Model of Continuous Review System with Backorder Case for Inventory Planning and Control: A Methanol Industry Case Application

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Abstract

The problem that generally occurs in methanol industry is auxiliary materials stock out, i.e. urea, NPK, and sulfuric acid. This condition leads to the production quantity only reach 75% of the target. Therefore, it is necessary to develop inventory control model so that the production target can be achieved. The estimation of auxiliary materials needs is done by forecasting method with the smallest mean absolute percentage error. Model of continuous review system with backorder case is used for inventory planning and control. With this model, the industry can determine the amount of safety stock and reorder point to avoid the risk of stock out or excess of raw materials so it can minimize the total inventory cost. The result shows that the model can reduce the total inventory cost up to 12,02% in the next one year planning period.

Keywords
Model of Continuous Review System Backorder Case, Modified EOQ, Inventory Control

1. Introduction

Inventory along the supply chain have major implications for financial performance of an industry. Inventory management that best suits with industrial operation plays a vital role to achieving a competitive performance (Ogbo et al, 2014). A balance between carrying costs and ordering cost becomes the goal of inventory control (Kulkarni and Raihans, 2013; Onanuga and Adekulne, 2014). Production inventory control is categorized as one of the main decisions in supply chain (Gholamian and Heydari, 2017). To implement a reliable inventory controls, it should be noted that there are various factors related to inventory. These factors include material requirements scheduling, ordering frequency, efficient forecasting and supply chain integration (Mogere *et al*, 2013). Demand pattern also plays as important factor for inventory management (Wanke, 2014; Eriksen and Nelsen, 2016).
Methanol industry is one of the industries that produce methanol. The main raw material is sugarcane drop which is a by-product of sugar factory. In addition, there are several auxiliary materials, i.e. urea (46% N), NPK (15% N 15% and K 15%), sulfuric acid (H_2SO_4), super-floc, TRO (turkey red oil) and yeast. The problem that often happens is materials stock out such as urea, NPK and sulfuric acid in methanol production. This condition leads to the production quantity only reach 75% of the target. Therefore, this research is done by using inventory continuous review model system with backorder case so that material inventory can be monitored at any time. In backorder case, the unfilled item is completely backordered in the following period (Jaksic and Fransoo, 2015).
A continuous review system or economic order quantity (EOQ) is the most fundamental concept adopted by many industries for inventory management practice (Appadoo *et al*, 2012; Islam, 2013; Drake and Marley, 2014). The inventory system with EOQ can be more effective than a just in time system for probabilistic and stochastic demand (Min Wu, 2011). The application of basic EOQ and material requirement planning (MRP) shows an effective cost saving for inventory management in a furniture industry (Zaidi *et al*, 2012). EOQ is used in multi- product case to determine the optimum order quantity for daily used products (Iwu *et al*, 2014).
Some modification of basic EOQ model are developed to improve the model performance (Korponai *et al*, 2017). Two-item EOQ model with partial backordering and substitution is formulated to determine order quantities and

order cycles for the two items (Zhang *et al*, 2010). An EOQ model with backorder case in a fuzzy situation is created by employing two types of fuzzy numbers, i.e. trapezoidal and triangular (Kazemi *et al*, 2010). Two EOQ models, i.e. EOQ with back order and EOQ without backorder have successfully been arranged for a deteriorating inventory problem (Widyadana *et al*, 2011)). An inventory model for deteriorating items also being developed by considering the use of preservation technology, shortages and salvage value to minimize total inventory cost (Mishra, 2013). An inventory model for deteriorating item is modified with finite production rate in a single-manufacturer and multi-buyer case (Ghiami and William, 2015).
EOQ model with linear and fixed backordering cost is introduced using a fractional coefficient (Sphicas, 2014). A model and solution for EOQ with all-unit discounts and partial backordering at a constant rate is determined using a multi-factor experiment (Taleizadeh and Pentico, 2014). A modified EOQ for defective item with permissible delay in payments and shortage is proposed to improve total profit (Sulak *et al*, 2015). EOQ model for imperfect quality items with partial backordering and screening errors is built to optimize the order size and backordering quantity (Sharifi *et al*, 2015). EOQ model with backorder and imprecise holding cost and shortage cost is formed to minimize fuzzy annual total inventory cost (Soni and Joshi, 2015). An EOQ model with shortage and inflation is proposed for significant total inventory cost reduction (Wulan and Nurjaman, 2015). A fuzzy optimization approach to EOQ model is used to determine the order quantity in the fuzzy decision space (Pattnaik, 2015).
Five models for EOQ problem is studied, four of this model is used for a single product by considering incremental discounts with or without backorders and all-unit discounts with or without backorders and one model is for multi-product (Pereira and Costa, 2017). Inventory model for deteriorating items with non-linear price dependent demand rate is developed using Weibull distribution (Rai and Sharma, 2017). A modified simulated annealing is used for continuous review system (Q, r) in perishable items to determine the quantity order and minimizing total inventory cost (Siriruk and Dungkokkruad, 2017).

2. Basic Theory

1.1 Model of Continuous Review System with Backorder Case

This model is used to anticipate a change rate of probabilistic demand. This model serves to prevent companies from raw materials stock out for products needed by customers. There are fifteen main stages in this model, i.e. (Handoko, 2011):

a. Calculating Q

$$Q = \sqrt{\frac{2D[S+ \pi.\sigma L.g(k)]}{h}} \quad (1)$$

Where D is demand/ year (unit), S is ordering cost, π is backorder cost/ unit, $\sigma L\ g(k)$ is planned stockout rate (unit) and h is holding cost/ unit/ year.

b. Determine order stock out rate (OSOR)

$$OSOR = \frac{h.Q}{\pi.D} \quad (2)$$

c. Determine safety factor (k) or z based on OSOR value using standard statistic table for normal distribution.

d. Calculating partial expectation g(k)

$$g(k) = \frac{Q.USOR}{\sigma L} \quad (3)$$

e. Calculating unit stock out rate (USOR). This value will be a constant for calculating g(k), because this value is minimum target of *stockout* probability.

$$USOR = \frac{g(k).\sigma L}{Q} \quad (4)$$

f. The result of g(k) then being used in Equation (1) for the next iteration process.

g. Recalculating $g(k)_{ij}$ from step f result Q_{ij} with USOR that already being calculated.

h. Step f and g is repeated until the convergen Q_{ij} and k_{ij} are obtained.

i. Calculating safety stock (SS)

$$SS = k * \sigma_L \quad (5)$$

j. Calculating *reorder point* (r)

$$r = D_L + SS \quad (6)$$

k. Calculating backorder quantity (B)

$B = \sigma_L * g(k)$ (7)

l. Calculating order frequency (m)

$m = \frac{Q}{D}$ (8)

m. Calculating order interval (T)

$T = \frac{1}{m}$ (9)

n. Calculating *unit service level* (USL)

$USL = 1 - USOR$ (10)

o. Calculating total inventory cost (TIC), where P is material price.

$TC = D.P + \left(\frac{S.D}{Q}\right) + h\left(\frac{Q}{2} + SS\right) + \left(\frac{\pi.D.B}{Q}\right)$ (11)

There is also an adjustment of the lead time period and the demand period for adjusting the standard deviation of demand and the standard deviation of lead time because lead times can vary, i.e. weekly or daily whereas demand is usually monthly.

a. Standard deviation of demand during lead time.

$\sigma_L = \sigma.\sqrt{L}$ (12)

Where σ is standard deviation of demand/ year and L is *lead time*

b. Average materials used during *lead time*

$D_L = D.L$ (13)

3. Research Method

This research is done in a methanol industry located in Yogyakarta, Indonesia. The object under this study is auxiliary materials, i.e. urea (46% N), NPK (N 15% P 15% and K 15%), sulfuric acid (H_2SO_4). The research is done with five main stages, i.e. data collection, demand forecast, inventory planning and control using current company policy, inventory control and planning using model of continuous review system with backorder case and comparative analysis. Some production data, i.e. demand of auxiliary materials, purchase price, ordering cost, holding cost, backorder cost or stock out cost and lead time are used to develop the inventory model. Forecasting demand of auxiliary materials is done to plan the number of needs in the next period. The forecasting method used is triple exponential smoothing (winters method) because it produces the smallest forecasting error value, i.e. Urea, NPK and sulfuric acid with forecast error respectively 2%, 4.3% and 0.1%. An inventory planning is developed using two models, i.e. current company policy and continuous review system with backorder case. The model of continuous review system with backorder case is developed using Eq. 1-13. Based on the results of data processing obtained parameters used in the planning of raw material inventory control. A comparative analysis is done to evaluate how big the difference between the inventory control using current company policy and continuous review system with backorder case.

4. Result and Discussion

Raw material requirement for the coming period can be estimated by a forecast using raw material requirement data in the previous period. The first step in forecasting is to determine the pattern of historical data to select an appropriate forecasting methods. Based on the data of auxiliary materials, urea (46% N), NPK (N 15% P 15% and K 15%), sulfuric acid (H_2SO_4) have a pattern of trend and seasonal. The forecasting methods chosen to forecast data with trend and seasonal data patterns are single exponential smoothing (SES), triple exponential smoothing (Winters Method) and autoregressive integrated moving average (ARIMA) methods. Then the most appropriate fore-casting methods is performed using the mean absolute mean deviation (MAD), mean square error (MSE) and mean absolute percentage error (MAPE) to estimate the error rate for each fore-casting method.

Table 1. Forecast Error

Materials	Parameter	Forecasting Method		
		Single Exponential Smoothing	Triple Exponential Smoothing (Winters Method)	ARIMA
Urea	MAD	686	67.2	294
	MSE	697199	27544.9	290809
	MAPE	22%	2%	9%
NPK	MAD	425	54.5	393
	MSE	318479	16458	300045
	MAPE	31%	4.3%	29.50%
H2SO4	MAD	201.6	0.85386	168
	MSE	71998.3	3.79988	49267
	MAPE	37.20%	0.1%	30%

Considering the smallest MAPE value as seen in Table 1, the most appropriate forecasting method for predicting auxiliary materials needs over the next twelve months is the triple exponential smoothing (winters method) method with each MAPE value less than 10%. Forecasting results for each materials and auxiliary materials for methanol production can be seen in Figure 1.

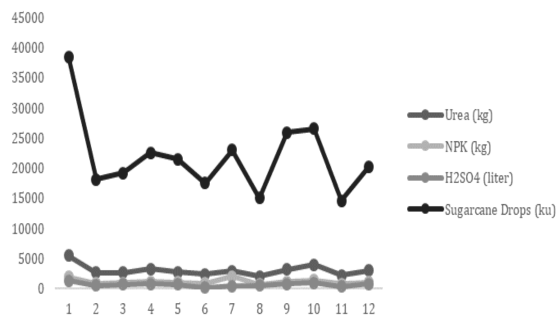

Fig. 1 Forecast Result of Material Used in Methanol Production

Calculated by continuous review system (Q) with backorder case for urea, the best iteration is obtained at the third iteration. The optimal order size (Q) is 2,199 kg for each order and the safety factor (k) of 2.244 as shown in Table 2. The value of reorder point (r) is 1,200.64 kg, which means when the inventory amount is equal to or less than the reorder point, then reordered by a fixed order quantity (Q). Obtained safety stock (ss) of 323.14 kg with the possibility of shortage of inventory in a year (B) of 0.615 kg. Ordering the urea done in a year (m) as much as 17 times with interval ordering time (T) 15 days. The total inventory cost (TIC) incurred by this model is Rp. 192,462,658 per year as shown in Table 3.

Table 2. Result of Continuous Review System with Backorder Case

	Q	**SS**	**r**	**B**	**m**	**T**	**USL**
Urea (kg)	2,199	323.12	1,200.64	0.615	17	15	99.97
NPK (kg)	1,489.26	54.56	397.09	7.6	10	25	99.49
H_2SO_4 (liter)	1,411.77	92.14	325.87	0.66	6	42	99.95

The calculation with continuous review system (Q) with backorder case is obtained at the second iteration with optimal order size (Q) of 1,489.26 kg for each order and safety factor (k) of 0.826 as shown in Table 2. The value of reorder point (r) is 397.09 kg which means when the amount of inventory equal or smaller than the reorder point, then reordered by a fixed order amount (Q). Obtained safety stock (ss) is 54.56 kg with the possibility of a shortage of inventory in a year (B) at 7.6 kg. The NPK order is made within a year (m) 10 times with a 25 days order time interval (T). The total inventory cost (TIC) generated is Rp 60,531,463 per year as shown in Table 3.
While calculation with continuous review system (Q) with backorder case for H_2SO_4, best iteration is obtained at third iteration with optimal order size (Q) of 1,411.77 liters for each order and safety factor (k) equal to 1.8315 seen in Table 2. While the value of reorder point (r) is 325.87 liters. Obtained inventory safety stock (ss) is 92.14 liters with the possibility of shortage of inventory in a year (B) at 0.66 liters. Ordering H_2SO_4 done in a year (m) as much as 6 times with interval ordering time (T) 42 days each time order. Thus, the total inventory cost (TIC) incurred is Rp 15,758,880 per year as shown in Table 3.

Table 3. Total Inventory Cost

No	Materials	Model of Continuous Review System With Backorder Case	Current Company Policy
1	Urea (Rp/ year)	Rp 192,462,658	Rp 217,902,778
2	NPK (Rp/ year)	Rp 60,531,463	Rp 68,845,182
3	H_2SO_4 (Rp/ year)	Rp 15,758,880	Rp 18,724,398
Total		Rp 268,753,001	Rp 305,472,358

The result of inventory continuous review system (Q) with backorder case model for auxiliary materials in methanol production process can decrease total inventory cost by Rp 36,719,357 or 12.02% in one year planning period.

5. Conclusion

From the research on inventory management of auxiliary materials in methanol production process using continuous review system model (Q) with backorder case, it can be concluded that for urea Q is equal to 2,199 kg or 2.2 tons with decreasing inventory cost by 11.7%. NPK Q is 1,489.26 kg or 1.49 tons with an inventory cost reduction at 12.1%. For H_2SO4 Q is equal to 1,411.77 liter with decreasing inventory cost equal to 15.8%. The total inventory cost of the three auxiliary materials decreased by Rp 36,719,357 or 12.02% over the next one year compared to the current company policy.

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