Analysis of Material Requirement Planning for Pentolite Production (Case Study: Indonesia's Explosives Manufacturing)

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ABSTRACT

A company engaged in manufacturing explosives produces several products, one of which is pentolite. This product is commonly used as primary blasting material for use in mining operations. Fluctuating coal exports affect the demand for pentolite, in addition to the dominant source of imported raw materials, which requires companies to make proper planning for the needs of pentolite raw materials. Material Requirement Planning (MRP) is an inventory planning and scheduling technique used to manage the manufacturing process, this method is appropriate because it can optimize inventory, reduce the risk of delays and increase efficiency. Several lot-sizing techniques will be used in this study to obtain the optimal order size at the lotting stage in MRP. The techniques used are lot for lot (LFL), economic order quantity EOQ), and period order quantity (POQ). The results show that for both P and T raw materials, the lot-sizing technique that gives the smallest inventory cost results is to use the period order quantity.

Keywords: *EOQ, LFL, MRP, POQ.*

1 INTRODUCTION

Pentolite is sensitive explosives to a detonator, with high energy and propagation speed of 7,000 m/s. Pentolite is used in quarry, coal, and mineral mining activities, as a primary explosive for initiating primary explosives, such as ANFO or emulsion. Pentolite is also used in the military field as a primary explosive for initiating the main load of bombs. Pentolite itself has produced only in explosives factories that have permits to mix explosives in each country. Currently, pentolite is widely produced in various countries such as Indonesia, India, Vietnam, China, America, and Australia. Coal mining is one of the largest sectors using pentolite explosives. The condition of coal exports greatly affects the sustainability of the company's business. Currently, the condition of coal exports is experiencing instability, as shown in Figure 1.1. There were fluctuations in coal prices during that period. One of the triggers comes from external factors such as coal import restrictions in several coal importing countries.

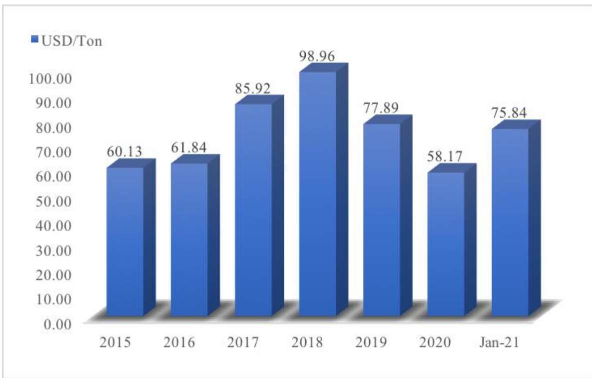

Figure 1 Coal price in 2015 – 2021
(Source: Minerba ESDM 2021)

The instability in the value of coal also affects the demand for pentolite explosive products. In the last three years, product demand tends to fluctuate as shown in Figure 2.

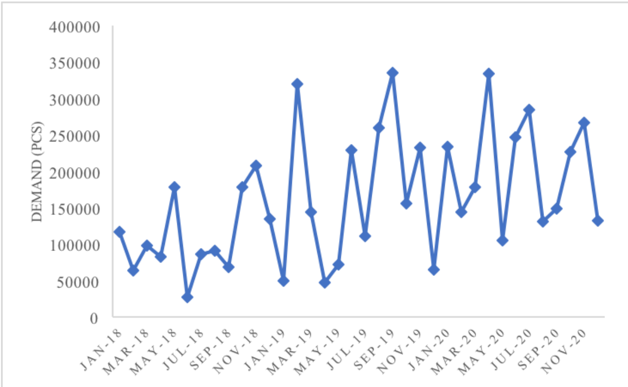

Figure 2 Demand of Pentolite in 2018 – 2020
(Source: Production Department)

In producing pentolite to meet the needs of the mining market, some raw materials are still imported from abroad (such as China, India, and Vietnam) because the supply of these raw materials is not yet available in Indonesia. The location of the source of raw materials affects the availability of raw materials in the company, the farther the source of raw materials, the more factors that need to be considered. The factors are longer delivery times and unexpected national or international policies. Raw materials are an essential resource, their availability must be optimized so that the process is smooth and uninterrupted production. Inventories are influenced by several factors, namely, the number of orders, the frequency of orders, and inventories to be issued by the company. Therefore inventory can affect the determination of the price of a product.

With a market that tends to fluctuate every year and a dominant source of imported raw materials, companies need to make a proper plan for the supply of pentolite raw materials. In this study, the planning of pentolite raw materials will be analyzed which can minimize inventory costs by using the Material Requirement Planning (MRP) method. MRP is considered appropriate to use because it can optimize inventory, reduce the risk of delays, and increase efficiency. The results of this study are expected to be an alternative in the selection of inventory models in the company.

2 LITERATURE REVIEW

MRP is a bound request consisting of a bill of materials (BOM) and an accurate inventory record. Based on this understanding, it can be interpreted that MRP is a material planning and control technique in a product unit produced[1]The objectives of the Material Requirement Planning (MRP)[2] are as follows:

a. Minimize inventory. MRP determines how much and when a component is needed according to the master production schedule (MPS). By using this method, procurement is carried out on components that are really needed so as to minimize inventory costs.

b. Reduce risk due to production or delivery delays. MRP identifies the number of materials and components needed both in terms of quantity and time by taking into account the production grace period and the procurement of components, so as to minimize the risk of unavailability of materials to be processed which can result in disruption of the production plan.

c. Realistic commitment. With MRP, it is hoped that the production schedule can be fulfilled according to the plan so that commitments to delivery of goods can be carried out more realistically. This encourages increased consumer satisfaction and trust.

d. Increase efficiency. MRP also encourages increased efficiency because the amount of inventory, production time, and delivery time can be better planned according to the master production schedule.

This process is carried out for each component in each planning period. According to the basic steps of the MRP system,[3] namely:

a. Netting

Netting is a calculation process to determine the number of net requirements, the amount of which is the difference between gross requirements and the state of inventory (which is in inventory and being ordered). The inputs needed in the process of calculating this net need are:

- The gross requirement is the amount of final product that will be consumed, for each period, during the planning period.
- Scheduled receipts from suppliers during the planning period.
- Inventory status owned at the beginning of the planning period.

b. Lotting

The lotting process is a process to determine the optimal order size for each product item based on the results of the calculation of net needs. The lotting process is closely related to determining the number of components/items that must be ordered/provided. The lotting process itself is very important in the material requirements plan. The use and selection of appropriate techniques greatly affect the effectiveness of the material requirements plan. The lot size is associated with the number of inventory costs, such as the cost of the ordering of goods (setup costs), holding costs, capital costs, and the price of the goods themselves.

c. Offsetting

This process is intended to determine the right time to carry out a planned order release to meet the level of net requirement. Order plans are made when the required material is determined by the lead time.

d. Explosion

The explosion process is the process of calculating the requirements of items that are at a lower level, based on the ordering plan that has been prepared in the offsetting process. In this explosion process, product structure and bill of materials have an important role because they determine the direction of the component item explosion.

The MRP system is an excellent way to determine the production schedule and net requirements of a production process. When there is a net requirement, a decision on how much to order must be made. This decision is called the lot sizing decision. The following are some of the lot-sizing techniques used; Economic Order Quantity (EOQ), Lot for Lot (LFL, and Period Order Quantity (POQ). The first two techniques are based on the level of demand, the other techniques are called different quantity measurement techniques. Because these techniques produce the same number of orders with net requirements in the integral value of successive planning periods. The measurement of different quantities does not create a residual unused quantity that is carried in the inventory to meet the needs of the next period in full.

a. *Lot for Lot* (LFL)

LFL is a lot of size determination technique that produces what is needed to fulfill the plan exactly. The Lot for Lot (LFL) method, or also known as the minimal inventory method, is based on the idea of providing material inventory (or producing) as needed only, the amount of inventory is kept to a minimum. The number of orders according to the actual quantity required (lot-for-lot) results in no inventory being kept. Thus, the costs incurred are only in the form of ordering costs. The assumption behind this method is that the supplier (from outside or from the factory floor) does not require a certain lot size, meaning that any lot size chosen will be fulfilled[4].

The LFL technique, also known as discrete ordering, is the simplest of the other techniques. The use of this technique reduces the cost of carrying inventory for items that are expensive or items with low assembly costs and unsustainable needs. Items with high production volumes and items exceeding special facilities sent to continuous production are usually ordered, lot for lot.

b. *Economic Order Quantity (EOQ)*

EOQ is one of the oldest and widely known inventory control techniques, this inventory control method answers two important questions, namely when to order and how much to order[5].

The EOQ model can be applied if the following assumptions are met:

a) The demand for the product is constant, uniform, and known
b) The price per unit of product is constant
c) Holding cost per unit per year is constant
d) Ordering cost per order is constant
e) The time between orders placed and goods received is constant
f) There is no shortage of materials

The EOQ formula used:

$$EOQ = \sqrt{\frac{2\ x\ D\ x\ S}{H}}$$

EOQ = economic order quantity
D = annual demand
S = setup or ordering cost
H = holding or carrying cost per unit per year

This simple formula is used to solve the monthly or quarterly average usage, the EOQ is based on a continuous fit, stable level requirement, and works best when actual demand estimates the assumption. The more unsustainable and non-uniform needs, the less effective EOQ will be. EOQ also assumes that order costs and inventory transportation costs are important concerns.

c. *Period Order Quantity (POQ)*

POQ is a lot of size technique that places the order or quantity required over a predetermined period, for example for 3 weeks. POQ is an order quantity that covers a certain demand for a certain interval. The quantity of each order is recalculated at the time the order occurred and never left more inventory.

The POQ technique is identical to the FPR except that the ordering interval is calculated using EOQ logic. EOQ calculates the standard formula, where the mass demand is the net MRP requirement schedule of the item. Then converted into the equivalent number of orders per year. The number of planning periods in a year is divided by this number to determine the ordering interval. A much better solution is to shorten the cycle time so that no released orders from any components below this level are affected by this last order. POQ fixed interval techniques avoid waste and thus reduce inventory costs. For this reason, they are more effective than EOQ (for the same number of periods) because the annual installation costs are the same but delivery costs are low. Simple periodic ordering techniques, avoid leftovers, make orders at regular intervals, and help smooth work input to the work center gateway (start). Compared to many other districts.

The POQ formula used[6]:

$$POQ = \frac{EOQ}{R}$$

POQ = Period Order Quantity
R = Average demand

3 RESEARCH METHODS

In this study, material requirements planning was completed following the basic steps of the MRP system·

a. Netting calculates the net requirement for each period. With gross requirements data from MPS, schedule receipt data from suppliers, and inventory status, a net requirement will be determined.

b. Lotting, which is calculating the amount of material to be provided each period. Using 3 lot sizing techniques, namely Lot for Lot, Economic Order Quantity, and Period Order Quantity (POQ). From the three alternatives, a lot-sizing policy will be determined which results in the minimum inventory cost

c. Offsetting aims to determine the right time to carry out a planned order release in order to meet the net requirement

d. Explosion, the process of calculating the gross requirement of items that are at a lower level, is based on an order plan that has been prepared in the offsetting process. In this explosion process, product structure data and Bill of Materials play an important role because they determine the direction of the component item explosion.

4 DISCUSSION

The preparation of the MRP requires some data and information related to the structure of the pentolite product, the bill of material, the gross requirement for each material that makes up the pentolite product, and other data. The data that have been collected are as follows:

a. Pentolite product structure, containing information on component level, component type, as well as the percentage and weight requirement of Pentolite raw material. The data is presented in table 1.

Table 1

Pentolite Product Structure and Raw Material Requirements

Component Level	Component/ material	Percentage of Usage	Usage Amount
0	Pentolite	100%	400 g
1	Material P	45%	180 g
1	Material T	55%	220 g

Percentage of usage is the percentage of usage in Pentolite production per gram of weight. Amount of usage (grams) = Percentage of usage (%) x Weight of Pentolite.

b. Data of price for each raw material, inventory costs which include ordering cost and holding cost, as well as initial inventory status of the two materials, are presented in table 2 and table 3.

Table 2

Purchase Data of Material

No.	Material	Price (Rupiah/kg)	Supplier's country of origin	Lead time (weeks)	Initial Inventory (kg)
1	P	81.526	India	4	36.800
2	T	42.644	India	3	30.654

Table 3

Inventory Cost

No.	Material	Ordering Cost (Rupiah/order)	Holding Cost	
			Fixed Cost (Rupiah/year)	Variable Cost (Rupiah/kg/year)
1	P	12.375.000	50.000.000	360
2	T	12.375.000	50.000.000	420

This fixed holding cost includes the cost of permits, maintenance, and warehouse security. This cost has the same amount every year, regardless of the amount of inventory stored in the warehouse.

c. Master Production Schedule and gross requirement for each material are present in table 4.

Table 4

Pentolite's Master Production Schedule and a Material Gross Requirement

No	Period	Production (Pcs)	Production (Kg)	Material P (Kg)	Material T (Kg)
1	January	191.735	76.694	34.512	42.182
2	February	190.046	76.018	34.208	41.810
3	March	188.357	75.343	33.904	41.439
4	April	186.669	74.668	33.600	41.067
5	Mei	184.980	73.992	33.296	40.696
6	June	183.291	73.316	32.992	40.324
7	July	181.602	72.641	32.688	39.952
8	August	179.913	71.965	32.384	39.581
9	September	178.224	71.290	32.080	39.209

10	October	176.535	70.614	31.776	38.838
11	November	174.846	69.938	31.472	38.466
12	December	173.157	69.263	31.168	38.095
			875.742	394.084	481.658

The data that has been collected is used to develop the MRP. In this section, the calculation steps for material P will be described.

a. MRP with Lot for Lot Policy

Orders are made every period, with a different amount in each period, according to the number of net requirements. Frequency of orders twelve times per year. MRP for material P with LFL lot-sizing policy is present in figure 3.

Lot sizing = LFL	past due	1	2	3	4	5	6	7	8	9	10	11	12
Gross Requirement		34,512	34,208	33,904	33,601	33,296	32,992	32,688	32,384	32,081	31,776	31,472	31,168
Schedule Receipt		0	0	0	0	0	0	0	0	0	0	0	0
On Hand	36,800	2,288	-										
Net Requirement			31,920	33,904	33,601	33,296	32,992	32,688	32,384	32,081	31,776	31,472	31,168
Plan Order Receipt		-	31,920	33,904	33,601	33,296	32,992	32,688	32,384	32,081	31,776	31,472	31,168
Plan Order Release		31,920	33,904	33,601	33,296	32,992	32,688	32,384	32,081	31,776	31,472	31,168	-

Figure 3 MRP for Material P with LFL Lot-sizing Technique

b. MRP with EOQ Policy

The inventory costs used to determine EOQ are ordering costs and holding costs. In the cost of storing raw materials P and T, there are 2 types of costs, namely fixed costs and variable costs. This fixed holding cost is fixed regardless of the value of Q, so this cost is not considered to obtain optimal EOQ.

$$EOQ = \sqrt{\frac{2\ x\ D\ x\ S}{H}}$$

$$EOQ = \text{Q} = \sqrt{\frac{2\ \ x\ 394.084x\ Rp.12.375.000}{Rp.360}} = 164.600\ kg$$

Every time you place an order using a fixed amount of Q.

$$Order\ Frequency = f = \frac{D}{Q} = \frac{394.084}{164.600} = 2{,}39 \approx 3\ times$$

MRP for material P with EOQ lot-sizing policy is present in figure 4.

Lot sizing = EOQ	past due	1	2	3	4	5	6	7	8	9	10	11	12
Gross Requirement		34,512	34,208	33,904	33,601	33,296	32,992	32,688	32,384	32,081	31,776	31,472	31,168
Schedule Receipt		0	0	0	0	0	0	0	0	0	0	0	0
On Hand	36,800	2,288	132,680	98,776	65,175	31,879	163,487	130,798	98,414	66,334	34,557	167,685	136,517
Net Requirement		-	164,600	-	-	-	164,600	-	-		-	164,600	-
Plan Order Receipt		-	164,600	-	-	-	164,600	-	-	-	-	164,600	-
Plan Order Release		164,600	-	-	-	164,600	-	-	-	-	164,600	-	-

Figure 4 MRP for Material P with EOQ Lot-sizing Technique

c. MRP with POQ Policy

$$POQ = \frac{EOQ}{R}$$

$$R = \frac{D}{12} = \frac{394.084}{12} = 32.840$$

$$POQ = \frac{164.600}{32.840} = 5{,}01 \approx 5\ periods$$

Every time you place an order includes five periods of gross requirements.

$$Order\ Frequency = f = \frac{12}{POQ} = \frac{12}{5} = 2{,}40 \approx 3\ times$$

MRP for material P with POQ lot-sizing policy is present in figure 5.

Lot sizing = POQ	past due	1	2	3	4	5	6	7	8	9	10	11	12
Gross Requirement		34,512	34,208	33,904	33,601	33,296	32,992	32,688	32,384	32,081	31,776	31,472	31,168
Schedule Receipt		0	0	0	0	0	0	0	0	0	0	0	0
On Hand	36800	2,288	133,794	99,889	66,289	32,992	-	127,713	95,329	63,248	31,472	0	(0)
Net Requirement		-	165,714	-				160,402		-			31,168
Plan Order Receipt		-	165,714	-	-	-	-	160,402	-	-	-	-	31,168
Plan Order Release		165,714	-	-	-	-	160,402	-	-	-	-	31,168	-

Figure 5 MRP for Material P with POQ Lot-sizing Technique

d. Selection of the optimal MRP based on the minimum total inventory cost

In the same way as above, the calculation of MRP for material T is obtained. Then, with the existence of two types of holding costs, to calculate the total cost of inventory, the formula is used:

Total Inventory Cost = Ordering cost + Variable Holding Cost + Fixed Holding Cost

The total variable holding cost is obtained by adding up all inventory per month and multiplied by the variable holding cost (rupiah/kg/month). The calculation of the total variable holding cost for each lot-sizing technique for both types of material is presented in table 5. Then the total inventory cost for each lot-sizing technique for both types of material is presented in table 6.

Table 5

The calculation of the total variable holding cost for each lot-sizing technique

Material	Lot Sizing Technique	Total inventory per month (kg/month)	variable holding cost (Rupiah/kg/month)	Total variable holding cost (Rupiah)
P	LFL	2.288	30	68.631
	EOQ	1,128,589		33.857.669
	POQ	653,013		19.590.404
T	LFL	0	35	-
	EOQ	1,058.835		37.059.231
	POQ	716.914		25.091.990

Table 6

The Total Inventory Cost for Material P and T

Material	Lot Sizing Technique	Order Frequency	Ordering Cost (Rupiah)	Variable Holding Cost (Rupiah)	Fixed Holding Cost (Rupiah)	Total Inventory Cost (Rupiah)
P	LFL	12	148.500.000	68.631	50.000.000	198,568,631
	EOQ	3	37.125.000	33.857.669	50.000.000	120,982,669
	POQ	3	37.125.000	19.590.404	50.000.000	106,715,404
T	LFL	12	148.500.000	-	50.000.000	198,500,000
	EOQ	3	37.125.000	37.059.231	50.000.000	124,184,231
	POQ	3	37.125.000	25.091.990	50.000.000	112,216,990

Based on the calculations in table 6, it is shown that the minimum total inventory cost for both P and T materials is MRP with POQ policy.

5 CONCLUSION

The results of this research are the lotting technique for controlling Pentolite raw material inventory in MRP, with the minimum total inventory cost, namely the POQ method which has inventory costs for material P of 106.715.404 rupiahs and material T of 112.216.990 rupiahs. If the company can order different quantities from suppliers for each delivery, the lot-sizing policy used is POQ. However, if the supplier can only deliver the same quantity, then the EOQ policy can be chosen

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