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KEPUTUSAN LOTSIZING PERSEDIAAN UNTUK PERENCANAAN KEBUTUHAN BAHAN UNTUK MEMINIMALKAN BIAYA PERSEDIAAN

INVENTORY LOTSIZING DECISIONS FOR MATERIAL REQUIREMENTS PLANNING TO MINIMIZE INVENTORY COSTS

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ABSTRACT

Inventory control is one of the most important factors in achievingoptimal organizational performance.Material Requirement Planning (MRP) is a common method used by businesses to manage inventories.This study focuses on a hydraulic firm that has been in operation since 2016.This research examines the planning of eleven components to get the best planning for the company.This study contributes to the integration ofMoving Average (MA) and Exponential Smoothing (ES) forecasting techniques alongside the MRP and three lot sizingtechniques, such as LFL, EOQ, and LUC.The minimum error valuesbetween MA and ES are evaluated and followed by the comparison between three lot sizingtechniques. The result shows that ES (α=0.1) is selected as the best forecasting technique, and LUC presents the lowest total inventory cost. However, LUC is only 0.05 percent lower than what LFL presents.A larger difference is shown by EOQ with 14.57 percent higher than LUCwhich makes EOQ unlikely to be selected.

Keywords: *Inventory control, Material Requirement Planning, Forecasting techniques, Lot sizing techniques*

ABSTRAK

Pengendalian persediaan merupakan salah satu faktor terpenting dalam mencapai kinerja organisasi yang optimal. Material Requirement Planning (MRP) merupakan metode yang umum digunakan oleh dunia usaha untuk mengelola persediaan. Penelitian ini berfokus pada perusahaan hidrolik yang telah beroperasi sejak tahun 2016. Penelitian ini mengkaji tentang perencanaan sebelas komponen untuk mendapatkan perencanaan terbaik bagi perusahaan. Penelitian ini berkontribusi pada integrasi teknik peramalan Moving Average (MA) dan Exponential Smoothing (ES) bersama dengan MRP dan tiga teknik lot sizing, seperti LFL, EOQ, dan LUC. nilai error minimum antara MA dan ES dievaluasi dan dilanjutkan dengan perbandingan antara ketiga teknik lot sizing. Hasilnya menunjukkan bahwa ES (α=0.1) terpilih sebagai teknik peramalan terbaik, dan LUC menyajikan total biaya persediaan terendah. Namun LUC hanya 0,05 persen lebih rendah dibandingkan LFL. Perbedaan yang lebih besar ditunjukkan oleh EOQ yang lebih tinggi 14,57 persen dibandingkan LUC sehingga membuat EOQ tidak mungkin terpilih.

Kata Kunci: Pengendalian Persediaan, Perencanaan Kebutuhan Material, Peramalan, Lot Sizing

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INTRODUCTION

Every organization will strive to achieve the objectives outlined in itsvision and mission. In general, any business strives to maximize profit orminimizecosts. Many businesses have startedduring the present globalization era, including those involved in services, manufacturing, and commerce. As a result, firm rivalry becomes more intense across the industry, and all companies strive to establish strategies for their businesses so that they can compete both domestically and globally.

Nowadays, inventory control is one of the most important factorsin achievingoptimalorganizational performance. Inventory is the stock of any goods or resources used in a company or organization (Nurprihatin, Gotami, et al., 2021). Therefore, inventory decision is a critical part when it comes to smooth business operations(Rembulan et al., 2022).

Material Requirement Planning (MRP)is a common method used by businesses to manage inventories. Currently, the MRP method for ordering components has not yet been applied by the company. Beforeplanning the inventory, the company is required to predict demand data for commodities such as raw materials, semi-finished goods, and completed goods. The MRP methodis a logical approach that uses decision rules and computer-based transaction procedures to convert master production plans into net demand. In this case, the demand for manufacturing products is classified into two types: independent demand and dependent demand.

This study focuses on a hydraulic firm that has been in operation since 2016. The Cylinder Wing Box is one product that has raw material availability issues. Several components encounter raw material excess and shortages, which can create delays in producing the product. In turn, the delay can increase the penalty cost due to tardiness(Nurprihatin et al., 2020). Therefore, planning on the products' components is required to avoidexcess materials and minimize unnecessary costs.

Eleven componentswere produced in 2020, and at the end ofeach month, all components encountered a shortage or excess of products. This research examines the planning of all components toget the best planning for the company. Moving average and Exponential Smoothing are used in forecasting to anticipate future demand, and then planning is carried out to achieve the lowest overall cost. MRP lotsizing decisions include the Least Unit Cost (LUC), Lot-for-Lot (LFL), and Economic Order Quantity (EOQ).

The objective of this study is to establish whether theforecasting approach, Moving Average or Exponential Smoothing, has the minimum error value and should be employed. Furthermore, this study identifies the technique for identifying the lotsizingwith the lowest cost in the MRP method for each component.

LITERATURE REVIEW

To produce cheap, fast, and high-quality products,it is necessary to pay attention to supply chainmanagement(Andry et al., 2023a). Especially when it comes to product excess or shortages, the management should consider any tools to control the inventory. In short, inventory is one of the wastes that should be managed well (Tannady et al., 2019).Any data incorrectness from the inventory report could be a major driver(Andry et al., 2023b).

The inventory model has been integrated into the vehicle routing problem to minimize the number of logistics costs(Rembulan et al., 2022).From an inventory perspective, several relevant costs should be considered, such as holding costs, ordering costs, and shortage costs. In this study, ordering cost is assumed to focus on telephone and fax costs, because shipping and insurance costs are borne by the component supplier. Ordering cost can also be approximated by the fixed transportation cost is often incurred regardless of the size of the order (Chopra & Meindl, 2016). A previous study discussed the transportation model to minimize the number of distribution costs (Nurprihatin & Tannady, 2018). Furthermore, as part of the network models, previous studies developed the extension analysis that integrates location-routing decisions (Nurprihatin, Octa, et al., 2019), considering the stochastic travel times (Nurprihatin, Elnathan, et al., 2019; Nurprihatin & Montororing, 2021), logistics costs (Nurprihatin, Regina, et al., 2021), and even constructed a new mathematical model (Nurprihatin & Lestari, 2020).

Table 1 represents the related works for this study. Previous studies utilized the Moving Average and Exponential Smoothing as the forecasting techniques(Conceição et al., 2021; Nurprihatin et al., 2020). MRP was also used to determine the proper time to order the items from suppliers (Nurprihatin et al., 2022; Nurprihatin, Gotami, et al., 2021). Several lot sizing techniques have been compared between LFL (Yao et al., 2020), EOQ (Conceição et al., 2021; Nurprihatin et al., 2022; Nurprihatin, Gotami, et al., 2021), and LUC (Conceição et al., 2021). This study presents the Moving Average and Exponential Smoothing forecasting technique alongside the MRP and three lot sizingtechniques, such as LFL, EOQ, and LUC.

Table 1. Related Works

Authors	**Forecasting Techniques**	**MRP**	**Lot Sizing Techniques**		
			LFL	**EOQ**	**LUC**
(Nurprihatin et al., 2022)	ARIMA	Yes	No	Yes	No
(Nurprihatin, Gotami, et al., 2021)	Triple Exponential Smoothing	Yes	No	Yes	No
(Nurprihatin et al., 2020)	Moving Average and Exponential Smoothing	No	No	No	No
(Conceição et al., 2021)	Moving Average and Exponential Smoothing	No	No	Yes	Yes
(Yao et al., 2020)	No	No	Yes	No	No
This Paper	Moving Average and Exponential Smoothing	Yes	Yes	Yes	Yes

METHODS

Data Collection

Data collection was carried out in the form of inventory demand, holding cost, ordering cost, and order lead time. Data collection was carried out based on secondary data, which means that the data is provided directly by the company.

Forecasting

Forecasting is carried out to obtain forecasted future demand. Forecasting of historical data for the past 1 year using the Moving Average and Exponential Smoothing methods. The limit on the Moving Average is used from period 2 to period 10, while the Exponential Smoothing used is α from 0.1 to 0.9.

Forecasting Error Measurement

From the forecasting data that has been calculated, the Mean Absolute Deviation, Mean Square Error, and Mean Absolute Percentage Error are obtained. After that, a comparison is made of the error values for each type of forecasting for each component of the Cylinder Wing Box. The purpose of doing a comparison of error sizes is to get a method that has the lowest error value so that it can beused for component forecasting.

Material Requirement Planning

After the forecasting stage for each component and continuing to look for the smallest forecasting error value, the step proceeded to obtain the number of units for the coming period. The lot sizing techniques used in this research areLFL, EOQ, and LUC. Calculations on each component are expected to help solve problems in the company in the form of component advantages and disadvantages and can minimize costs. LFL rule sets the production quantities to the requirements of each period (Thevenin et al., 2021).

Economic Order Quantity

Economic Order Quantity (EOQ) is one of the lot-sizing techniques to perform the MRP calculation(Nurprihatin, Gotami, et al., 2021). The EOQ formula is presented in Equation (1).

$$EOQ = \sqrt{\frac{2.D.S}{I.C}} = \sqrt{\frac{2.D.S}{H}} \quad (1)$$

where:

D	: Annual demandfor the product
S	: Fixed cost incurred per order
I	: Holding cost percentage
C	: Cost per unit of product
H	: Holding cost per unit per year

RESULTS AND DISCUSSION

Dependent Demand

Table 2 shows the number of demands for each component of the Cylinder Wing Box.Holding cost, the price of each component,ordering cost, and lead time are shown in Table 3.

Table 2. Demands for Each Component of the Cylinder Wing Box

Component	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total	Surplus/Shortage
Compact Seal	400	300	400	500	350	506	523	403	400	300	4,082	68
A154 25x33x55	400	300	400	500	350	504	522	401	400	300	4,077	73
DKB 25 (25x37x6/9)	160	550	400	500	350	504	522	400	400	300	4,086	208
ID 15x3	400	300	400	500	350	500	524	401	400	300	4,075	75
ID 44x33.5	400	300	400	500	350	500	522	400	400	300	4,072	78
Bushing DU 25/28x20	400	300	410	500	350	508	522	406	400	300	4,096	1,342
Safety Pin Lock 200	800	700	800	1,000	700	1,000	1,044	800	800	600	8,244	8,436
Ring Plat Galvanize M20	800	700	800	1,000	700	1,000	1,044	800	800	600	8,244	3,036
M18x2.5	400	350	400	500	350	500	522	400	400	300	4,122	-284
Mur M20x1.5	400	350	400	500	350	500	522	400	400	300	4,122	-84
Nipple Grease M6x10	800	700	800	800	700	1000	1,144	800	800	600	8,144	-468

Source: Primary Data

Table 3. Relevant Costs and Lead Time

Component	Price (IDR/Unit)	Holding Cost (IDR/Unit/Year)	Ordering Cost (IDR/Order)	Lead Time (Days)
Compact Seal	39,663	3,966.3	10,000	7
A154 25x33x55	13,711	1,371.1	10,000	7
DKB 25 (25x37x6/9)	7,362	736.2	10,000	7
ID 15x3	770	77.0	10,000	7
ID 44x33.5	171	17.1	10,000	7
Bushing DU 25/28x20	10,500	1,050.0	10,000	7
Safety Pin Lock 200	1,100	110.0	10,000	5
Ring Plat Galvanize M20	532	53.2	10,000	7
M18x2.5	2,600	260.0	10,000	5
Mur M20x1.5	2,750	275.0	10,000	7
Nipple Grease M6x10	2,600	260.0	10,000	5

Source: Primary Data

Table 4. Forecasting for Safety Pin Lock 200

Forecasting	MAD	MSE	MAPE (%)
MA (2 Period)	173.50	33,663.0	21.22
MA (3 Period)	174.48	33,562.4	21.80
MA (4 Period)	171.17	34,466.5	22.27
MA (5 Period)	178.08	35,508.9	22.31
MA (6 Period)	166.50	35,641.0	22.30
MA (7 Period)	134.86	28,390.5	20.71
MA (8 Period)	155.50	34,180.3	24.76
MA (9 Period)	249.33	62,167.1	41.56
MA (10 Period)	249.33	62,167.1	41.56
ES (α = 0.1)	130.00	23,820.9	15.90
ES (α = 0.2)	140.44	25,367.6	17.37
ES (α = 0.3)	147.95	26,625.3	18.41
ES (α = 0.4)	153.28	27,654.4	19.14
ES (α = 0.5)	157.13	28,626.3	19.66
ES (α = 0.6)	159.99	29,727.0	20.04
ES (α = 0.7)	162.18	31,112.1	20.33
ES (α = 0.8)	163.83	35,156.4	20.56
ES (α = 0.9)	164.93		20.74

Source: Authors' Own Calculations Based on Primary Data

Forecasting Results

Forecasting is done using the Moving Average method with limits from period 2 to period 10, while Exponential Smoothing with an α value from 0.1 to 0.9. Forecasting is calculated to obtain the MAD, MSE, and MAPE values as a consideration in each forecasting method. For example, Table 4 shows the result of forecasting for Safety Pin Lock 200. The smallest MAD, MSE, and MAPE values are 130.002, 23820.9, and 15.90%, respectively, represented by the Exponential Smoothing (α = 0.1).

As a summary, the lowest errors among Moving Average and Exponential Smoothing forecasting for all cylinder wing box components are shown in Table 5.

MRP Based on LFL Lot Sizing

The calculation result based on LFL is shown in Table 6. Table 6 only shows the calculation results for Safety Pin Lock 200, just for the example. After calculating the MRP using the LFL method, the total cost of inventory is obtained, as shown in Table 7.

As a summary, the calculation for all components to obtain the total cost based on LFL has been solved. The total cost for all Cylinder Wing Box components using the LFL lot sizing is IDR 34,853,498, as shown in Table 8.

Table 5.Forecasting Results for Components of Cylinder Wing Box

Component	Forecasting Methods
Compact Seal	ES (α = 0.1)
A154 25x33x55	ES (α = 0.1)
DKB 25 (25x37x6/9)	MA (2 Period)
ID 15x3	ES (α = 0.1)
ID 44x33.5	ES (α = 0.1)
Bushing DU 25/28x20	ES (α = 0.1)
Safety Pin Lock 200	ES (α = 0.1)
Ring Plat Galvanize M20	ES (α = 0.1)
M18x2.5	ES (α = 0.1)
Mur M20x1.5	ES (α = 0.1)
Nipple Grease M6x10	ES (α = 0.1)

Source: Authors' Own Calculations Based on Primary Data

Table 6.LFL Lot Sizing for Safety Pin Lock 200

	Day							
	3	**8**	**10**	**15**	**17**	**22**	**25**	**30**
Gross Requirement	0	203	0	203	0	203	0	204
On-hand Inventory	0	0	0	0	0	0	0	0
Net Requirement	0	203	0	203	0	203	0	204
Planned Order Receipts	0	203	0	203	0	203	0	204
Planned Order Release	203	0	203	0	203	0	204	0

Source: Authors' Own Calculations Based on Primary Data

Table 7. Total Costfor Safety Pin Lock 200 (LFL)

Relevant Cost	Day				Cost (IDR)	Total Cost (IDR)
	8	15	22	30		
Purchasing cost (IDR)	223,300	223,300	223,300	224,400	894,300	934,300
Holding cost (IDR)	0	0	0	0	0	
Ordering cost (IDR)	10,000	10,000	10,000	10,000	40,000	

Source: Authors' Own Calculations Based on Primary Data

Table 8. Total Inventory Cost Based on LFL LotSizing for Each Component

No.	Component	Total Cost (IDR)
1	Compact Seal	16,103,515
2	A154 25x33x55	5,579,244
3	DKB 25 (25x37x6/9)	2,616,700
4	ID 15x3	350,310
5	ID 44x33.5	108,913
6	Bushing DU 25/28x20	4,292,500
7	Safety Pin Lock 200	934,300
8	Ring Plat Galvanize M20	472,516
9	M18x2.5	1,095,600
10	Mur M20x1.5	1,156,500
11	Nipple Grease M6x10	2,143,400
Total		**34,853,498**

MRP Based on EOQ Lot Sizing

Based on Equation (1), the EOQ value is the following:

$$EOQ = \sqrt{\frac{(2)(D)(S)}{H}} = \sqrt{\frac{(2)(10569)(10000)}{110}}$$

$$EOQ = 1387\ units$$

The calculation for MRP based on EOQ value is represented in Table 9. Table 9 only shows the calculation for the Safety Pin Lock as an example. After calculating the MRP using the EOQ method, the total cost is obtained. The total costs incurred in carrying out inventory can be seen in Table 10. As a summary, the EOQ lot sizing performance comes with the total cost for all components, which is IDR 39,910,259, as shown in Table 11.

MRPBased on LUC LotSizing

Table 12 represents the summary of the gross requirement for Safety Pin Lock 200 and is used as the basis for the MRP calculation. After performing the LUC calculation, the total costs are obtained as shown in Table 13. Based on the results shown in Table 13, the MRP calculation is performed. Table 14 represents the results of MRP based on LUC lot sizing. The total costs incurred in carrying out inventory can be seen in Table 15. As a summary, the total cost for all components based on LUC calculations is shown in Table 16.

To conclude, Table 17 shows the comparison of total inventory cost for each lot sizing. It shows that LUC has the lowest total inventory cost. However, LUCis only 0.05 percent lower than what LFL presents. A larger difference is shown by EOQ with 14.57 percent higher than LUC.

Table 9. EOQ Lot Sizing Safety Pin Lock 200

	Day								
	3	8	10	15	17	22	25	30	1
Gross Requirement	0	203	0	203	0	203	0	204	0
On-hand Inventory	0	0	0	1,184	0	981	0	778	574
Net Requirement	0	203	0	0	0	0	0	0	0
Planned Order Receipts	0	1,387	0	0	0	0	0	0	0
Planned Order Release	1,387	0	0	0	0	0	0	0	0

Source: Authors' Own Calculations Based on Primary Data

Table 10.Total Cost for Safety Pin Lock 200 (EOQ)

Relevant Cost	Day				Cost (IDR)	Total Cost (IDR)
	8	15	22	30		
Purchasing cost (IDR)	223,300	223,300	223,300	224,400	894,300	1,291,170
Holding cost (IDR)	130,240	107,910	85,580	63,140	186,870	
Ordering cost (IDR)	10,000	10,000	10,000	10,000	40,000	

Source: Authors'Own Calculations Based on Primary Data

Table 11. Total Inventory Cost Based on EOQ Lot Sizing for Each Component

No.	Component	Total Cost (IDR)
1	Compact Seal	17,176,315
2	A154 25x33x55	6,476,912
3	DKB 25 (25x37x6/9)	2,980,567
4	ID 15x3	601,976
5	ID 44x33.5	231,000
6	Bushing DU 25/28x20	4,875,200
7	Safety Pin Lock 200	1,291,170
8	Ring Plat Galvanize M20	757,513
9	M18x2.5	1,465,740
10	Mur M20x1.5	1,529,925
11	Nipple Grease M6x10	2,523,940
Total		**39,910,259**

Table 12. Gross Requirements for Safety Pin Lock 200

	Period			
	1	2	3	4
Gross Requirement	203	203	203	204

Source: Primary Data

Table 13. LUC LotSizing for Safety Pin Lock 200

Iterations	Period	Cumulative Demand	Ordering Cost	Holding Period (Period)	Holding Cost (IDR)	Total Cost (IDR)	Unit Cost (IDR)	Remarks
1	1	203	10,000	0	0	10,000	49	Selected
	1 and 2	406	10,000	1	22,330	32,330	80	Discarded
2	2	203	10,000	0	0	10,000	49	Selected
	2 and 3	406	10,000	1	22,330	32,330	80	Discarded
3	3	203	10,000	0	0	10,000	49	Selected
	3 and 4	407	10,000	1	22,440	32,440	80	Discarded
4	4	204	10,000	0	0	10,000	49	Selected

Source: Authors' Own Calculations Based on Primary Data

Table 14. LUC Lot Sizing for Safety Pin Lock 200

Day

	3	8	10	15	17	22	25	30	1
Gross Requirement	0	203	0	203	0	203	0	204	0
On-hand Inventory	0	0	0	0	0	0	0	0	0
Net Requirement	0	203	0	203	0	203	0	204	0
Planned Order Receipts	0	203	0	203	0	203	0	204	0
Planned Order Release	203	0	203	0	203	0	204	0	0

Source: Authors' Own Calculations Based on Primary Data

Table 15. Total Cost for Safety Pin Lock 200 (LUC)

Relevant Cost	**Day**				**Cost (IDR)**	**Total Cost (IDR)**
	8	**15**	**22**	**30**		
Purchasing cost (IDR)	223,300	223,300	223,300	224,400	894,300	934,300
Holding cost (IDR)	0	0	0	0	0	
Ordering cost (IDR)	10,000	10,000	10,000	10,000	40,000	

Source: Authors' Own Calculations Based on Primary Data

Table 16. Total Inventory Cost Based on LUC Lot Sizing for Each Component

No.	**Component**	**Total Cost (IDR)**
1	Compact Seal	16,103,515
2	A154 25x33x55	5,579,244
3	DKB 25 (25x37x6/9)	2,616,700
4	ID 15x3	345,864
5	ID 44x33.5	94,094
6	Bushing DU 25/28x20	4,292,500
7	Safety Pin Lock 200	934,300
8	Ring Plat Galvanize M20	472,516
9	M18x2.5	1,095,600
10	Mur M20x1.5	1,156,500
11	Nipple Grease M6x10	2,143,400
Total		**34,834,233**

Table 17. Comparison on Total Inventory Cost for Each Lot Sizing

No.	**Lot Sizing**	**Total Cost (IDR)**
1	LFL	34,853,498
2	EOQ	39,910,259
3	LUC	34,834,233

CONCLUSION

Forecasting is conducted on the cylinder wing box components using the moving average and exponential smoothing methods using a tool in the form of QM for Windows, the forecast results for each component have a value of MAD (Mean Absolute Deviation), MSE (Mean Square Error), and MAPE (Mean Absolute Percentage Error).) the smallest among other exponential smoothing methods with α=0.1 there are Compact Seals (405 units), A15425x33x55 (403 units), ID 15x3 (403 units), ID 44x3.5 (403 units), Bushing DU 25/28x20 (405 units), Safety Pin Lock 200 (813 units), Ring Plat Galvanize M20 (813 units), M18x2.5 (406 units), Nut M20x1.5 (406 units), Nipple Grease M6x10 (809 units), and the Moving Average method with 2 periods, namely DKB 25 (350 units).

The suitable method for planning MRP with the smallest planning cost for each component of the Cylinder Wing Box includes Compact Seal getting the LUC method LFL with a value of IDR 16,103,515, A154 25x33x55 getting the LUC method, and LFL with a value of IDR 5,579,244, DKB 25 get the LUC method and LFL with a value of IDR 2,616,700, ID 15x3 get the LUC method with a value of IDR 345,864, ID 44x3.5 get the LUC method with a value of IDR 94,094, Bushing DU 25/28x20 get the LUC method and LFL with a value of IDR 4,292,500, Safety Pin Lock gets the LUC method and LFL with a value of IDR 934,300, Ring Plat Galvanize M20 gets the LUC method and LFL with a value of IDR 472,516, M 18x2.5 gets the LUC method and LFL with a value of IDR 1,095,600, Mur M20x1.5 gets the LUC method and LFL with a value of IDR 1,156,500, Nipple Grease M6x10 gets the LUC and LFL methods with a value of IDR 2,143,400.

This paper considers the total cost to determine the best MRP method between three lot sizing techniques: LFL, EOQ, and LUC. The total cost for the LFL, EOQ, and the LUCmethod is IDR 34,853,498, IDR

39,910,259, and IDR 34,834,233, respectively.Therefore, the LUC method is the best method to minimize the inventory cost so that the companydoes not experience excess or shortage of components.

Further research can includeshortage cost that is known as the result of external and internal disruption of supply.It is also recommended to filter the items into several categories using ABC analysis (Thazin & Sakulbumrungsil, 2022). Therefore, only significant items are discussed further.

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