PalArch's Journal of Archaeology of Egypt / Egyptology

DYNAMIC LOT SIZING MODEL FOR RETAILERS WITH MULTI SUPPLIER, QUANTITY DISCOUNTSAND CAPACITY CONSTRAINS

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Rendiyatna Ferdian, Erlina Febriani, Tika Ageng, Obsatar Sinaga. Dynamic Lot Sizing Model For Retailers With Multi Supplier, Quantity Discounts And Capacity Constrains-- Palarch's Journal Of Archaeology Of Egypt/Egyptology 17(5), 1024-1031. ISSN 1567-214x

Keywords: Dynamic Lot Sizing, Multi Supplier, Quantity Discounts

ABSTRACT

Onderhoud is a Small Medium Enterprises (SMEs) engaged in the field of custom shoes production services. Nowadays the company spends a large amount of money on ordering a leather raw material from suppliers. Orders are made to several suppliers every time there is an order. The swelling of production costs was identified due to the amount of the cost of the order made by the company. To reduce production costs, companies need to plan production by determining the optimal order lot to minimize overall production costs. Another limitation that is owned by the company is the production capacity, where in one period (one week) the company is only able to produce 15 units of shoes. In this research, the development of models from pre-existing models is carried out to determine the optimal lot order that must be done by the company. The test results show that the developed model is able to solve the problems faced by the company. Based on the results of testing the data, it can be seen that by using a plan that is carried out using the results of the development model, the company can increase profits by 1.47% compared to using the current ordering method.

Keywords: Dynamic Lot Sizing, Multi Supplier, Quantity Discounts

I. INTRODUCTION

Onderhoud is a business that is classified into the type of small and medium enterprises (SMEs) located in the city of Bandung. Founded in 2012, Onderhoud is engaged in the production of shoes with leather-based materials. The production system adopted by the company is Make to Order (MTO) where all shoes sold are based consumers order, no shoes are made as stock. Constraints experienced by the company include difficulties in determining the amount of raw material purchases. As experienced by other SMEs, capital constraints are a factor in the difficulty of purchasing raw materials. In addition, limited storage space for raw material inventory is also a matter that must be considered by companies in determining the amount of raw material purchases. This research discusses how to determine the lot size of raw material purchases that produce a minimum cost to keep fulfilling the number of orders from consumers. This study aims to produce a dynamic lot sizing model for retailers that considers multi-supplier cases, quantity discounts, and capacity constraints with the objective function of minimizing production costs.

II. LITERATURE REVIEW

Economic Order Quantity (EOQ) is a booking decision model that was first developed by Ford W. Harris in 1913. The model was created to determine the optimal order quantity with the objective function of minimizing order and storage costs with a constant number of requests throughout the period.

$$EOQ = \sqrt{\frac{2AD}{h}}$$

A : Setup Cost (Order Cost)

D : Number of Demand

h : Holding Cost per unit per period

The weakness of this model is the number of requests that are constant throughout the period. Wagner and Whitin in 1958 state that if the assumption of the constant demand is omitted, the formulation of the square root of EOQ is no longer guarantees that the result is a minimum cost.

2.1 Dynamic Lot Sizing

Decisions in lot sizing are about when and how much to order or receive goods (Bodt et al, 1994). Another opinion addresses the problem of lot sizing as a matter of production planning by regulating between lots of production (Brahimi et al, 2006). Meanwhile according to Zhu et al (1993), lot sizing is the decision about when the material is sent or received. Dynamic Lot Sizing (DLS) itself is a model developed by Wagner and Whitin in 1958 by considering the number of requests each period that is not the same along period.

The current DLS model is applied mainly to the process of Material Requirement Planning (MRP). Classification of types of lot sizing problems can be categorized into several criteria including the number of machines, the number of production levels, capacity limitations, the length of the production period, and so forth. Figure 1 provides an overview of the types of problems in the DLS model. The research of Bodt et al., 1984 classified the problem in the aspect of time into two broad categories namely fixed horizon and rolling horizon.

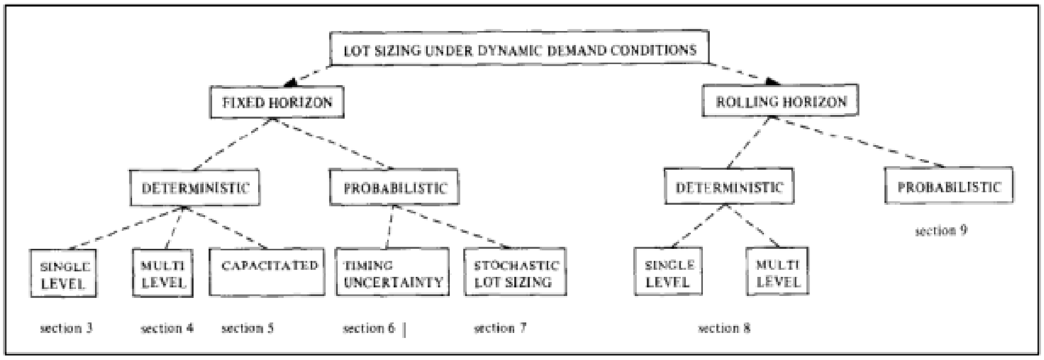

Figure1 Overview of Lot Sizing Technique Problem (Bodt, 1984)

Each of these categories has the same type of problem including the type of demand that is deterministic or probabilistic in nature, the number of levels of a single and multi-level product and the lot sizing problem with limited capacity and without capacity limit.

2.2 Single-Level Lot Sizing Problem (SLSP)

The simple SLSP model can be seen mathematically as follows.

Objective Function

$$Min\ Z = \sum_{t=1}^{T} [S\delta(x_t) + hI_t]$$

Subject to:

$$I_{t-1} + x_t - I_t = d_t \qquad t = 1, \dots, T$$

$$x_t \geq 0, I_t \geq 0$$

$$I_o = 0$$

d_t : demand on period t

x_t : production on period t

I_t : inventory at the end of period t

S : setup cost

h : holding cost per unit per period

T : planning horizon

$$\delta(x_t) = \begin{cases} 0, if\ x_t = 0 \\ 1, if\ x_t > 0 \end{cases}$$

Several heuristic approaches have been successfully developed to solve SLSP problems. Some of these models include Lot for Lot (LFL), Fixed Order Quantity (FOQ), Economic Order Quantity (EOQ), Period Order Quantity (POQ), Least Unit Cost (LUC), Least Total Cost (LTC), Part Period Balancing (PPB), Silver-Meal (SM), etc (Bodt dkk, 1984).

2.3 Single Item Lot Sizing Problem(SILSP)

SILSP is a planning problem when there are a number of requests in varying time for a single product during the T period (Brahimi et al, 2006). The SILSP model has the aim to produce a production quantity solution, as well as inventory that must be carried out by the company to minimize production costs incurred while still meeting the number of customer requests.

III. RESEARCH METODOLOGY

Problem solving that was carried out in this research about DLS was carried out as follows.

1. Literature Study, conducted to get a general picture of the problems that occur in the production system.
2. Problem Formulation, namely determining the research topic of several problems that have been identified previously.
3. Finding Reference Model, which is looking for models related to the problems faced in this study. The reference model is used as a basis for developing a proposed model.
4. Developing the Proposed Model, adding some aspects that have not been found in the previous reference model. Proposed models are developed to solve problems that cannot be solved using pre-existing models.
5. Model Testing and Analysis, which is a numerical testing process of the proposed model. Testing is done to analyse the characteristics and nature of the model of the problem cases encountered in this study.
6. Conclusions and Recommendations, the final step in this research is to make conclusions from the results of the proposed model that has been developed previously and provide proposals for further research.

IV. MODEL DEVELOPMENT

4.1 Problem Formulation

A SMEs company called Onderhoud is engaged in the production of custom shoes that market and sell products online. The production system applied is Make to Order, where the customer first determines the type of material, size and model of shoes to be ordered for later to be produced by the company. Most of the shoe products that are made have leather as the main raw material.

The company does not have a permanent supplier of raw materials. So far, the company has ordered and bought leather raw materials in turn with a number of suppliers. These suppliers have a discounted scheme for purchasing certain raw materials.

This study considers how the ordering process must be determined by the company to suppliers to fill inventory in order to meet consumer demand. The process of ordering raw materials to suppliers needs to be considered so that in addition to meeting the number of requests from consumers, it can also produce optimal ordering costs so that it is expected to increase overall company revenue.

4.2 Model Formulation

The objective function of the research model is to minimize the total cost consisting of 4 main cost components, namely: fixed costs, purchasing costs (ordering cost per unit), and holding costs (holding costs). Total costs are calculated based on the sum of all major cost components throughout the period.
Objective Function:

$$min\ Z = \sum_{t=1}^{T}\sum_{s=1}^{S} p_{st}R_{st} + \sum_{t=1}^{T}\sum_{k=1}^{K}\sum_{s=1}^{S} C_{kst}X_{kst} + \sum_{t=1}^{T} h_t I_t \qquad (\text{IV}.1)$$

Subject to:

$$I_t - I_{t-1} + d_t - \sum_{k=1}^{K}\sum_{s=1}^{S} X_{kst} = 0 \qquad ;\forall t\ (\text{IV}.2)$$

$$I_{t-1} + \sum_{k=1}^{K}\sum_{s=1}^{S} X_{kst} \geq 0 \qquad ;\forall t\ (\text{IV}.3)$$

$$\sum_{k=1}^{K} X_{kst} \leq MR_{st} \qquad ;\forall s,t\ (\text{IV}.4)$$

$$\sum_{s=1}^{S} R_{st} \leq 1 \qquad ;\forall s,t\ (\text{IV}.5)$$

$$I_T = 0 \qquad (\text{IV}.6)$$

$$\sum_{k=1}^{K} Y_{kst} \leq 1 \qquad ;\forall t\ (\text{IV}.7)$$

$$X_{kst} - Y_{kst} \geq 0 \qquad ;t = 1\ ;\forall k,s\ (\text{IV}.8)$$

$$X_{kst} - Y_{kst}\left(1 + Q_{(k-1)st}\right) \geq 0 \qquad ;t = 2,\dots,T\ ;\forall k,s\ (\text{IV}.9)$$

$$X_{kst} - Y_{kst}Q_{kst} \leq 0 \qquad ;\forall k,s,t\ (\text{IV}.10)$$

$$\sum_{k=1}^{K}\sum_{s=1}^{S} X_{kst} \leq j \qquad ;\forall t\ (\text{IV}.11)$$

$$x_{kst} \geq 0, \qquad I_t \geq 0 \qquad ;i = 0,\dots,L+G-1\ ;\forall t\ (\text{IV}.12)$$

$$Y_{kst} = 0{,}1 \qquad ;\forall k,s,t\ (\text{IV}.13)$$

$$R_{st} = 0{,}1 \qquad ;\forall s,t\ (\text{IV}.14)$$

Constrain (IV.2) is a limiting function that aims to balance the amount of inventory in the warehouse. Constrain (IV.3) ensures that all consumer requests can be fulfilled, so that there are no late requests. Constrain (IV.4) has an M value which is a very large positive number to ensure that the number of orders is sufficient to meet the number of requests in period t. The value of M can be assumed to be greater or equal to the total sum of requests in period 1 to period T. Constrain (IV.5) ensures that in each order period, the company only orders one supplier. Constrain (IV.6) ensures that the amount of inventory at the end of period T is 0 so that at the end of the planning period no inventory is available at the warehouse. The ending value of inventory can be adjusted according to company policy to provide a number of products for safety stock or not, so the constrain (IV.6) is dynamic and can change according to company policy.

Constrain (IV.7) - (IV.10) determine the quantity of orders made by companies that are between the lower limit and the upper limit of the price level k given by the supplier for each supplier and in each period. Constrain (IV.11) shows the production capacity limit of the production system, where the total number of orders in each period for all suppliers and the price level is less than the production capacity. Constrain (IV.12) - (IV.14) indicate the type of each variable. Values X and I are positive numbers, while the values of variables Y and R are binary numbers.

V. NUMERICAL EXAMPLES

Numerical data testing is performed using LINGO 11.0 software and laptops with Intel Core i3-5005U @ 2.00GHz (4 CPUs) specifications with 4GB of RAM. The data used in the test is the number of Onderhoud customer requests per week from March 1 to May 20 2018 and shown in Table 1.

Table1 Demand per Period

Period	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Demand	15	5	3	7	1	2	13	8	7	9	3	7

Costs incurred every time an order is made is Rp. 200,000 which consists of transportation costs, as well as employee costs. Product storage costs are assumed to be Rp. 10,000 per unit per period, this value is based on the average amount of electricity per week divided by the product's storage capacity. The value of saving costs fluctuates every period, but in this study the value is assumed to be constant throughout the period.

The selling price of leather shoes is Rp. 700,000, the amount is taken based on the average value of the price of a standard shoe. For shoes with certain specifications the price is higher, but in this study the cost is assumed to be fixed. The average production cost of a shoe excluding raw material purchases is Rp. 300,000, these costs include overhead and others. There are 2 suppliers of leather raw materials, each supplier has a discounted scheme as shown in Table 2.

Table2 Supplier Quantity Discounts Scheme

Supplier 1		Supplier 2	
Order Quantity (meter)	Price	Order Quantity (meter)	Price
1-5	Rp. 58,000	1-3	Rp. 56,000
6-10	Rp. 55,000	4-6	Rp. 55,000
11-etc	Rp. 52,000	7-9	Rp. 54,000
		10-etc	Rp. 53,000

The current production capacity that can be done by the company is 15 units of shoes per week. The company wants to determine how many orders for leather raw materials must be ordered to suppliers to meet consumer demand.

The total costs incurred by the company to make a booking plan is Rp. 5,780,000. The results of testing the model using more complete company data can be seen in Table 3.

Table3 Model Testing Results Using Onderhoud Company Data

Period	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Demand	0	15	5	3	7	1	2	13	8	7	9	3	7
Order (R1t)	0	15	0	0	0	0	0	13	15	0	12	0	0
Order (R2t)	0	0	8	0	10	0	0	0	0	0	0	0	7
Inventory (I)	0	0	3	0	3	2	0	0	7	0	3	0	0

Without using planning, the company currently orders raw materials every time there is an order with a one-time order, a number of orders with multiples of 10 meters and re-orders when the raw materials are used up. By using the method currently carried out, the company incurred an booking fee of Rp. The model resulted from testing using LINGO 11.0 software results that the proposed model class is Integer Linear Programming (ILP) with optimal global solution results. There are 2278 iterations to produce an optimal solution with the value of the objective function 5780000. The model is completed in computing time for 0 minutes, 2 seconds. The results of the Lingo Solver Status Model can be seen more clearly in Figure 2.

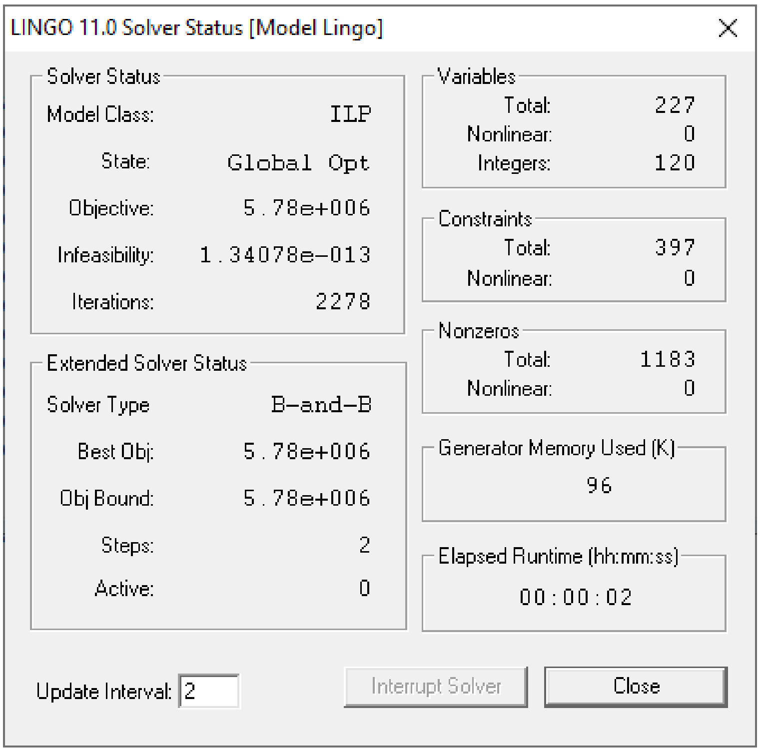

Figure2 Solver Status Lingo Model

VI. CONCLUSION

6.1 Conclusion

This research was conducted to develop the DLS model by considering multi suppliers and quantity discounts. Based on the results of the analysis of the research that has been done, the following conclusions can be obtained:

In general, the development model in this study can solve the problem in retail and the company has a choice of several suppliers with a discounted scheme from the supplier to minimize the total cost of production or ordering, so the results of the development of the model in this study can solve the case on Onderhoud which is the object of research studies real case.

6.2 Future Research

The developed model still has some weaknesses, so it is hoped that in the future it can be developed further to produce a better model. Some suggestions that will be input for further research are:

1. The model needs to consider selling with online systems, where companies now have started selling through online systems.
2. The process of testing data using a longer planning horizon needs to be done to determine the characteristics of the model of system changes.
3. It is necessary to consider delays in production, where production processes often experience delays that causes products cannot be delivered on time to consumers.

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