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Determination of lot size orders of furniture raw materials using dynamic lot sizing method

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Determination of lot size orders of furniture raw materials using dynamic lot sizing method

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Abstract. Wisanka is an indoor and outdoor furniture manufacture and export company in Indonesia. In the production activities, inventory control of raw materials is very important and needs to be handled properly so that the production process can run smoothly and orders from consumers can be fulfilled in a timely manner. Problems faced in the company that there is no optimal planning in determining the size of ordering of raw materials. Reservations made during this only based on the quantity of raw materials ordered can meet the needs during a certain period without considering the total cost incurred. The main purpose of this research is to determine the policy of controlling raw material requirement for the coming period by paying attention to the inventory cost incurred. In this research used lot sizing technique based on Silver Meal algorithm and Wagner Within algorithm. The use of lot sizing technique based on Wagner Within algorithm resulted in a cost efficiency of 3.6% for klabang material while Silver Meal of 2.9% for semi-polished rattan and 3.4% for leles compared to the lot sizing technique applied by the company.

1. Introduction

Inventories are managed by a business or company to anticipate some future demand [1]. Supply is made to deal with uncertainty in business. This uncertainty can be either out of stock, demand that exceeds estimates or overstock. Timing and quantity of supply is one way to deal with out of stock or overstock. Refueling is the company's attempt to place orders to suppliers for the purpose of storing inventory. Companies often get into trouble because of unavailability of materials (inventory), or too much material stacked in warehouses [2]. Overstock can cause a risk of damage to higher material inventories, higher storage costs, and the emergence of idle funds. Out of stock may cause delays in the production process or demand fulfillment, resulting in loss of customers due to delayed order fulfillment [3].

The use of the Lot Sizing technique is appropriate for use in determining the quantity of inventory orders in which in addition to minimizing the number of orders, it can also minimize the cost of direct inventory and inverse cost of inventory orders [4]. The optimal solution for single-sizing economic lot-sizing (ELS) problems has been known since Wagner and Whitin published their dynamic programming analysis [5]. The use of the Wagner-Within method continues to be developed, such as the efficient implementation of the non-concave cost (WWA) formula [6], with the application of branch and bone techniques to achieve faster solutions [7], and integration of the WWA algorithm with the horizon-planning theorem [8], and developed a near-optimal lot-sizing model for material requirements planning systems [9], as well as development based on theoretical planning and economic concepts, which is Economic Part Period (EPP).

Silver and Meal developed a heuristic method for selecting case lot size from deterministic time-varying demand rate and discrete opportunity to recharge, later known as the Silver-Meal method [10]. The Silver - Meal method can be used to determine the calculation of the value of inventory, especially the safety stock, reorder point, and lot sizing, then determine the best method [11], to calculate inventory cost and determine order quantity and frequency [12].

Wisanka is one of furniture manufacturer and exporter company in Indonesia. Wisanka manufactures various types of furniture, including outdoor furniture, indoor furniture, rattan furniture, and lighting furniture. The raw materials used are rattan, mahogany frame, and woven material. The furniture production process is based on order from consumer (make to order). Therefore the production strategy of the company is made to order causes the demand for furniture needs become very volatile. The supply of raw materials should be sufficient to anticipate the fluctuating demand.

Optimal planning in determining the size of raw material ordering becomes a problem in Wisanka. Reservations made so far only consider the quantity of raw materials that can meet the needs during a certain period without considering the inventory cost to be spent by the company, the quantity of ordering of raw materials is done based on the intuition of the number of products ordered. In addition, the company has also never conducted an evaluation and comparing existing inventory systems with other methods.

Proper handling of raw materials into a requirement for the production process to run smoothly and orders from consumers can be met in a timely manner. This research proposes the use of two methods, namely the Silver – Meal algorithm and Wagner – Whitin algorithm. The consideration of the selection of the silver-meal algorithm method is to provide an optimal local cost value on every raw material repurchase and over a long period of time has a probability that it can provide a lower cost. The selection of the Wagner – Whitin algorithm method is to provide the optimal solution used to determine the minimum cost [13].

2. Literature Review

2.1. Silver Meal Algorithm

The Silver-Meal algorithm is one of the methods for planning and controlling the supply of raw materials based on the cost period stating that the purchase of materials is only done at the beginning of the period, while the cost of storing is only charged to material stored over a period by considering the capacity of the warehouse [14]. The steps in calculating the silver-meal algorithm are as follows [13]:

1) Calculate the first lot size starting from period T. Lot size = requirement (net requirement) in period T, then calculate message cost and store cost in that period (if there is save fee). After calculating the total cost multiply by 1 divided by a sequence of period (if lot of first-order then multiplied 1/1 if lot second order then multiplied 1/2).
2) The second lot size, the need for the next period plus the first lot size, calculate the total cost per period. After counting multiply by 1/2 because it is the second lot order. The formulas that can be used are:

$$\mathrm{TRC(T)} = \frac{\mathrm{C+P_h \sum_{k=1}^{T}(k-1)\, R_k}}{\mathrm{T}} \tag{1}$$

   Where *TRC (T)* = relevant total cost in period T; *T* = period (T = 1, 2, 3, ..., T); *C* = order cost per period; *h* = percentage of shelf cost per period; *P* = purchase cost per unit; P_h = storage cost per period; and R_k = average demand in period k
3) Compare total cost per current period with before, if *TRC(L)* = *TRC(L-1)* as well as lot size = warehouse capacity back to step two and *TRC(L)* > *TRC (L-1)* go to step 4 and if not then go back to the first step.

4) Lot size in the period

$$\sum_{t=T}^{L}(t-T)dt \tag{2}$$

5) If $T = L$, and the time frame of the planning horizon has been reached, then the algorithm can be stopped. If it does not, return to the first step.

2.2. Wagner Whitin algorithm

The Wagner-Whitin algorithm is one heuristic method that uses a dynamic programming approach. This method can provide optimal value for dynamic demand or lot sizing problems to find the optimal solution [15]. The steps of the Wagner-Within algorithm are as follows:

1) Calculating the total cost of the inventory variable for each possible alternative ordering in a given period with N periods, which falls into the total cost of the variable is the cost of the message and the save cost by the following formula:

$$Z_{ce} = C + hP\sum_{i=c}^{e}(Q_{ce} - Q_{ci});\ 1 \leq e \leq c \leq N \tag{3}$$

Note:
C = ordering cost (IDR/order)
h = cost saving per unit per period (IDR/ unit/period)

$$Q_{ci} = \sum_{i=c}^{e} D_i \tag{4}$$

D_i = demand in period *i.*
C = initial limit of the period covered by order Q_{ci}
e = maximum limit of the period covered by order Q_{ci}

2) Calculate the minimum cost (f_n) in period c to e with an inventory assumption at the end of period 0. This algorithm will start with f_0 = 0 and calculate the f_n value. The formula for calculating the value of $f_e = min(Z_{ce} + f_{c-1})$ for c = 1, 2, 3, ..., e.
3) Find the optimal solution f_N by counting the number of orders backward by looking for the minimal value of each column that meets the period on the same line. The f_N value is the total cost value and the optimal lot order is calculated by the formula shown as below:
   a. The last order is made in the period c to meet demand from period c to period N. The formula as shown below:

$$f_N = Z_{ce} + f_{c-1} \tag{5}$$

   b. Order prior to the last order must be made in the period v to period v - 1. The formula is shown below:

$$f_{c-1} = Z_{vc-1} + f_{v-1} \tag{6}$$

   c. The first order is made in period 1 to meet the demand from period 1 to period u - 1. The formula is shown as below:

$$f_{u-1} = Z_{u-1} + f_0 \tag{7}$$

2.3. Research Methods

This research was conducted to evaluate raw material procurement in the past and to plan procurement for the future in Wisanka, one of the UKM furniture in Indonesia. The procurement data of raw materials during the period of June 2017 - May 2018 is used as the basis for forecasting raw material demand in the period of June 2018 - December 2018. Forecasting methods used to follow the pattern of raw material demand in the past, taking into account the minimal error rate. The analysis is done by calculating the total cost of raw material procurement that will come with the company's applied policy, then compared with the total cost of procurement if applying Silver Meal method and the use of Wagner Whitin algorithm.

3. Results and Discussion

Data on the amount of raw material consumption used in the period of June 2017-May 2018. This data is used as a basis in the process of forecasting demand for the period June 2018 - December 2018, to illustrate the forecast of raw material needs in the period. Furniture raw materials are calculated based on the identification that includes classification A (which has a big handling priority). The selection of these raw materials is based on classification calculations using the ABC method, where this method focuses inventory control on high-value inventory types rather than low-value ones. The ABC analysis divides the inventory into three classes based on the value (or volume) of inventory [16].

Based on the calculation of the ABC method of phase 1, out of 23 raw materials calculated, it is included in category A of 7 types of raw materials, category B of 5 types and category C of 11 species. Grouping stage 2 uses the ABC method, for 7 types of raw materials in category A in grouping phase 1, obtained 3 types of raw materials belonging to category A. The three raw materials are klabang, semi-polished rattan, and leles, respectively.

Figure 1. Klabang.

Figure 2. Semi-polished rattan.

Figure 3. Leles.

Based on the pattern of past data in the period of June 2017 - May 2018 (see Table 1) that is seasonal, forecasting is done using 3 methods: double exponential smoothing (DES), linear trend (LT), and winters method additive (WMA). While the calculation of forecasting accuracy is done by 3 methods: mean absolute deviation (MAD), mean squared error (MSE) and mean absolute percentage error (MAPE). Forecasting results to be selected based on the smallest forecasting error. Forecasting results for July 2018 - December 2018, are shown in Table 2.

Table 1. Procurement data for the raw materials demand (on kgs)

Periods	Klabang	Semi-polished rattan	Leles
June 2017	1,274.00	136.00	359.85
July 2017	2,762.50	690.25	318.00
August 2017	2,133.25	455.50	652.50
September 2017	4,879.00	520.00	524.70
October 2017	4,879.00	750.75	824.70
November 2017	2,917.00	550.75	937.00
December 2017	2,337.00	739.25	517.85
January 2018	3,872.50	1,070.00	860.50
February 2018	1,100.75	423.50	456.25
March 2018	2,593.50	606.60	562.10
April 2018	3,845.50	436.50	744.25
June 2018	2,468.50	799.00	451.10

Table 2. Forecast result for the raw materials demand (on kgs)

Periods	Klabang	Semi-polished rattan	Leles
June 2018	3,004.09	751.15	681.49
July 2018	3,016.74	774.68	693.91
August 2018	3,029.39	798.21	706.34
September 2018	3,042.04	821.75	718.76
October 2018	3,054.69	845.28	731.18
November 2018	3,067.33	868.82	743.61
December 2018	3,079.98	892.35	756.03

3.1. Silver Meal methods
Calculation of lot size with Silver Meal method needs to consider the capacity of the warehouse. Based on the steps described in Eq. (1) and Eq. (2), calculations can be made for raw material demand and order times. After calculating the combined cost of a period and the combination with the following period, a comparison of the total cost per period for each combination is performed. In addition, also pay attention to the accumulation of orders with warehouse capacity. The calculation will be repeated for another combination of periods to find the optimal result or average cost per smallest period exceeding the warehouse capacity. Silver Meal method processing results can be shown in Table 3.

Table 3. Result of lot sizing for raw material using Silver Meal methods

# Order	Klabang		Semi-polished rattan		Leles	
	Periods (week-)	Amount (kgs)	Periods (week-)	Amount (kgs)	Periods (week-)	Amount (kgs)
I	1	5,266.65	1	1,924.48	1	1,905.15
II	8	5,304.59	11	1,854.81	12	1,998.33
III	15	5,342.52	20	1,972.48	23	1,127.83
IV	22	5,380.48	-	-	-	-

3.2. Wagner-Whitin methods
The wagner-whitin algorithm can provide optimal value for the problem of dynamic sizing request in accordance with certain period horizon. Based on forecasting results and known inventory cost, the Wagner-Within algorithm steps are performed using Eq. (3) to Eq. (7), to determine the minimum cost. The minimum cost can be calculated assuming that the condition of the inventory amount at the end of the period is zero. The results of Wagner-Whitin algorithm processing can be shown in Table 4.

Table 4. Result of lot sizing for raw material using Wagner-Whitin algorithms

# Order	Klabang		Semi-polished rattan		Leles	
	Periods (week-)	Amount (kgs)	Periods (week-)	Amount (kgs)	Periods (week-)	Amount (kgs)
I	0	4,512.46	0	1,138.49	0	1,028.44
II	6	2,262.55	6	387.34	6	346.96
III	9	4,553.57	8	598.66	8	529.75
IV	15	5,348.86	11	404.99	11	356.27
V	22	2,303.66	13	410.87	13	359.38
VI	25	2,309.99	15	1,485.13	15	1,282.68
VII	-	-	22	434.41	22	371.80
VIII	-	-	24	446.17	24	378.02
IX	-	-	26	446.17	26	378.02

3.3. Company Policy
The company has its own policy in lot sizing. The determination of lot sizing is not based on cost, but uses needs over the next several periods adjusted to the lead time of arrival of raw materials. The company has set raw material policy to meet production requirement for 2 weeks. So orders are made in periods 1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, and 27.

3.4. Cost Comparison
Total inventory cost is calculated by summing up the ordering cost, storage cost, and purchase cost. The ordering cost is obtained from the ordering frequency multiplied by the cost of order. The cost of storage is obtained from the stored cost multiplied by the volume of stored material and the length of storage. The purchase cost is obtained from the amount of raw materials multiplied by the price of raw materials. Table 5 shows the value of ordering costs, storage costs and raw material prices observed.

Table 5. Result of lot sizing for raw material using Silver Meal methods

Raw Material	Ordering cost (IDR)	Storage cost (IDR)	Material price (IDR)
Klabang	1,168.75	408.00	8,000.00
Semi-polished rattan	376.45	713.00	13,500.00
Leles	360.44	637.00	12,000.00

Comparison of method is done to find method which give optimum cost so that can be used to do planning of optimal raw material inventory. The result of cost comparison can be seen in Table 6.

Table 6. Comparison of inventory cost between company policy, Silver Meal method and Wagner Whitin algorithm

Raw materiaks	Company policy (IDR)	Total inventory cost			
		Silver Meal		Wagner Within	
		Cost (IDR)	Saving	Cost (IDR)	Saving
Klabang	191,057,396	185,951,619	2.7%	**184,225,871**	**3.6%**
Rotan Semi Poles	85,454,341	**82,960,217**	**2.9%**	84,342,360	1.3%
Leles	67,177,269	**64,898,619**	**3.4%**	65,941,121	1.8%

The result of raw material requirement planning can provide the minimum cost solution that company issued in terms of inventory cost by using Silver Meal algorithm method. Therefore the results of this research can be used to help make company policy in June-December 2018. The savings for each raw material that is klabang using Silver Meal method with total cost of IDR 184,225,871,- and result in savings of 3.6%. As for raw materials of semi-polished rattan and leles with total cost of IDR 82,715,424,- and IDR 64,402,867,-, respectively. The application of the Silver Meal method is expected to provide savings of 2.9% for semi-polished rattan and leles by 3.4% compared to company policies.

4. Conclusion
Analysis of the plan calculation of optimal raw material needs based on forecasting method, by looking at the accuracy of the smallest forecast errors, in the case observed is based on linear trend method. The result of raw material requirement analysis done by Wagner Whitin and Silver Meal method can minimize the cost of the company in terms of inventory cost when compared to the fulfillment of raw materials using the company's policy. In the case observed, for planning for the period of June - December 2018, optimal conditions can be achieved for the raw materials of klabang using Wagner Within method can save by 3.6%. As for the raw materials of semi-polished rattan and leles using Silver Meal method, can save by 2.9% and 3.4%, respectively.

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