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Control of Plastic Packaging Raw Material Inventory Using Economic Order Quantity with Disruptions (EOQD) at PT X

Nuraini Rahmad[1], Siti Dinar Rezeki Ramadhani[2], Bagas Adji Nurfadillah Alzorfa[1]
[1]*Industrial Engineering Study Program, Universitas Indonesia Mandiri, Lampung, Indonesia*
[2]*Industrial Engineering Study Program, Institut Teknologi Perkebunan Pelalawan Indonesia, Riau, Indonesia*
[1]*nurainirahmad@uimandiri.ac.id*

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Abstract - *The supply chain is a system that involves all entities necessary to transform raw materials into finished products, consisting of several stages such as suppliers, manufacturers, distributors, wholesalers, and retailers. In most cases, the supply chain is always faced with uncertainty. One type of supply chain uncertainty that has gained attention over the past decade is supply disruption, such as that resulting from customs delays, supplier uncertainty, labor strikes, epidemics, and natural disasters. Major studies on supply disruption began in the early 1990s, along with efforts to incorporate supply disruption into classic inventory models. PT. X Industri is a company engaged in the plastic materials industry. One of the products manufactured by the company is plastic packaging bottles. In producing plastic packaging bottles, the basic material used is Polyethylene Terephthalate (PET) and the product uses a bottle cap as a closure. PT. X often experiences a shortage of raw materials for bottle caps for packaging the plastic bottles that have been produced. This study uses EOQD calculations for its resolution. The calculation results obtained a dry period probability with a coefficient value of 0.289 and a dry period cycle of 2, which indicates that PT. X will experience a 2-day stockout of bottle cap materials. When the company experiences a stockout, there will be additional costs incurred by the company for its production cycle amounting to IDR 87,933,868.*

Keywords - *Supply Chain Disruption, Inventory, EOQD*

1. Introduction

As the industrial sector develops, Indonesia has entered the Asian free trade area, which will certainly lead to fierce competition in the business world. This competition encourages every industry to manage its resources as optimally as possible in order to produce high-quality products that are always available when needed. The goal is for every industry to be able to survive and compete with other industrial sectors. Companies will make various efforts to satisfy consumers, whether through the prices they offer, the quality of their products, their customer service, or the accuracy and speed of product delivery in meeting demand. Meeting product demand is very important for companies because when demand is met, it will affect customer loyalty and increase company profits [1]. One way for companies to obtain optimal profits is to implement a management policy that takes into account optimal inventory.

Inventory is used as a storage place for materials in the form of raw materials, goods in process, and finished goods. This inventory is a capital investment needed to store materials under certain conditions [2]. Inventory is one of the fundamental issues that plays an important role in supporting the production process in a company. If inventory in a company is managed well, the production process will run smoothly. Companies must control inventory to ensure the availability of materials, items, or raw material components when needed to meet production schedules, guarantee the availability of finished products for consumers, and maintain inventory at minimum levels. This will greatly affect the company's products, from raw materials to finished goods, so as not to cause delays in the production process.

Currently, inventory is considered one of the more expensive operational costs of a business. In some industries, inventory management has emerged as an important factor in profitability and productivity optimization. Production material inventory in a company is the key to smooth production processes, both in small-scale industries and large companies that plan production material requirements, as well as manage operations and regulate production material inventory. Inventory is part of supply chain activities [3]. The supply chain is a system that involves all entities needed to convert raw materials into finished products, consisting of several stages such as suppliers, manufacturers, distributors, wholesalers, and retailers [4]. In most cases, the supply chain is always faced with uncertainty. One type of supply chain uncertainty that has been a concern over the past decade is supply disruptions, such as those arising from customs delays, supplier uncertainty, labor strikes, epidemics, and

natural disasters. Over the past few years, companies have developed many strategies to mitigate the impact of these disruptions. One strategy is to hold more inventory with additional quantities that serve as a buffer against disruptions.

PT. X is a company engaged in packaging. Among the many products it produces are plastic bottle packaging. Plastic bottle packaging is produced using Polyethylene Terephthalate (PET) material. To complete a product, the company uses components in the form of packaging caps, often referred to as bottle caps (plastic cap long neck). The bottle caps are ordered from outside the region in quantities of 4,000 dozen per month. A shortage of bottle caps has caused the company to experience delays in selling its products to customers. This has prompted the company to be more responsive by reviewing orders and considering the quantity of bottle caps to order each time in accordance with demand. Delays in meeting customer demand can cause customers to switch to other companies or products of a similar nature, which can affect the company's profits.

2. Literatur Review

Inventory is used as a storage place for materials in the form of raw materials, goods in process, and finished goods. This inventory is a capital investment needed to store materials under certain conditions [2]. According to [5], inventory is material or goods stored for specific purposes, including for the production process. If it is raw material, it will be further processed; if it is components (spare parts), it will be resold as merchandise. Another definition according to [5] is that inventory is materials or goods that are stored to be used for specific purposes, such as for use in the production or assembly process, for resale, or for spare parts for equipment or machinery. Inventory can be raw materials, auxiliary materials, goods in process, finished goods, or spare parts. It can be said that no company operates without inventory, even though inventory is actually just an idle source of funds, because before inventory is used, the funds tied up in it cannot be used for other purposes.

Supply disruptions began in the early 1990s, and attempts to incorporate supply disruptions into classical inventory models suggested that a company's suppliers could be disrupted when the company wanted to place an order. A detailed review of studies in this field can be found in [6], which is organized according to categories of mitigation strategies developed for supply chain disruptions. This research falls under the category of disruptions through inventory. This study falls under the category of mitigation of disruptions through inventory. This inventory model can be categorized in relation to several dimensions, such as in the classic inventory model, which is primarily periodic vs. continuous review, reordering vs. lost sales, single vs. multi-echelon, cost structure, and decision variables. The inventory model is the classic economic order quantity (EOQ). The study by Parlar and Berkin in the 1990s was the first to introduce disruptions into this model, which has been referred to as EOQ with Disruptions in the literature [4].

3. Materials and Methods

This research involves controlling bottle cap inventory for production needs. In this study, the author will expand on previous research by including supply chain disruptions (EOQD). This research is based on the quantity of bottle cap orders and the demand for bottle caps. This study uses the EOQD method, assuming that suppliers become unavailable or experience disruptions at random points in time and for random periods of time, so that no orders can be placed. Suppose that suppliers are not fully reliable, functioning normally for a certain period of time (wet period) and then shutting down for a certain period of time (dry period). During the dry period, no orders can be placed, and if the retailer runs out of stock during the dry period, all observed demand until the start of the next wet period will be lost, with a stockout cost of (p) per lost sale. The durations of the wet period and dry period are exponentially distributed, with rates λ and μ, respectively. Each order placed by the retailer for the same quantity, Q, is only placed when the inventory level reaches 0, and orders placed during the wet period are received immediately (no waiting time). The objective of the model is to select Q to minimize the expected annual cost.

Companies whose supply processes are affected by disruptions may experience transportation delays and malfunctions at some of their facilities, which can lead to inventory shortages. Although companies can take measures to prevent this, some disruptions are unavoidable. Therefore, to avoid the drastic impact of these disruptions, companies need to protect themselves. There are several tactics that companies can choose from to manage the risk of disruptions. One of the most common tactics is to use inventory to buffer additional uncertainty. The main concern in inventory management is to find the optimal replenishment policy that dictates when, from whom, and how much to order. Consider a single-location, single-item inventory system facing deterministic and continuous demand at a rate of d units per year. Assume that there is a fixed order cost K per order and a storage cost of hours per unit per year. Then the occurrence of disruptions causes the EOQ to have a derivative of the EOQ formula, figure 1 based on [7].

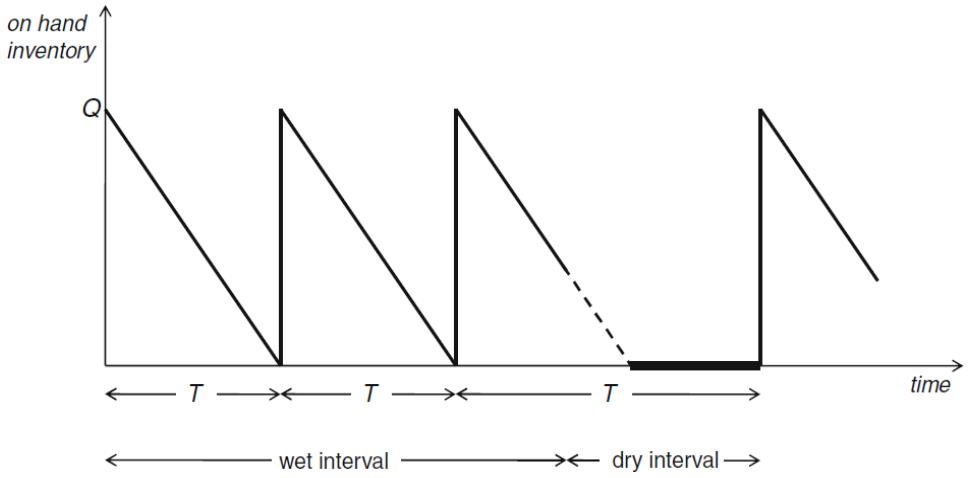

Figure 1. EOQD Model Inventory Curve

A typical inventory curve is shown in Figure 1. Note that the inventory position never becomes negative because unmet demand will disappear. Where T is defined as the time between successive order receipts (random variable). The formulation for the EOQD formula is as follows:

- Calculating the length of the dry period cycle $E[T]$.
  $E[T] = \frac{Q}{d} + \frac{\beta}{\mu}$
- Calculation of supplier probability during dry periods (β).
  $$\beta = \frac{\lambda}{\lambda + \mu}(1 - e^{-(\lambda+\mu)\frac{Q}{d}})$$

Where the coefficient β is the probability that the supplier is in the dry interval when the retailer's inventory level reaches zero. The expected cost per cycle is:

$$E[C] = K + \frac{hQ^2}{2d} + \frac{db\beta}{\mu}$$

Using the renewal theorem, the expected annual cost can be written as $C(Q) = \frac{E[C]}{E[T]}$. Specifically, proposing an estimate of C(Q) by replacing β with $\beta' = \frac{\lambda}{\lambda+\mu}$. Based on estimates, the order quantity for minimizing C(Q) is:

$$Q^* = \sqrt{\frac{2Kd}{h} + a^2 + b - a}, \qquad \text{where} \quad a = \frac{\beta' b}{\mu} \text{ and } b = \sqrt{\frac{2d^2 p\beta'}{h\mu}}$$

Notation:

$E[T]$ = Length of dry period cycle
$E[C]$ = Cost incurred during dry period
Q = Economic Order quantity
d = Demand
p = Lost sales cost/unit
h = Storage cost
K = Ordering cost
β = Probability of supplier during dry period when inventory is close to 0
μ = Exponential rate during dry period
λ = Exponential rate during wet period

This study has several assumptions, including:
a. Lost sales cost (p) is assumed to be positive (non-negative).
b. The exponential rate during the dry period (μ) is assumed to be positive (non-negative).
c. The exponential rate during the wet period (λ) is assumed to be positive (non-negative).
d. The assumption that $\lambda < \mu$, where the wet period lasts longer than the dry period.

4. Results and Discussion

4.1. Case Study

Companies whose supply processes are affected by disruptions may experience transportation delays and malfunctions at some of their facilities, which can lead to inventory shortages. Although companies can take measures to prevent this, some disruptions are unavoidable. Therefore, to avoid the drastic impact of these disruptions, companies need to protect themselves. There are several tactics that companies can choose from to manage the risk of disruptions. One of the most common tactics is to use inventory to buffer additional uncertainty. The main concern in inventory management is to find the optimal replenishment policy that dictates when, from whom, and how much to order. Consider a single-location, single-item inventory system facing deterministic and continuous demand at a rate of d units per year. Assume that there is a fixed order cost K per order and a storage cost of hours per unit per year. Then the occurrence of disruptions causes the EOQ to have a derivative of the EOQ formula.

PT. X has experienced supplier disruptions and has had problems with its raw material purchasing system. Raw materials were ordered when stock levels reached zero (zero inventory) because the distance between the factory and the supplier was relatively close. Therefore, it was necessary to calculate the costs that would be incurred when the supplier experienced a dry period using a modified classic EOQ formula known as EOQD (Economic Order Quantity with Disruptions) in order to anticipate the possibility of similar problems in the future and determine the optimal order quantity. The known data and assumptions are as follows: raw material purchases/demand of 4000 dozen and daily demand of 4000 dozen, purchase cost of IDR 50,000/dozen, order cost of IDR 5,940,000 per order, and storage cost of IDR 2,517/dozen /day. Regarding the uncertainty that occurs, it is assumed that the average exponential rate is 0.78 and the exponential rate is 0.53.

4.2. Data Processing and Analysis

The following is a calculation using Economic Order Quantity with supply disruption (EOQD).
Given:
Q = 4.000 dozen
d = 4.165 dozen
p = Rp. 50.000 / dozen
h = Rp. 2.517/ dozen
K = Rp. 5.940.000/ dozen
μ = 0,78
λ = 0,53

Calculation of supplier probability during dry periods (β)

$$\beta = \frac{\lambda}{\lambda + \mu}(1 - e^{-(\lambda+\mu)\frac{Q}{d}})$$

$$\beta = \frac{0,53}{0,53+0,78}(1 - e^{-(0,53+0,78)\frac{4000}{4165}})$$

$$\beta = 0,405\ (1 - e^{-(1,26)})$$

$$\beta = 0,405\ (1 - 0,716) = 0,289$$

This yields a β value of 0,289. We then proceed to calculate the cycle length of the dry season

Calculating the length of the dry period cycle $E[T]$

$$E[T] = \frac{Q}{d} + \frac{\beta}{\mu}$$

$$E[T] = \frac{4.000}{4.165} + \frac{0,289}{0,53}$$

$E[T] = 0{,}96 + 0{,}55 = 1{,}51 \approx$ 2 days

Calculating the cost incurred per cycle $\boldsymbol{E}[\boldsymbol{C}]$

$$E[C] = K + \frac{hQ^2}{2d} + \frac{dp\beta}{\mu}$$

$$E[C] = Rp.\ 5.940.000 + \frac{Rp.\ 2.517 + 4.000^2}{2\ x\ 4.165} + \frac{4.165 \text{ x Rp. } 50.000 \text{ x } 0{,}289}{0{,}78}$$

$$E[C] = Rp.\ 5.940.000 + Rp.\ 4.834.573 + Rp.\ 77.159.295$$

$$E[C] = Rp.\ 87.933.868$$

Therefore, the cost incurred per cycle is $Rp.$ 87,933,868.

Calculation of expected annual cost C(Q)

$$C(Q) = \frac{E[C]}{E[T]} = \frac{Rp.\ 87.933.868}{2} = Rp.\ 43.966.934$$

Specifically, propose the C(Q) approach by replacing β with β'.

$$\beta' = \frac{\lambda}{\lambda + \mu}$$

$$\beta' = \frac{0{,}53}{0{,}53 + 0{,}78}$$

$$\beta' = \frac{0{,}53}{1{,}31} = 0{,}40$$

Calculating demand quantity to reduce costs.

$$a = \frac{\beta' b}{\mu}$$

$$a = \frac{0{,}53 \times 4.165}{0{,}78}$$

$$a = \frac{0{,}53 \times 4.165}{0{,}78}$$

$$a = 2.830$$

$$b = \sqrt{\frac{2d^2 p\beta'}{h\mu}}$$

$$b = \sqrt{\frac{2 \times 4.165^2 \times 50.000 \times 0{,}40}{2.517 \times 0{,}78}}$$

$$b = \sqrt{\frac{2 \times 4.165^2 \times 50.000 \times 0{,}40}{2.517 \times 0{,}78}}$$

$$b = \sqrt{353.437.140}$$

$$b = 18.799{,}92 \approx 18.800$$

$$Q^* = \sqrt{\frac{2Kd}{h} + a^2 + b - a}$$

$$Q^* = \sqrt{\frac{2 \times 5.940.000 \times 4165}{2.517} + 2.830^2 + 18.800 - 2.830}$$

$$Q^* = \sqrt{19658402 + 8.008.900 + 18.800 - 2.830}$$

$$Q^* = \sqrt{1968425} = 4.434$$

5. Conclusion

Based on the calculation results, it can be concluded that from the EOQD method, the probability of a dry period is obtained with a coefficient value of 0.289 and a dry period cycle of 1.51 ≈ 2, where the dry period cycle indicates that PT. X will experience a stockout of bottle caps for 2 days. When the company experiences a stockout, there will be additional costs incurred by the company for its production cycle amounting to IDR 87,933,868. The expected annual cost for the company is IDR 43,966,934. Perhaps this amount is not significant for an industry. However, this is very likely to happen for several other items, which could also significantly reduce the company's profits if not anticipated. To anticipate this, the order quantity can be recalculated to reduce additional costs to 4.434 units as a reference for purchasing raw materials when suppliers experience disruptions. Then, to overcome this problem, companies need to maintain reserve supplies of bottle caps to anticipate stock shortages, thereby enabling companies to save costs.

Conflicts of Interest

The authors declare no conflict of interest

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References

[1] Maharani MP, Sari T. PENGENDALIAN PERSEDIAAN BAHAN BAKU MENGGUNAKAN METODE ANALISIS ABC , PERAMALAN , DAN ECONOMIC ORDER QUANTITY (EOQ) PADA PT . XYZ. J Tek Ind. 2025;20(2).

[2] Wardhani DK, Sukmono T. EOQ Optimization Revolutionizes Inventory Management, Delivering Cost Savings Globally. Indones J Innov Stud. 2024;25(4):1–11.

[3] Kandi N, Johannes Nadapdap H. Pengendalian Persediaan Bahan Baku Tebu Di Pg X. Forum Agribisnis. 2020;10(2):86–94.

[4] Islam MT, Azeem A, Jabir M, Paul A, Paul SK. An inventory model for a three-stage supply chain with random capacities considering disruptions and supplier reliability. Ann Oper Res [Internet]. 2022;315(2):1703–28. Available from: https://doi.org/10.1007/s10479-020-03639-z.

[5] Nasirly, R., et. al., (2024). Buku Ajar Supply Chain Management.Jambi: PT. Sonpedia Publishing Indonesia

[6] Snyder, Lawrence V. (2014). A Tight Approximation for an EOQ Model With Distruption. International Journal Production economics Vol. 155(91-10).

[7] Mehrotra, A., & Ray, S. (2012). Supply chain disruptions: Theory and practice of managing risk (pp. 21-46). H. Gurnani (Ed.). London: Springer.