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INVENTORY PLANNING AND CONTROL METHOD FOR CEMENT RAW MATERIAL WITH MATERIAL REQUIREMENT PLANNING (MRP)

Singgih Saptadi[1]*, Helvina Aulia Zahra, Ary Arvianto, Purnawan Adi Wicaksono and Wiwik Budiawan

[1]Department of Industrial Engineering, Faculty of Engineering, Diponegoro University
Jl. Prof. Soedarto SH, Undip Tembalang Campus, Semarang, Central Java, Indonesia 50275

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ABSTRACT

The supply of raw materials is an important asset for the company. Inaccuracies in the preparation of raw material supplies can have an impact on the production process and incur greater inventory costs. Therefore, more accurate planning of raw material supplies is needed so that there are no excesses or shortages of stock. This research aims to find out inventory policies, control the availability of gypsum and trass raw materials, and minimize inventory costs. In planning gypsum and trass inventory control, the Material Requirement Planning (MRP) method will be used. MRP methods used in this paper are Lot-for-Lot (LFL), Economic Order Quantity (EOQ), and Periodic Order Quantity (POQ) as a comparison for companies in planning gypsum and trass inventory. Calculations are carried out theoretically as well as with a real approach to the terms of the quantity of purchases of the company. For gypsum material, the most minimum supply is generated by the LFL method, both theoretically and with a real approach. Theoretically, the resulting savings for gypsum are 2.80% and with a real approach the resulting savings of 1.88%. For trass materials, the most minimum supply is also generated by the LFL method. Theoretically, the resulting savings for trass are 0.78% and with a real approach the resulting savings are 0.11%. It can be proposed to the company to apply the LFL method to obtain the most minimum inventory costs with the amount of inventory corresponding to the number of net needs in the corresponding period.

KEYWORDS: Inventory Control, Raw Material, Cement, Material Requirement Planning (MRP), Lot Sizing.

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1. INTRODUCTION

Production planning is a process carried out to convert raw materials into finished goods that have added value, with activities that have been arranged so that all production processes run smoothly and do not cause harm to companies and consumers. In carrying out production planning, the company requires control of the supply of raw materials from time to time. Control of raw material supplies is carried out in order to serve production needs so that the smooth production process can be guaranteed. Besides being able to serve production needs, good inventory control can also reduce inventory costs by controlling the amount of inventory stock so that there are not too many or too few. Excess supplies can increase the risk of material damage, increase storage costs, and the emergence of idle funds [1, 2]. Stock shortages can result in delays in the production process and fulfillment of demand, resulting in loss of customers [3].

Production planning and control is currently still a scourge for most supply chain managers in the manufacturing industry and is still a challenging issue in operations research [4]. Lot sizing is one of the problems in production planning. Because of its complexity and importance, lot sizing has been widely studied as both an academic and real-life problem [5].

In planning the control of raw material supplies, one of the methods used is Material Requirement Planning (MRP) [6]. MRP aims to convert the Master Production Schedule (MPS) into a production or purchase plan for all products and their components. MRP is used to determine the component and subcomponent requirements as well as the quantity so that production process are always updated [7]. Based on the results of research by Prakash M., et al. [7], using MRP calculations helps to place subcomponent orders and supplies can be managed effectively. This calculation also helps in making better decisions in manufacturing.

In MRP, there are wide variety of methods for approaching the problem of lot sizing [8]. Florim et al. [5] examine the behavior of 9 different lot sizing methods regarding different manufacturing environments and underlying production philosophies and related application specifications. The 9 methods include Lot-for-Lot (LFL), Economic Order Quantity (EOQ), Periodic Order Quantity (POQ), Silver-Meal (S-M) or Least Period Cost (LPC), Least Unit Cost (LUC), Part-Period Balance (PPB), Freeland & Cooley, McLaren Order Moment, and Wagner-Within (WW). Pooya et al. [9] examine a systematic approach to evaluating lot sizing policies on different request and lead time scenarios using LFL, Fixed Order Quantity (FOQ), Fixed Period Ordering (FPO), and EOQ. Önal & Albey [10] examines economic lot sizing methods for supply-dependent demand issues. Djunaidi, et al. [1] reviewed the dynamic lot sizing methods of S-M and WW to determine the size of furniture raw material order lots. Kholil et al [11] reviewed chip (semi dull) inventory planning with LFL, EOQ, FOQ, and FPR methods. Christifan & Gozali [12] reviewed EOQ method for planning the control of TV cabin raw material supplies. Some lot sizing methods may be more suitable than others to be applied in certain manufacturing scenarios and environments.

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The cement plant in Tarjun, Kotabaru is a cement factory owned by one of the largest cement companies in Indonesia. This factory processes cement from mining, processing, packing, to become cement that is ready to be distributed. The main raw materials of cement are mostly obtained by mining alone. The raw materials mined include Limestone, Clay, Silica Sand, and Laterite Iron-Ore. As for gypsum and trass raw materials, the company buys from suppliers in its procurement.

Based on historical data from the number of gypsum and trass usage, the company has actually controlled raw materials using the Min-Max method so that the Supply Department, especially the Inventory Control Section can find out how much minimum stock must be in the warehouse to meet the production quantity capacity and how much maximum raw material stock can be accommodated in the warehouse so that there is no additional cost expenditure for the warehouse. pile up stock. However, in July - August 2021, the company experienced a shortage of Trass raw material stocks to below the minimum stock that has been determined by the company. This results in a hampered production process because it needs to make adjustments to the production schedule and cement composition. Then in September 2021, the company experienced an excess of Trass raw material stock because the stock that should have come in the previous period experienced a delay so that it piled up in that period. This results in the company needing to spend additional costs to do stock pile up. Therefore, a more accurate method of planning for control of raw material supplies is needed so that there are no excesses or shortages of stock. This research aims to find out inventory policies, control the availability of raw materials, and minimize inventory costs.

2. RESEARCH METHODS

This research was conducted at the Supply Department of a cement factory in Tarjun, Kotabaru. The study time was conducted from January 6 to March 14, 2022. The object studied is the supply of raw gypsum material and trass as raw materials for cement constituents. The data used in this study include historical data on cement demand for the last 12 months (January - December 2021), data on ordering costs and raw material storage costs, raw material lead time data, raw material safety stock data, raw material end stock data as of December 2021, and raw material storage capacity. The data that has been obtained at the next data collection stage is processed and analyzed using the Lot-for-Lot (LFL), Economic Order Quantity (EOQ), and Periodic Order Quantity (POQ) methods.

Lot-for-Lot (LFL) is a method of measuring lots where the net requirement that occurs in each period is the number of orders [2]. In this technique, the fulfillment of clean needs is carried out in every period that requires it. The size of the order quantity (lot size) is equal to the number of net needs that must be met in the period concerned. In this method, the order is made with the consideration of minimization of the cost of savings.

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The Economic Order Quantity (EOQ) model is used to determine the quantity of inventory orders that minimize the direct cost of inventory storage and the cost of ordering inventory [13]. This model assumes that all parameters, namely average demand per unit time (D), ordering/setup costs per lot (S), and holding costs per item and unit time (H), which include the physical cost of keeping items in stock and interest and depreciation, are constant and deterministic [14]. This method is usually used for planning for a year (12 months). Lot size is determined based on ordering cost and holding cost.

Periodic Order Quantity (POQ) is a development of the EOQ method, namely by transforming the quantity of orders into the optimal order frequency [15]. According to Silver et al. [16] in Florim et al. [5], in this method the time interval in which the order will be made is determined, and the number of batch sizes must suppress the need until the next order. This method aims to save the total cost of inventory (total inventory cost) by emphasizing the effectiveness of order frequency to be more patterned.

Lot sizing is done by classic LFL, EOQ, and POQ methods, as well as taking into account the minimum order quantity that has been set by the company [17]. The minimum order quantity is determined based on the capacity of the material transporting vessel [18]. The results of the calculation of lot sizing with these three methods will be compared with the results of the company's calculations. The method with the results of calculating the cost of the cheapest inventory will be the method chosen to be suggested to the company.

3. RESULTS AND DISCUSSION

3.1 Forecasting

Forecasting is the initial stage in determining the needs of raw materials based on cement needs. According to Fildes & Kingsman [19] in Barrow & Kourentzes [20], the selection of forecasting methods is an important determinant of inventory costs. The combination of forecasting methods improves accuracy and reduces error variance which is useful for inventory management.

At this stage, there will be a forecasting of cement needs for the next 12 months (January - December 2022) based on historical data on cement demand in January - December 2021. The methods used are Single Moving Average, Single Exponential Smoothing, Double Exponential Smoothing, and Holt-Winter Multiplication. The method with the smallest error value will be the selected period because it can predict more closely with the number of requests in the future. Here is a comparison of the error values of each method shown in Table 1.

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Table 1: Error Value of Each Forecasting Method

Method	MAPE
3 SMA	11.31%
5 SMA	13.12%
SES	9.56%
DES	10.22%
Holt-Winter Multiplicative	5.00%

Based on the error comparison table for the forecasting method above, the smallest error value is obtained in the Holt-Winter Multiplicative method. Forecasting results with this method are then used as a Master Production Schedule (MPS) for the next 12 periods, as shown in Table 2.

Table 2: Master Production Schedule

	JIP
Jan-22	244,791
Feb-22	187,583
Mar-22	186,987
Apr-22	225,569
May-22	224,027
Jun-22	252,600
Jul-22	261,243
Aug-22	313,267
Sep-22	303,832
Oct-22	280,083
Nov-22	276,337
Dec-22	247,148

3.2 Calculation of Raw Material Requirement

Based on MPS and Bill of Material, we can determine the Gross Requirement (GR) of each cement constituent material. Here is the GR of gypsum and trass shown in Table 3.

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Table 3: Gross Requirement of Raw Materials

PERIOD	Necessity	Month											
		1	2	3	4	5	6	7	8	9	10	11	12
POR SEMEN	-	244,791	187,583	186,987	225,569	224,027	252,600	261,243	313,267	303,832	280,083	276,337	247,148
GYPSUM	3%	7,344	5,627	5,610	6,767	6,721	7,578	7,837	9,398	9,115	8,402	8,290	7,414
TRASS	11%	26,927	20,634	20,569	24,813	24,643	27,786	28,737	34,459	33,422	30,809	30,397	27,186

3.3 Material Requirement Planning (MRP)

In ordering raw materials, the company must know exactly the amount of raw materials needed and the time when the raw materials are needed for the production process, as well as the number of raw materials ordered according to the lot size. There are several methods that companies can apply to determine lot sizes, but in this study the author provides 3 lotting methods: Lot-for-Lot (LFL), Economic Order Quantity (EOQ), and Period Order Quantity (POQ).

a) Company's Policy

The order policy used by the company for gypsum material is to place an order with a fixed quantity, which is 8,200 tons per order and the order is made 2 times a month. For trass material, the company places an order with a quantity of 7,500 tons per order and the order is made 3 times a month. However, if the number of orders is still less than the estimated gross requirement in the next period, the company can order more while still adjusting the multiples of the order quantity. The quantity of the order adjusts the capacity of the raw material transport ship. Here is a lotting calculation with the company method shown in Table 4.

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Table 4: Lotting with Company's Policy

Material	Company's Policy												
	Period	1	2	3	4	5	6	7	8	9	10	11	12
Gypsum	GR	7,344	5,627	5,610	6,767	6,721	7,578	7,837	9,398	9,115	8,402	8,290	7,414
	NR	7,344	3,425	5,610	6,767	6,721	7,578	7,837	9,398	9,115	8,402	8,290	7,414
	POP		16,400		16,400		16,400		16,400		16,400		
	POH	2,202	12,975	7,365	16,998	10,277	19,099	11,262	18,264	9,149	17,147	8,857	1,442
Trass	GR	7,344	5,627	5,610	6,767	6,721	7,578	7,837	9,398	9,115	8,402	8,290	7,414
	NR	18,270	16,240	14,144	16,292	18,271	23,392	21,910	33,705	29,352	29,942	30,120	27,087
	POP	22,664	22,664	22,664	22,664	22,664	30,219	22,664	37,774	30,219	30,219	30,219	30,219
	POH	4,394	6,425	8,521	6,372	4,394	6,827	755	4,069	867	277	99	3,132

Here is the example of inventory cost calculation of gypsum.

- Holding cost = Holding cost/ton × POH
  = Rp8,414.44 × 135,039
  = Rp1,136,276,693.85
- Ordering cost = Ordering cost × ordering frequency
  = Rp115,886,020.00 × 10
  = Rp1,158,860,200.00
- Material cost = Material cost/ton × POP
  = Rp552,722.05 × 82,000
  = Rp45,323,208,000.00
- Total cost = **Rp47,618,344,893.85**

b) Lot-for-Lot (LFL)

In the LFL method, the order lot size will be equal to the net requirement in the corresponding period. Here is a lotting calculation with the LFL method shown in Table 5.

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Table 5: Lot-for-Lot (LFL)

Material	LFL													
	Period		1	2	3	4	5	6	7	8	9	10	11	12
Gypsum	Theoritical	GR	7,344	5,627	5,610	6,767	6,721	7,578	7,837	9,398	9,115	8,402	8,290	7,414
		NR	7,344	3,425	5,610	6,767	6,721	7,578	7,837	9,398	9,115	8,402	8,290	7,414
		POP		3,425	5,610	6,767	6,721	7,578	7,837	9,398	9,115	8,402	8,290	7,414
		POH	2,202	0	0	0	0	0	0	0	0	0	0	0
	With capacity constraint	GR	7,344	5,627	5,610	6,767	6,721	7,578	7,837	9,398	9,115	8,402	8,290	7,414
		NR	7,344	3,425	835	6,767	6,123	5,501	5,138	6,336	7,251	7,453	7,543	6,758
		POP		8,200	8,200		8,200	8,200	8,200	8,200	8,200	8,200	8,200	8,200
		POH	2,202	4,775	7,365	598	2,077	2,699	3,062	1,864	949	747	657	1,442
Trass	Theoretical	GR	26,927	20,634	20,569	24,813	24,643	27,786	28,737	34,459	33,422	30,809	30,397	27,186
		NR	18,270	20,634	20,569	24,813	24,643	27,786	28,737	34,459	33,422	30,809	30,397	27,186
		POP	18,270	20,634	20,569	24,813	24,643	27,786	28,737	34,459	33,422	30,809	30,397	27,186
		POH	0	0	0	0	0	0	0	0	0	0	0	0
	With capacity constraint	GR	26,927	20,634	20,569	24,813	24,643	27,786	28,737	34,459	33,422	30,809	30,397	27,186
		NR	18,270	16,240	14,144	23,847	18,271	23,392	21,910	33,705	29,352	29,942	30,120	27,087
		POP	22,664	22,664	15,110	30,219	22,664	30,219	22,664	37,774	30,219	30,219	30,219	30,219
		POH	4,394	6,425	966	6,372	4,394	6,827	755	4,069	867	277	99	3,132

In the calculation with a real approach of capacity constraint, the number of orders lots is adjusted to the provisions of the company's order size, which is a multiple of 8,200 tons for gypsum and a multiple of 7,554 tons for trass.

c) Economic Order Quantity (EOQ)

In the EOQ method, the size of the order lot is determined based on the calculation of the quantity of economic orders from each raw material. Here is an example of EOQ calculation for gypsum.

$$\text{EOQ} = \sqrt{\frac{2\text{DC}}{\text{H}}} = \sqrt{\frac{2\times\left(\frac{90{,}104}{12}\right)\times \text{Rp}115{,}886{,}020.00}{\text{Rp}8{,}414.44}} = 14{,}382 \qquad (1)$$

Here is a lotting calculation with the EOQ method shown in Table 6.

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Table 6: Economic Order Quantity (EOQ)

Material	EOQ													
	Period		1	2	3	4	5	6	7	8	9	10	11	12
Gypsum	Theoritical	GR	7,344	5,627	5,610	6,767	6,721	7,578	7,837	9,398	9,115	8,402	8,290	7,414
		NR	7,344	3,425	5,610	1,420	6,721	1,337	7,837	4,190	9,115	7,325	1,233	7,414
		POP		14,382		14,382		14,382		14,382		14,382	14,382	
		POH	2,202	10,957	5,347	12,962	6,241	13,045	5,208	10,192	1,077	7,057	13,149	5,734
	With capacity constraint	GR	7,344	5,627	5,610	6,767	6,721	7,578	7,837	9,398	9,115	8,402	8,290	7,414
		NR	7,344	3,425	5,610	6,767	6,123	7,578	5,138	9,398	7,251	8,402	7,543	7,414
		POP		16,400			16,400		16,400		16,400		16,400	
		POH	2,202	12,975	7,365	598	10,277	2,699	11,262	1,864	9,149	747	8,857	1,442
Trass	Theoritical	GR	26,927	20,634	20,569	24,813	24,643	27,786	28,737	34,459	33,422	30,809	30,397	27,186
		NR	18,270	16,519	14,703	17,130	19,388	24,789	8,756	20,830	9,482	17,906	25,918	8,334
		POP	22,385	22,385	22,385	22,385	22,385	44,770	22,385	44,770	22,385	22,385	44,770	22,385
		POH	4,115	5,866	7,682	5,255	2,997	19,981	13,629	23,940	12,903	4,479	18,852	14,051
	With capacity constraint	GR	26,927	20,634	20,569	24,813	24,643	27,786	28,737	34,459	33,422	30,809	30,397	27,186
		NR	18,270	16,240	14,144	16,292	18,271	23,392	6,800	18,595	29,352	14,833	22,565	27,087
		POP	22,664	22,664	22,664	22,664	22,664	45,329	22,664	22,664	45,329	22,664	22,664	45,329
		POH	4,394	6,425	8,521	6,372	4,394	21,937	15,864	4,069	15,977	7,832	99	18,242

d) Periodic Order Quantity (POQ)

In the POQ method, the optimal order frequency is determined. Here is an example of a POQ calculation for gypsum.

$$\text{POQ} = \sqrt{\frac{2\text{S}}{\text{DH}}} = \sqrt{\frac{2\times \text{Rp}115{,}886{,}020.00}{\left(\frac{90{,}104}{12}\right)\times \text{Rp}8{,}414.44}} = 2 \qquad (2)$$

Here is a lotting calculation with the EOQ method shown in Table 7.

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Table 7: Periodic Order Quantity (POQ)

Material	POQ													
	Period		1	2	3	4	5	6	7	8	9	10	11	12
Gypsum	Theoritical	GR	7,344	5,627	5,610	6,767	6,721	7,578	7,837	9,398	9,115	8,402	8,290	7,414
		NR	7,344	5,627	3,407	6,767	6,721	7,578	7,837	9,398	9,115	8,402	8,290	7,414
		POP	5,627		10,174		14,299		17,235		17,517		15,705	
		POH	7,830	2,202	6,767	0	7,578	0	9,398	0	8,402	0	7,414	0
	With capacity constraint	GR	7,344	5,627	5,610	6,767	6,721	7,578	7,837	9,398	9,115	8,402	8,290	7,414
		NR	7,344	3,425	5,610	6,767	6,721	7,578	7,837	9,398	9,115	8,402	8,290	7,414
		POP		16,400		16,400		16,400		16,400		16,400		
		POH	2,202	12,975	7,365	16,998	10,277	19,099	11,262	18,264	9,149	17,147	8,857	1,442
Trass	Theoritical	GR	26,927	20,634	20,569	24,813	24,643	27,786	28,737	34,459	33,422	30,809	30,397	27,186
		NR	18,270	20,634	20,569	24,813	24,643	27,786	28,737	34,459	33,422	30,809	30,397	27,186
		POP	18,270	20,634	20,569	24,813	24,643	27,786	28,737	34,459	33,422	30,809	30,397	27,186
		POH	0	0	0	0	0	0	0	0	0	0	0	0
	With capacity constraint	GR	26,927	20,634	20,569	24,813	24,643	27,786	28,737	34,459	33,422	30,809	30,397	27,186
		NR	18,270	16,240	14,144	23,847	18,271	23,392	21,910	33,705	29,352	29,942	30,120	27,087
		POP	22,664	22,664	15,110	30,219	22,664	30,219	22,664	37,774	30,219	30,219	30,219	30,219
		POH	4,394	6,425	966	6,372	4,394	6,827	755	4,069	867	277	99	3,132

3.4 Inventory Cost Analysis

Cost analysis is carried out to provide a comparison between the condition of the old inventory system in the company and the condition of the new inventory system after the implementation of the MRP method. The following is a recapitulation of the overall cost of trass and gypsum raw materials shown in Table 8.

Table 8: Recapitulation of Inventory Costs

Material	Lotting	Cost (Theoretically)	Cost (Capacity Approach)
Gypsum	LFL	Rp46,282,917,512.12	Rp46,721,365,664.99
	EOQ	Rp49,870,121,051.68	Rp47,066,357,676.09
	POQ	Rp46,449,905,237.03	Rp47,618,344,893.85
	Company	Rp47,618,344,893.85	Rp47,618,344,893.85
Trass	LFL	Rp62,999,971,448.57	Rp63,427,324,776.28
	EOQ	Rp66,462,604,679.87	Rp67,051,029,552.08
	POQ	Rp62,999,971,448.57	Rp63,427,324,776.28
	Company	Rp63,496,323,178.50	Rp63,496,323,178.50

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Based on the calculation of the cost of each lotting method theoretically, it was obtained that the lotting method that incurred the minimum cost was the LFL method with a total cost for gypsum of Rp46,282,917,512.12 and the total cost for trass amounted to Rp62,999,971,448.57. When compared with the cost of inventory based on the method applied by the company, gypsum inventory costs of Rp47,618,344,893.85 and trass inventory costs of Rp63,496,323,178.50. In the cost of gypsum supply, there is a cost saving of 2.80%. While in the cost of trass inventory, there is a cost saving of 0.78%.

But in its real condition, there are several company policies with suppliers regarding the amount of raw materials ordered per order. The amount of raw materials ordered needs to be adjusted to the capacity of the transport ship, so that in order to maximize the amount of raw materials and minimize the cost of messages, the company will place an order according to the maximum capacity of the raw material transport ship. Therefore, the calculation of lot sizing is adjusted again taking into account the order policy that has been set by the company.

Based on the results of calculating the cost of each lotting method with capacity approach (right column of Table 8), it was found that the lotting method that incurred the minimum cost was the LFL method with a total cost for gypsum of Rp46,721,365,664.99 and the total cost for trass of Rp63,427,324,776.28. When compared with the cost of inventory based on the method applied by the company, gypsum inventory costs of Rp47,618,344,893.85 and trass inventory costs of Rp63,496,323,178.50. In the cost of gypsum supply, there is a cost saving of 1.88%. While in the cost of trass inventory, there is a cost saving of 0.11%.

Based on the results of these calculations, both theoretically and with the real approach of the company's purchasing policy, it can be proposed to companies to use the LFL method in planning gypsum and trass needs because the LFL method generates the most minimum inventory costs. With this method, the ordering of net needs is carried out in accordance with the number of net needs that need to be met in the period concerned. The advantage of the LFL method is that it minimizes storage costs because the amount ordered is equal to the amount needed, so no inventory incurs costs. Although in calculations with a real approach there is still a residual supply resulting from the purchase that corresponds to multiples of 8,200 tons for gypsum and 7,500 tons for trass, but with the LFL method can be obtained the minimum storage costs among other methods. So that for the overall cost of inventory, the company can minimize these costs by using the LFL method that minimizes storage costs.

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4. CONCLUSION

Based on the results of data analysis and discussions that have been carried out, the results obtained for planning raw material inventory of Gypsum and Trass with MRP will result in lower inventory costs compared to the method applied by Supply Department both theoretically and with a capacity approach to the company's policy. Of the three methods used in lotting, the minimum cost is obtained by the Lot-for-Lot (LFL) method. From the results of calculations using the LFL method theoretically, the gypsum inventory cost was Rp. 46,282,917,512.12 and the trass inventory cost was Rp. 62,999,971,448.57. With capacity approach, the gypsum inventory cost was Rp. 46,721,365,664.99 and the trass inventory cost was Rp. 63,427,324,776.28. Meanwhile, if using the method applied by the company, the cost of gypsum inventory is Rp47,618,344,893.85 and the cost of trass inventory is Rp63,496,323,178.50. Based on the theoretical LFL calculation, the resulting savings for gypsum is 2.80% and 0.78% for trass. Meanwhile, based on the LFL calculation with capacity approach, the resulting savings for gypsum is 1.88% and for trass it is 0.11%.

Referring to the results of data processing, it can be seen that MRP can help companies to plan gypsum and trass inventories better and can save inventory costs. The lotting method that can be proposed to the company is the LFL method because it has the minimum inventory cost and can minimize the accumulation of raw material stock because the number of orders is adjusted to the production needs of the related period.

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Author Profile

Singgih Saptadi holds bachelor's, master's and doctoral degrees in industrial engineering, from the Bandung Institute of Technology. Since 2001, he has been a lecturer at the Department of Industrial Engineering, Diponegoro University and joined the Decision Support System Laboratory. Much of his research is in the implementation of decision-making and information technology in various industries.