be able to fulfill demand.

Based on the calculation of the holding cost, and the order cost, the total cost of the existing inventory of the company was IDR 43,974,829.44. While the total inventory cost is IDR 20,173,848.24. So that the company is able to reduce costs by IDR 23,800,981.20.

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