

Dynamic Simulation to Minimize Inventory Cost of Coal Considering Uncertainty Demand of Product

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Abstract—This paper briefly discusses the inventory management of coal in a cement industry. The cement company uses coal as fuel in the production process. Continuous production process must be maintained, thus the coal supply must be met to the production demand. In this study, we develop a dynamic simulation of coal inventory control system. We implemented periodic review system (P system) and continuous review system (Q system) method. Our simulation scenario consider some decision variables such as supply, variation of demand, and fluctuation of demand in order to understand the behaviour of the proposed model. This method is expected to provide recommendations for improve the inventory control policies in determining the optimum amount of coal in the warehouse and the optimal interval between orders with a minimum total inventory cost at uncertainty demand condition of product clinker and cement.

Keywords—Dynamic Simulation, Coal Inventory, Inventory Costs, Uncertainty Demand.

I. INTRODUCTION

PT. XYZ is one of the cement factories in Indonesia which is located in the eastern of Java, using coal as fuel in the production process. In existing conditions, coal inventory levels tend to fluctuate and are not always between the minimum and maximum stock values set by the company, which is a minimum stock of 120,000 tons and a maximum stock of 160,000 tons. Trending at the beginning of the year stock is quite high, because these periods are the peak of the rainy season, the lead time of shipping is usually longer due to weather constraints, so in order to anticipate and maintain operational safety, stocking is carried out more than the maximum stock. Whereas at the end of the year, inventories tend to be low and pass the minimum limit, potentially causing shortages. Based on the specified limit of minimum and maximum stock, it is known that the company applies a periodic review system inventory control method, but the realization of its deployment is still not appropriate.

The current problems at PT XYZ related to coal usage are inventory management method is not appropriate based on supply-demand patterns and product characteristics, at risk of excess and lack of stock: (Figure 1)

1. The amount of coal inventory held by the company is less effective
2. Invalid supply intervals and not according to demand

II. LITERATURE REVIEW

A. Dynamic Simulation Modelling

Model is an imitation and simple form of a system that presents the characteristics of a real system. The model is used

to facilitate the study of real system behavior. The model developed with a dynamic system has the following characteristics:

1. Describe a causal relationship (causal loop diagram)
2. Simple mathematical equation
3. Synonym with industrial, economic and social terminology in nomenclature
4. Many variables can be used
5. Can produce changes that are not continuous if the decision is needed

Dynamic simulation models are built for the purpose to forecasting or designing policy. Unlike the static model, the dynamic model approach is deductive and is able to eliminate weaknesses in the assumptions made so that agreement on the assumptions can be obtained. Dynamic simulation models emphasize the process of change from one condition to another. Delay time becomes important in dynamic modeling because change requires time. If in the static model the variable level of the state and behavior of the system then determines the current level of stock and behavior of the system, then in the dynamic system model the temporal relationship only applies to stock levels and not to the behavior of the system. The behavior of the system at the present time cannot be shown by its behavior in the past, but rather by the mechanism of interaction of micro structures in the system [1].

Problems in dynamic systems are not only caused by external influences, but by the internal structure of the system. "The purpose of a dynamic system methodology based on a causal philosophy (cause and effect) is to gain a deep understanding of the work procedures of a system" [2].

B. Inventory Management System

Inventory mean all materials that will be used for the production process as raw materials and spare parts, in process material, and product. Inventories arise because of uncertainty of demand [3]. Inventory has several functions, including as a stabilizer of the production process and efforts to maintain the service level of the company. However, the amount of inventory must be controlled because both excess and lack of inventory will both have their own impact on the company. If there is a shortage of inventory, it will cause disruption in the production process and reduce the service level of the company, whereas if there is an excess of inventory, it will cause an increase in procurement costs and the cost of storing the goods. Inventory cost components:

1. Purchase Cost
2. Procurement costs
3. Storage costs (Holding costs)
4. Cost of lack of inventory

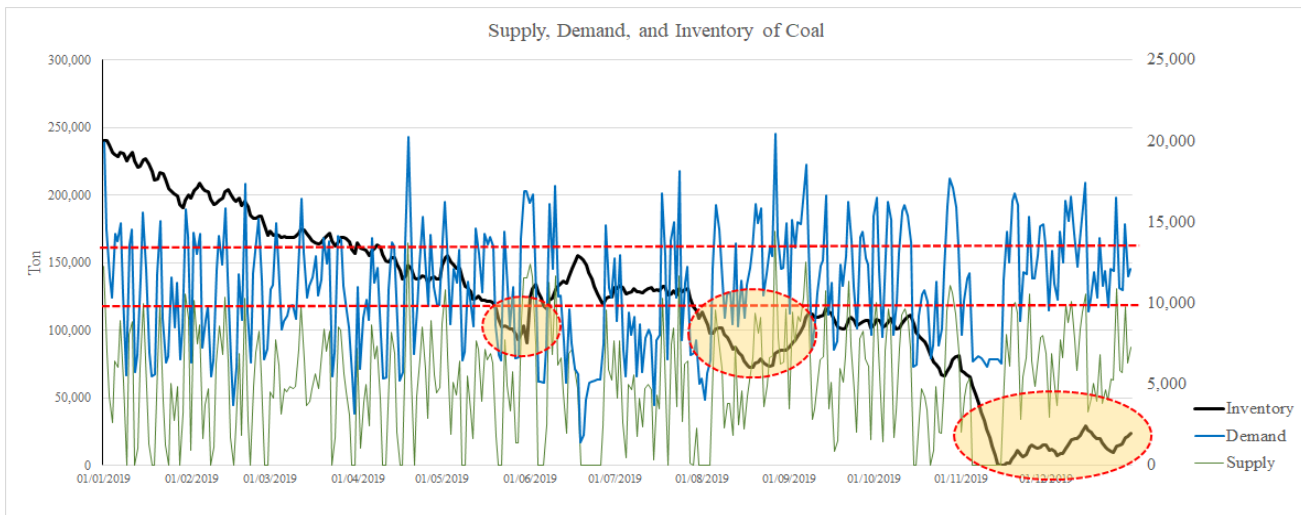


Figure 1. Supply, Demand, and Inventory of Coal PT XYZ.

Total cost = purchase cost+ order cost + holding cost + shortage cost (1)

Purchase costs: Cost of goods (unit price of goods multiplied by the amount of demand)

Ordering fee : Annual order fee (demand / Q x Co)

Save cost : Annual save fee (Q / 2 x h)

Shortage costs : costs that arise if there is a shortage of inventory

1) Continuous review (Q system)

According to Silver et al (1998), inventory control policies in continuous review are divided into two system; (s, S) and system (s, Q). The system (s, Q) is also called the order point, order-quantity system. Just like the system (s, S), this system also makes an order when the inventory position touches a certain position (s), the difference lies in the order quantity or the amount ordered, which is equal to Q. The Q value is fixed for each order placed.

There are 2 parameters of the number of reorder, Q and equal to the difference between the level of inventory and maximum inventory (S). Inventory parameter Q (for control system s, Q) is the optimal order quantity, while the parameter S (for control system s, S) is the maximum inventory whose parameter value is the amount between the minimum inventory and the optimal order quantity. For the re order point (s) can be formulated as follows:

$$ROP(s) = D \times L + SS \quad (2)$$

D: average demand

L: lead time

Ss: safety stock

2) Periodic review (P system)

Silver divide the continuous review inventory control policy into two, system (R, S) and system (R, s, S) [4]. The system (R, S) will place an order at each review period. Order quantity or the amount ordered by the system (R, S) does not fix, based on the difference between the actual inventory position and the maximum inventory position (S) because in each review period inventory fulfillment will be carried out to position S.

System (R, s, S) is a combination of system (s, S) and (R, S). Reviews are conducted every certain period (R). If during the review period the actual inventory position is more than or above the value of the reorder point (s), there will be no orders in the review period. Conversely, if the inventory position is less than or below the value of the reorder point

(s), then an order is made with an amount that is not fixed according to the actual inventory position because every order will be filled up to S.

The reorder interval in the periodic review system is always fixed and the quantity or number of reorder changes according to the difference between the inventory level and the target inventory. There are 2 inventory parameters in the periodic review system (R, S), namely the review period (R) which is determined according to management policies based on company conditions and inventory targets (S) whose magnitude is affected by the review period intervals.

Inventory targets in the (R, S) and (R, s, S) methods can be formulated as follows:

$$Inventory Target (S) = d \times (1 + R) + ss \quad (3)$$

R: review period

III. DESIGN OF SIMULATION

A. Problem Description

The problem for the proposed simulation model is determine the method of inventory management in accordance with the pattern of supply-demand and the characteristics products. There are 2 inventory management methode, continuous review system dan periodic review system. The objective is to get a minimum inventory cost and maximum revenue by improve management inventory methode and fulfillment the demand. There are 2 products, cement and clinker, and cement has 2 types, OPC (ordinary portland cement) and PCC (portland pozzolant cement). Initially the demand was only cement, currently the demand for cement has decreased while demand for clinker is increased. The model restricted by some assumptions. The volume of the demand using the forecasting demand from the company. The biggest selling profit margin is PCC cement, then OPC cement, and the smallest is clinker. Coal index in the product as shown on Figure 2:

B. Causal Loop Diagram and Stock Flow Diagram

Causal loop diagrams are the translation of a causal event into a particular drawing language (Muhammadi, et al., 2001). With the causal loop diagram it will be easy to understand the relationship and the influence of certain variables on system behavior.

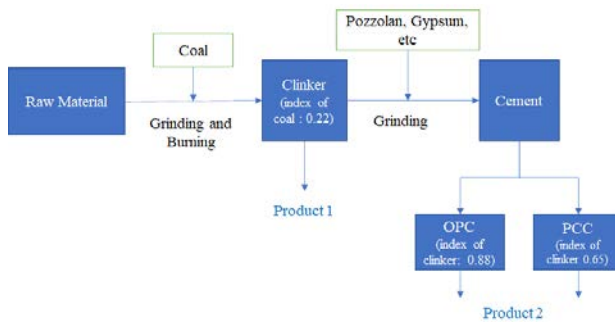


Figure 2. Index material in the product.

Supply is influenced by ROP (re-order point, or the minimum level of stock that is maintained based on demand and lead time), while demand is influenced by customer needs. These two things are uncertain / probabilistic which is also influenced by other external factors. Other systems that affect coal supply are the clinker production process and cement production process, which is the process that involves the coal. Then the next sector is the revenue system, which will be used to purchase the coal (as a loop) (Figure 3).

The stock and flow diagram in this model is built based on the causal loop diagram above with several parameters that are used as the main variable, and each of these variables has their own formulation. The formulation is based on general formulation, actual conditions, or related data. The main system model will show the interrelationships between variables that have been identified previously.

C. Scenario Model

In this study, a number of dynamic simulation scenarios will be carried out to provide an overview of the cost of inventories and total revenue under conditions of fluctuations in demand and supply. Total revenue expected to be at higher level as indicator of the better, while the total inventory cost is expected to be at a lower level as indicator of the better.

1) 1st scenario, existing demand with variable supply (existing and theoretical) (Table 1 and 2)

At the same demand conditions, the application of the periodic review system method provides an improvement but is less than optimal, because changing patterns of demand require more flexible stock management. The shorter monitoring period, the more efficient inventory costs, and the most appropriate method is continuous review system.

The difference between existing condition and continuous review system supply method (as the lowest total inventory cost) is due to the existing coal stock tends to be higher than demand at the beginning of the year and lower at the end of the year. This results in high total inventory costs, due to high purchase cost and holding costs plus the emergence of shortage costs. Whereas in the management of supplies according to the continuous review system method (scenario D) coal stocks are flat throughout the year at the optimal level stock, minimizing excess nor lack of stock.

From the calculation using continuous review system method, the optimum stock of coal that we have to maintain is about 127.643 tons and supply interval is determined by calculating the optimum volume of barge (transport coal) divided by daily demand, which is $7.500 / 5.807 = 1.29$ so that order are made every 1.29 days or 4th in 5 days.

The weakness of this scenario is that the demand is assumed to be fixed (demand pattern of 2019), whereas the

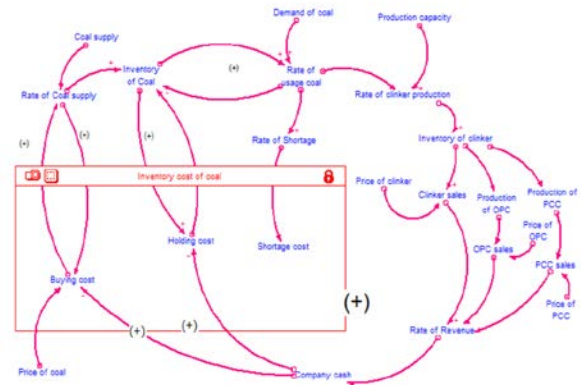


Figure 3. Causal loop diagram.

actual demand changes over time so supply and inventory management must be monitored at all times.

2) 2nd scenario, Supply is adjusted by the continuous review system method and demand is fluctuations each product

Running 2nd scenario, involved each product both clinker and cement, both OPC and PCC. The amount of each product is based on the company's work plan and budget in 2020. There are 3 scenarios, which are optimistic, moderate and pessimistic according to the Table 3 and 4.

From the simulation results above, it is known that the total inventory cost is different for each demand mode, because coal supply fitting with coal demand, which is influenced by product demand. While from total revenue, it can also be seen that each mode of demand has different values depending on the type of product sold. The lowest percentage of total inventory cost is the moderate mode, so the moderate mode is the most beneficial to be applied.

The weakness of this scenario is the difficulty in implementation because the uncertainty of demand is directly applied to the production process. Production costs fluctuate and tend to be high, because running equipment at variable capacities and planning often change.

3) 3rd scenario, Supply are adjusted by the continuous review system method and demand varies according to product type at maximum capacity

Running 3rd scenario was conducted to determine the effect of inventory costs and total revenue if demand change in terms of variations in the products sold. In this 3rd scenario the authors simulate inventory costs under conditions of fluctuations in demand between the main cement products (2 main types of cement produced, OPC and PPC) and Clinker, in a state of maximum production capacity. (Table 5)

From the Table 5 and 6, we know that the more clinker we sell, the inventory cost will increase and the company's revenue will decrease. At the maximum production, 1% increase in clinker demand will increasing inventory cost by 0.01% or Rp 161.34 million and decreasing total revenue by 0.47% or Rp 56.59 billion.

From this scenario, we can optimize the proportion of cement and clinker production sold to get the maximum profit based on existing demand. For example in 2020 which is estimated decrease on cement demand and increase on clinker demand, the cement demand must be prioritized, and the remaining capacity for clinker sales.

Weakness of 3rd scenario is the assumption that the simulation is performed on the optimum capacity of

Table 1.
1st scenario's variable

Scenario#1	Supply	Demand
A	Existing	Existing (100% cement)
B	Periodic review system metode (7 days)	Existing (100% cement)
C	Periodic review system metode (1 days)	Existing (100% cement)
D	Continuous review system metode	Existing (100% cement)

Table 2.
Result of 1st scenario

1 st Scenario		Total Inventory Cost (Rupiah/yr)	Total Revenue (Rupiah/yr)	%
A	Existing	1,256,777,755,524	9,856,369,487,106	0.1275
B	Periodic review system metode (7 days)	1,206,306,961,081	10,154,226,163,835	0.1188
C	Periodic review system metode (1 days)	1,203,849,967,924	10,154,226,163,835	0.1186
D	Continuous review system metode	1,201,941,295,227	10,154,226,163,835	0.1184
Difference		54,836,460,297	-297,856,676,729	

Table 3.
2nd scenario's variable

Scenario#2	Supply	Demand (ton/yr dan %)		
		Clinker	OPC	PCC
Optimistic	Continuous review system metode	1,666,000	4,205,633	8,640,096
		15.17	33.70	51.13
Moderate	Continuous review system metode	1,449,000	4,143,930	8,362,934
		13.76	34.63	51.62
Pesimistic	Continuous review system metode	1,185,000	3,984,219	7,961,439
		12.01	35.54	52.45

Table 4.
Result of 2nd scenario

Mode	Scenario#2			Total Inventory Cost (Rupiah/yr)	Total revenue (Rupiah/yr)	%
	Clinker	OPC	PCC			
Optimistic	15.17	33.70	51.13	1,390,417,235,078	9,920,287,060,900	0.1402
Moderate	13.76	34.63	51.62	1,488,171,857,732	11,020,295,209,840	0.1350
Pesimistic	12.01	35.54	52.45	1,428,369,507,990	10,527,437,756,395	0.1357

Table 5.
3rd scenario's variable

Scenario#3	Supply	Demand		
		Clinker	OPC	PCC
A	Continuous review system metode	0%	30%	70%
B	Continuous review system metode	10%	27%	63%
C	Continuous review system metode	25%	23%	53%

Table 6.
Result of 3rd scenario

Mode	Scenario 3			Total Inventory cost (Rupiah/yr)	Total revenue (Rupiah/yr)	%
	Clinker	OPC	PCC			
A	0%	30%	70%	1,497,756,079,565	11,446,116,864,000	13.09
B	10%	27%	63%	1,499,369,515,565	10,951,946,914,426	13.69
C	25%	23%	53%	1,501,789,669,565	9,978,235,706,926	15.05

production equipment, If an unplan shutdown occurs, this potential income will decrease. Inventory costs are also assumed to be stable, supply is carried out smoothly as needed (re-order point), if there is an extreme delay there will potentially increase inventory costs due to rising costs of inventory shortages. At the maximum production, 1% increase in clinker demand will decreasing total revenue by 0.47% or Rp 56.59 billion, so that the cement demand must be prioritized, and the remaining capacity for clinker sales.

IV. CONCLUSION

In the lumpy demand condition at PT XYZ as it is today, the more appropriate inventory control method applied is the continuous review system method. This method was able to

reduce the total inventory cost by 4.36% or equivalent to Rp. 54.84 Billion / year (from Rp. 1,256 T to Rp. 1,201 T). The optimal level of inventory is maintained at the level of 127.643 tons, with intervals of supply every 1.29 days or 4rd in 5 days per 7,500 tons (in the 2019 demand pattern) and adjusted by continuous review system metode in dynamic demand. Based on the simulation results of 2 company forecasting scenarios, the lowest percentage of total cost of inventory is obtained in B mode (Clinker/OPC/PCC= 13.76%/34.63%/51.62%), so the most beneficial mode applied is B. At the maximum production, 1% increase in clinker demand will increasing inventory cost by 0.01% or Rp 161.34 million and decreasing total revenue by 0.47% or Rp 56.59 billion, so that the cement demand must be prioritized, and the remaining capacity for clinker sales. During the

research, it necessary to improve an existing design method to increase the efficiency of the system.

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