Inventory control system using economic production quantity with scrap and backorders: a pipe industry case study

Mailani Puspita[1], Parwadi Moengin[2]

[123]Department of Industrial Engineering, Trisakti University, Jakarta Indonesia
[1]mailani.puspita@yahoo.co.id
[2]parwadi@trisakti.ac.id (corresponding author)

Abstract. Companies engaged in the pipe manufacturing industry often face problems. The problem faced by the company is that the company does not yet have an optimal inventory system for buffer pipes. The purpose of this study is to provide a buffer pipe inventory control design using the economic production quantity (EPQ) method taking into account the existence of Backorders and Scrap in the company which is expected to meet consumer demand. By using the economic production quantity (EPQ) method, taking into account the company's backorders and scrap, the total cost of inventory needed by the company can be minimized, with the optimal amount of production for each product optimally determined. This study applies the EPQ method by considering backorders and scrap in the pipe manufacturing industry
Keywords: economic production quantity, inventory, backorder, scrap

1. Introduction

There are 2 types of industry, namely industry engaged in services and industry engaged in manufacturing. In its development, the industry in Indonesia continues to grow in order to meet customer needs and face competition at home and abroad. Various efforts have been made to increase customer satisfaction starting from the production process, the quality of the products produced, to the services provided to consumers. These efforts are made to produce products expected by consumers so as to increase customer satisfaction. The problem that is usually faced by pipe manufacturing companies is not using a good inventory system, especially finished goods inventory. In the absence of a good inventory control system, it causes a shortage of finished goods inventory so that the company cannot meet consumer demand. The shortage of finished goods inventory was also caused by the company checking the quality of the goods at the end, so that there were many re-checks of some of the goods to be transported. Therefore we need a method to control the inventory system, especially finished goods in order to meet consumer demand. The inventory system is expected not to be excessive or lacking. The aim of the research is to be able to provide a design for controlling finished product inventory systems using the Economic Production Quantity (EPQ) approach by considering backorders and scrap from buffer pipe products.

Some terms in inventory (Inventory) [1], [2]:

1. Safety Stock is the amount of security reserves. Where safety stock can be in the form of raw materials that have the goal of preventing shortages of raw materials in the production process. Safety stock can be used in conditions where there is a material shortage during the production process.
2. Backorder is a condition where the goods that have been ordered have not been or cannot be provided properly. As a result of these conditions, some customers wait until the goods ordered can be fulfilled as desired.

3. Scrap is the remaining percentage of the production process of a product or item that is used as added value for a particular product.
4. Shortage is a condition of shortage of inventory. Where inventory is not sufficient for the number of customer requests.
5. Lost Sales is a condition where the goods ordered have not been or cannot be provided properly in whole or in part, resulting in the customer canceling the purchase of goods so that the company loses sales.

Inventory has the goal of getting the right amount of goods at the right time at minimum cost. Some components of inventory costs include [3]. [4]:

1. Procurement Cost. There are 2 types of procurement costs, namely ordering costs and setup costs. Ordering costs are costs required to buy or order an item.
2. Cost of manufacture (Setup Cost) is the cost incurred in preparing the production of an item. Manufacturing costs arise because there are costs incurred. Costs that may incur manufacturing costs include:
   a. The cost of preparing production equipment
   b. Machine repair costs
   c. Cost of preparing work drawings
3. Purchase Cost (Purchase Cost) is the cost that must be incurred to buy an item. Purchase costs are influenced by the number of items to be purchased and the price of these items.
4. Holding Cost/Carrying Cost is a cost incurred due to the storage of an item. Storage costs are affected by the number of items to be stored.
5. Cost Shortage (Shortage Cost) is a cost that arises due to insufficient supply of goods demand.

Methods

The data collection needed in calculating the Economic Production Quantity (EPQ) model is general company data, products produced, production processes, demand data, backorder data, production scrap data, machine setup costs, shortage costs, production costs, and machine setup time respectively. -each product. The data that has been collected is then processed using the Economic Production Quantity (EPQ) model, Economic Production Quantity (EPQ) with scrap, Economic Production Quantity (EPQ) with backorders, and Economic Production Quantity (EPQ) with scrap and backorders.

Notation and Terinology

Parameter :

P_j : Production rate
D_j : Demand
$\boldsymbol{\theta}_j$: Scrap rate
$E[X_j]$: Average scrap
S_j : Setup time
t_j1 : The time when starting the production process
t_j2 : The time when the request occurred
t_j3 : The time when there is a production shortage
t_j4 : Time to fulfill the occurrence of backorders
A : Setup cost
C_p : Production cost per unit
C_h : Holding costper unit
C_s : Storage cost per scrap
C_b : Backorder cost per unit

Variables:

Q : Optimal number of Production units in units
I : Maximum inventory level
T : Length of Production period
B : Number of backorder units
TC : Total cost

***Economic Production Quantity* (EPQ)**

Economic Production Quantity (EPQ) is the optimal production level where a certain amount of production is produced by minimizing inventory costs. The Economic Production Quantity (EPQ) method can be achieved if the amount of inventory costs (set up costs) and storage costs (carrying costs) are incurred in a minimum amount. The production level can be said to be optimal if the total inventory cost (TIC) is minimum. The Economic Production Quantity (EPQ) method considers the level of inventory of finished goods and demand for finished products.

The calculation formula used for Economic Production Quantity (EPQ) inventory is as follows [5]:

Maximum Amount of Invetory, $I = Q^*(1-\frac{D}{P})$ ....(1)

The time during the production process, $t_1 = \frac{Q*}{P}$ ....(2)

The time when the request, $t_2 = \frac{I*}{D}$....(3)

Optimum cycle frequency, $N = \sqrt{\frac{\sum D_j . C_{hj} . (1-\frac{D_j}{P_j})}{2A}}$ ....(4)

Available production time per cycle, $T = \frac{Number\ of\ working\ day}{N}$ ....(5)

The optimal length of production period per observation period, T*= T x N ....(6)

Optimal production amount per cycle, $Q^* = \frac{Dj}{N}$....(7)

Total cost, $TC^* = \sum D_j . Cp_j + 2\ N\ A$ ....(8)

***Economic Production Quantity* (EPQ) with *Scrap* [5]**

Economic Production Quantity (EPQ) taking into account Scrap is a condition where the production rate is greater than the level of demand and the value of the production rate itself is considered constant, where

Optimal Production Rate (θ) = P. E[X] ....(9)

- $P_j - D_j - \theta_j \geq 0$ ....(10)
- $(1-\frac{D}{p}) \geq E[X] \geq 0$ ....(11)

Optimal production $(Q^*) = \sqrt{\frac{2AD}{C_h\left(1-\frac{D}{P}\right)-2C_h\left(1-\frac{D}{P}\right)E[x]+C_h . E[X]^2}}$....(12)

Optimal Production Time $(T^*) = \frac{Q(1-E[X]}{D}$.... (13)

Total cost $(TC^*) = (C_p.Q^*)+(C_s.E[X].Q^*)+A+C_h\frac{I}{2}T^* + C_h\frac{E[X].Q*}{2}t$.... (14)

where

$I = Q^* . (1-E[X]-\frac{D}{P})$ .... (15)

$t = \frac{Q*}{P}$ .... (16)

Economic Production Quantity* (EPQ) with *Backorder

Economic Production Quantity (EPQ) taking into account backorders is a method of inventory control taking into account backorder conditions. Calculations from the Economic Production Quantity (EPQ) model taking into account backorders according to Pentico et. al (2008) is as follows [6]

Optimal Production Amount (Q*) = $\sqrt{\frac{2AD}{C_h(1-\frac{D}{P})}}\sqrt{\frac{C_b+C_h}{C_h}}$ .... (17)

Optimal Production Time (T*) = $\sqrt{\frac{2A}{DC_h(1-\frac{D}{P})}}\sqrt{\frac{C_b+C_h}{C_h}}$ .... (18)

Optimal Number of Backorders (B*) = $\sqrt{\frac{2AD}{C_b}}\sqrt{\frac{C_h}{C_b+C_h}}\sqrt{1-\frac{D}{P}}$ .... (19)

Total Cost (TC*) = $\sqrt{\frac{2.A.D.C_h.C_b.(1-\frac{D}{P})}{C_h+C_b}}$ .... (20)

Economic Production Quantity **(EPQ) with *Backorder* and *Scrap***

Economic Production Quantity (EPQ) taking into account backorders and scrap is a method with the aim of controlling the amount of inventory by determining the optimal amount of production in the presence of scrap and backorders. Calculations from the Economic Production Quantity (EPQ) method taking into account backorders and scrap are as follows [5]. [6]:

$1-E[X_j]-\frac{D_j}{P_j} \geq 0$ .... (21)

Optimal Production Period Length (T*)

$T = \sqrt{\frac{A}{\sum_{j=1}^{n}\gamma_j-\sum_{j=1}^{n}[\frac{(B_j)^2}{4\alpha_j}]}}$ .... (22)

where

$\alpha=[\frac{(C_h+C_b)(P-\theta)}{2\,D\,(P-D-\theta)}]$ .... (23)

$\beta=[\frac{C_h(P-\theta)}{P(1-E[x])}]$ .... (24)

$\Upsilon=[\frac{C_h D[(P-\theta)(P-D-\theta)+D)}{2(P)^2(1-E[x])^2}$ .... (25)

$Tmin = \frac{\sum_{j=1}^{n}S}{1-\sum_{j=1}^{n}\frac{D}{P(1-E[x])}}$ .... (26)

Optimal Number of Backorders (B*) = $\frac{\beta}{2a}$T* .... (27)

Optimal Production Amount (Q*) = $\frac{D.T^*}{1-E[x]}$ .... (28)

Total cost (TC*) = $\sum_{j=1}^{n}\alpha_j\,\frac{(B_j)^2}{T^*}-\sum_{j=1}^{n}\beta_j.B_j^{\,*}$

$+\sum_{j=1}^{n}\gamma_j.T^*+\sum_{j=1}^{n}\lambda_j+\frac{A.}{T^*}$ .... (29)

where

$\boldsymbol{\lambda}=[\frac{(C_p+C_s E[x])D}{1-E[x]}]$ .... (30)

17. Result and Discussion

The data needed for data processing can be seen from the following table:

Table 1. Required data

Product	Demand (D)	Production rate	Production cost (Rp)	Holding cost (Rp)	Backorder cost (Rp)	Shortage cost (Rp)	Setup time (minutes)	Scrap (%)

1	3568	5976	1.7 mio	0.4 mio	1.8 mio	0.3 mio	2	1.24
2	3998	5229	1.2 mio	0.3 mio	1.3 mio	0.2 mio	2	1.4
3	4128	5229	2.6 mio	0.6 mio	2.8 mio	0.5 mio	3	3.28
4	3850	5478	0.7 mio	0.2 mio	0.7 mio	0.2 mio	4	2.12
5	3924	5229	0.8 mio	0.2 mio	0.9 mio	0.2 mio	2	2.4
6	4759	5478	1.2 mio	0.3 mio	1.3 mio	0.2 mio	5	3.6
7	4990	6723	1.3 mio	0.3 mio	1.4 mio	0.2 mio	2	2.1

Economic Production Quantity (EPQ)

Through calculations using the Economic Production Quantity (EPQ) method, it is possible to find out the optimal amount of production for each product through calculating the optimal period length and the total costs in a year issued by the company.

Table 2. Calculation with Economic Production Quantity (EPQ)

Product	Q* per cycle (unit)	Q* year (unit)	N (no. of cycle in 1 year)	T* (no. of day per cycle)	T* (no. of day in 1 year)	TC(per year)
1	67	3618				
2	75	4050				
3	77	4158				
4	72	3888	54	5	270	Rp. 40.6 bio
5	73	3942				
6	89	4806				
7	93	5022				

From the results of the calculation of the Economic Production Quantity (EPQ) in table 1.2, it shows that the company spent Rp. 40,587,888,276, - with the optimal production quantity for each product being 3618 units, 4050 units, 4158 units, 3888 units, 3942 units , 4806 units, and 5022 units in a year with the number of days in a year is 270 days with 5 cycles where each cycle requires 54 days.

Economic Production Quantity (EPQ)* with *Scrap

Calculations using the Economic Production Quantity (EPQ) method with Scrap where the amount of scrap from production affects the optimal amount of production and the total cost to be incurred.

Table 3. Economic Production Quantity (EPQ) with Scrap

Product	Q* per cycle (unit)	Q* year (unit)	N (no. of cycle in 1 year)	T* (no. of day per cycle)	T* (no. of day in 1 year)	TC(per year)
1	361	3605	10	25	250	Rp. 43.6 bio
2	594	4153	7	37	259	
3	446	4459	10	27	270	
4	696	4175	6	45	270	
5	699	4191	6	44	264	
6	883	5298	6	45	270	

7	620	5578	9	31	279	

Based on calculations with the Economic Production Quantity (EPQ) with Scrap costs incurred by the company in a year for 7 products amounting to IDR 43,623,777,660, - where for each optimal production amount, number of cycles, optimal production time in a year and in each cycle have different values.

Economic Production Quantity (EPQ)* with *Backorder

Calculations using the Economic Production Quantity (EPQ) with the Backorder. By considering the existence of backorders where the company has a limit that is allowed for the number of units that cannot be fulfilled.

Table 4. Economic Production Quantity (EPQ) with Backorders

Product	Q* per cycle (unit)	Q* year (unit)	B_j* (per cycle)	B_j* (per year)	N (no. of cycle in 1 year)	T* (no. of day per cycle)	T* (in 1 year)	TC(per year)
1	395	3555	30	270	9	28	252	Rp. 50.9 bio
2	649	4543	29	203	7	41	287	
3	480	4320	19	171	9	29	261	
4	756	4536	42	252	6	49	294	
5	757	4542	36	216	6	49	294	
6	949	4745	24	120	5	50	250	
7	674	5392	33	264	8	34	272	

From calculations using the Economic Production Quantity (EPQ) with Backorders, the total costs incurred amounted to Rp. 50,868,806,132, - with each number of backorders for each product of 270 units, 203 units, 171 units, 252 units, 216 units, 120 units, and 264 units in a year. With each cycle and the optimal production time varies.

Economic Production Quantity (EPQ)* with *Scrap* and *Backorder

The calculation of the Economic Production Quantity (EPQ) in the presence of Scrap and Backorders is a calculation taking into account the occurrence of backorders and the presence of scrap under the same conditions.

Table 5. Economic Production Quantity (EPQ) with Scrap and Backorder

Product	Q* per cycle (unit)	Q* year (unit)	B_j* (per cycle)	B_j* (per year)	N (no. of cycle in 1 year)	T* (no. of day per cycle)	T* (in 1 year)	TC(per year)
1	209	3553	16	272	17	15	255	Rp. 41.6 bio
2	234	3978	10	170				
3	246	4182	9	153				
4	227	3859	12	204				
5	232	3944	10	170				
6	285	4845	6	102				
7	294	4998	14	238				

This research is applied to the pipe industry by proposing an inventory system that considers scrap and backorders. If this research is applied to other industries, it is not necessarily suitable. This study recommends that the proposed supply system is more suitable for the pipe industry. For further research, it is necessary to examine inventory systems that do not only consider scrap and backorder.

18. Conclusion

Using the Backorder and Scrap Economic Production Quantity (EPQ) Model requires a total cost of IDR 41,560,449,900, - with 17 cycles a year. With the optimal number of production units for each product 1 of 3553 units, product 2 of 3978 units, product 3 of 4182 units, product 4 of 3859 units, product 5 of 3944 units, product 6 of 4845 units, and product 7 of 4998 units in a year. With an optimal backorder per year for product 1 of 272 units, product 2 of 170 units, product 3 of 153 units, product 4 of 204 units, product 5 of 170 units, product 6 of 102 units, product 7 of 238 units in a year. Sensitivity analysis by changing parameters including machine setup costs. With sensitivity analysis, it shows that the parameters directly affect the total cost of inventory. Where if the parameter increases, the total cost of inventory also increases.

Referensi

[1[Chiu, S.W., Chiu, Y.P and Wu, B.P. 2013. An Economic Production Quantity Model with The Steady Production Rate of Scrap Items. *International Journal of Production Reaserch,* iFirst, 1-23

[2] Krajewski, L. Ritzman, L. Malhotra, M. 2007. *Operation Management*. Pearson International Edition.

[3] Love, Stephen, 2019. *Inventory Control.* McGraw-Hill International Book Company.

[4] Plossl, George W., 2017. *Production and Inventory Control Principles and Techniques.* 2nd Edition Tersine,

[5] Richard J. 1994. *Principles of Inventory and Material Management* (4th edition). New Jersey: Prentice-Hall, Inc.

[6] Pentico,D.W.,Drake, M. J., & Toews, C. 2018. The deterministic EPQ with partial backordering : A new Approach. *Omega*, 37, 624-636

[7] Taleizadeh, A,. Najafih, A., Akhavan Niaki, 2014. Economic Production Quantity Model with Scrapped Items and Limited Production Capacity. *Journal of Transaction E:Industrial Engginering*.