# Economic Order Quantity Model Considering Product Damage and Permissible Delay in Payment

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## Abstract

In consumer goods business there are two factors that related to the inventory policy. First, there is a permissible delay in payments given by the vendor. This delay on payment can be used by the company to make extra profit but with a risk of given fine cost if the payments exceed the promised date. Second, there is a possibility of some damaged products, which cannot be sold to the customer. The purpose of this research is to develop an inventory model considering both the damage factor in product and payments delay. There were previous researches, considering payment delay and perishable product, same with damaged product, separately, that were the basis of the developed model. The data from the previous models was applied to the developed model and a comparison has been made. It can be concluded that the developed model is applicable to obtain optimal order quantity by considering damage factor in product and delay in payment. The developed model had also more complete cost components, lower order quantity, and higher total inventory cost compared to the previous ones.

## Keywords
Economic Order Quantity, Permissible Delay in Payment, Product Damage Factor

## 1. Introduction
In manufacturing processes, materials are needed as an input. Manufacturing companies need raw materials to be processed, spare parts for maintenance activities, and final product to be sold. These materials should be procured and kept as an inventory, to ensure service level, because there are uncertainty and lead time. The inventory itself should be kept minimum in order to retain inventory cost as minimum as possible (Bahagia 2006). The trade-off between service level and inventory cost is the basic problem of inventory policy.

Company profit, especially in consumer products business, is not only related to the pricing strategy, but also in the coordination of inventory policy (Silitonga 2019). There are two factors that could affect a mini market business, an example of consumer product business. Referring to the Customer Protection Law in Indonesia, damaged products cannot be sold to customer (Sekretariat Negara 1999). This law statement could affect the inventory cost as when there are possibilities for the product stored in the warehouse could be damaged or depreciated (Bahagia 2006). If the number of inventories stored in warehouse is high, it will increase the possibilities to have a greater number of damaged products. If the number of inventories stored are kept low, the cost of placing order will increase (Limansyah 2011). Another factor that could affect the inventory cost is the permissible delay in payment factor. From the vendor's perspective, this permissible delay is used to increase their product demand (Shinn 2018). Here, the company can purchase a product from a vendor using credit term. The vendor will give time before the company must settle the account (Sunendar 2019). This delay in payment period can be used to earn some extra profits which will compensate inventory cost. However, if the company unable to settle the transaction in the given time, there will be some penalty fee for the company (Goyal 1985). Hence, there is a trade-off between minimizing inventory stored to reduce product damage factor and maximizing inventory stored to earn maximum extra profit using permissible delay in payments.

Some studies have been done considering each of these factors. Limansyah (2011) did a research on an economic order quantity inventory model considering perishable product. In this research, the amount of product perishable is computed by using congruence principle. Limanjaya (2018) developed Limansyah (2011) model by using probabilistic demand, the amount of perishable product in this research is computed using a percentage. Goyal (1985) did a research on economic order quantity by considering delay in payments, however this previous research did not considered both of these factors at the same time. Based on the explanation above, the purpose of this paper is to develop economic order quantity inventory model by considering damage factor in product and permissible delay in payment.

## 2. Model

### 2.1. Model Description

This research would combine Limansyah (2011) for product damage model and Goyal (1985) for permissible delay in payment model. However, to determine the damaged product, the study will use proportion, based on Limanjaya (2018), instead of a computation using the congruence principle (Limansyah 2011). The developed model has 2 possible scenarios: (1). The amount of good condition product is sold out before the end of permissible delay period that can be seen in Figure 1. Otherwise (2). The amount of good condition product is sold out after the end of permissible delay period that can be seen on Figure 2.

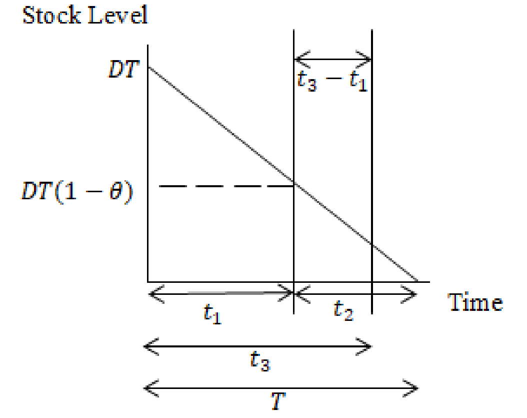


Figure 1. The amount of good condition product is sold out before the end of permissible delay period.

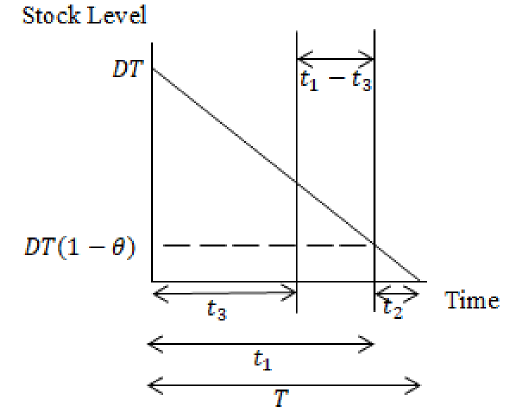


Figure 2. The amount of good condition product is sold out after the end of permissible delay period.

### 2.2. Notation

There are several notations used in this paper as follow:

$D$ : Demand in one planning horizon
$Q$ : Optimal quantity in one order
$P$ : Unit purchase price in Rupiah
$S$ : Cost of placing one order in Rupiah
$h$ : Unit cost of holding per year
$U$ : Unit cost of stock out in Rupiah
$T$ : Time interval between successive orders
$t_1$ : Time period until product in good condition is sold out in year
$t_2$ : Time period in shortage in year
$t_3$ : Permissible delay in payment in year
$I_d$ : Percentage of interest can be earned in Rupiah
$I_c$ : Percentage of fine given by vendor in Rupiah per unit have not paid
$\theta$ : Fraction of product in good condition
$(1-\theta)$ : Fraction of product in good condition
$Z$ : Total inventory cost in Rupiah

### 2.3. Development of Model

There are several assumptions used in this research as follow, (1). The demand in the planning horizon is deterministic, (2). The amount of each order is constant, (3). The entire lot size is added to inventory at the same time, (4). The unit price is constant, (5). Ordering cost is constant, (6). The holding cost is proportional to the amount of stocked product, time length of the stocked product, and product's unit price, (7). There are no limitations of warehouse capacity, (8). The fine cost will be proportional to the amount of stored product after the end of permissible delay period, (9). Stock out periods will begin after there is no product in the warehouse, (10). Damaged product will be discarded after all of the good product is sold out, (11). The length of permissible delay given is already known at the start of the planning period, (12). The length of permissible delay given will always less than one order cycle, (13). The percentage of interest and fine will be computed each day, with 1% for the interest rate and 3% for the fine rate, (14). Proportion of the good condition product already known at the start of the planning period and the proportion is constant, (15). Before the account is settled, the purchasing value will be deposited in a bank account that will give interest and will be taken out at the end of permissible delay period, (16). The company cash is limited to the value of stocked product in the warehouse, and (17). There is no minimal amount of funds needed in for a bank account to generate interest.

There are six cost components, namely ordering cost, holding cost, stock out cost, damage cost, fine cost, and interest revenue. The addition of those six cost components will result in total inventory cost.

$$Z = Ordering\ C + Holding\ C + Stock\ Out\ C + Damage\ C + Fine\ C - Interest\ Revenue \quad (1)$$

Ordering cost is computed by multiplying the ordering cost for one order and the ordering frequency in the planning horizon.

$$Ordering\ Cost = \frac{S}{T} \quad (2)$$

Holding cost per year is the cost spent to maintain the stocked product per year.

$$Holding\ Cost = Ph\frac{(DT+DT(1-\theta))t_1}{2T} \quad (3)$$

$t_1$ is the time length until all of the good condition products have been sold. It can be computed using $t_1 = T\theta$ equation. After the $t_1$ ended the damaged product will be discarded so there is no holding cost after $t_1$.

Stock out cost per year is a cost spent when company cannot fulfil the customer demand. $t_2$ can be computed by $T = t_1 + t_2$ equation.

$$Stock\ Out\ Cost = U\frac{DT(1-\theta)t_2}{2T} \quad (4)$$

Damage cost per year is a cost spent in a year for the damaged products that cannot be sold.

$$Damage\ Cost = DT(1-\theta)\frac{P}{T} \quad (5)$$

Fine cost in a year is a cost charged for the items kept in stock after the end of permissible delay period. This cost will appear on scenario 2, where the amount of good condition product is sold out after the end of permissible delay period.

$$Fine\ Cost = PI_c\frac{(DT-Dt_3+DT(1-\theta))(t_1-t_3)}{2T} \quad (6)$$

Interest revenue is an interest earned from deposited purchasing value on bank account during the permissible delay period. There will be different equation used between each scenario. In scenario (1) the interest revenue is computed by:

$$Interest\ Revenue = \left(\frac{Dt_1}{2}t_1 + Dt_1(t_3 - t_1)\right)\frac{PI_d}{T} \quad (7)$$

In scenario (2) the interest revenue is computed by:

$$Interest\ Revenue = PI_d\frac{Dt_3^2}{2T} \quad (8)$$

Total inventory cost for scenario (1) is the sum of equation (2), (3), (4), (5), and (7).

$$Z = \frac{S}{T} + \frac{DT\theta Ph(2-\theta)}{2} + \frac{DTU(1-\theta)^2}{2} + DP(1-\theta) - \left(D\theta PI_d t_3 - \frac{DT\theta^2 PI_d}{2}\right) \quad (9)$$

To optimize the time interval between successive orders in scenario (1), the derivation of equation (9) should be determined.

$$T^* = \left(\frac{2S}{2D\theta Ph(2-\theta)+DU(1-\theta)^2+D\theta^2 PI_d}\right)^{1/2} \quad (10)$$

Total inventory cost for scenario (1) is the sum of equation (2), (3), (4), (5), (6), and (8)

$$Z = \frac{S}{T} + \frac{DT\theta Ph(2-\theta)}{2} + \frac{DTU(1-\theta)^2}{2} + DP(1-\theta) + \frac{PI_c(2DT-DT\theta-Dt_3)\left(\theta-\frac{t_3}{T}\right)}{2} - \frac{DPI_d t_3^2}{2T} \quad (11)$$

To optimize the time interval between successive order, equation (9) should be derived:

$$T^* = \left(\frac{2S+DPt_3^2(I_c-I_d)}{D\theta Ph(2-\theta)+DU(1-\theta)^2+2D\theta PI_c-D\theta^2 PI_c}\right)^{1/2} \quad (12)$$

### 2.4. Procedures

There are some procedures should be followed to determine the total inventory cost

1. Compute $T^*$using equation (10).
2. Compute $t_1$, then check for result validity with the stated condition in scenario (1).
3. If the result does not valid, compute $T^*$ using equation (12).
4. Validate the result for the scenario (2).
5. Compute $Z$ for each validated scenario.
6. Compare the $Z$ for each validated $T^*$.
7. Choose $T^*$ with the lowest amount of $Z$.
8. Compute $Q$ with equation $Q = DT^*$.

## 3. Result and Discussion

The developed model was used to compute the example problem given in Limansyah (2011). There are some additional parameters and cost component assumed which are not considered in Limansyah (2011). The proportion of the good condition products will be taken from Limanjaya (2018), the time length of permissible delay in payment will be taken from (Sunendar 2019) and the interest also fine rate will be taken from Bank Central Asia (interest account (2020) and credit fine (2020)). The data used in Limansyah (2011) and the assumed parameters can be seen in Table 1.

Table 1. Parameter and cost component.

| Number | Parameter | Value |
|---|---|---|
| 1 | Demand in one year | 500 unit |
| 2 | Fraction of holding cost | 0.8 |
| 3 | Fraction of product in good condition | 0.95 |
| 4 | Time length of permissible delay in payment period | 0.08 |
| 5 | Fine rate | 0.03 |
| 6 | Interest rate | 0.01 |
| 7 | Unit purchasing cost per unit | Rp 11,000 |
| 8 | Ordering cost per order | Rp 150,000 |
| 9 | Stock out cost per unit | Rp 50 |

The first step is to compute $T^*$using both scenarios, comparing the total inventory cost between each scenario, then determining $Q$ by choosing the scenario with the lowest amount of total inventory cost. The result using developed model to determine the $Q$ is given at Table 2.

Table 2. Data processing result.

| Number | Result | Value |
|---|---|---|
| 1 | Total inventory cost | Rp 1,431,971.26 |
| 2 | Optimal order quantity | 129 unit |
| 3 | Total damaged product | 7 unit |
| 4 | Total fined product | 89 unit |
| 5 | Time between each successive order | 0.257 year |

It can be seen that $t_1$ in scenario (1) is not valid. Each component cost will be given in Table 3.

Table 3. Component cost.

| Number | Component | Scenario (1) | Scenario (2) |
|---|---|---|---|
| 1 | Validation of the scenario (Y/N) | N | Y |
| 2 | Ordering Cost | - | Rp 583,657.59 |
| 3 | Holding Cost | - | Rp 5863,986.50 |
| 4 | Stock Out Cost | - | Rp 8.03 |
| 5 | Damage Cost | - | Rp 275,000.00 |
| 6 | Fine Cost | - | Rp 10,003.97 |
| 7 | Interest Revenue | - | Rp 684.82 |

The second step is to compare the result between the developed model and the previous model. When computing using Limansyah (2011) model, a parameter named price of the perishable product was used. The result of each model was given in Table 4 and Table 5.

Table 4. Result comparison.

| Number | Result | Limansyah [4] | Goyal [6] | Developed Model |
|---|---|---|---|---|
| 1 | Total inventory cost | Rp 1,525,028.87 | Rp 1,151,673.08 | Rp 1,431,971.26 |
| 2 | Optimal order quantity | 174 unit | 129 unit | 129 unit |
| 3 | Total damaged product | 115 unit | - | 7 unit |
| 4 | Total fined product | - | 89 unit | 89 unit |
| 5 | Time between each successive order | 0.348 year | 0.257 year | 0.257 year |

Table 5. The comparison of total cost components.

| Number | Result | Limansyah [4] | Goyal [6] | Developed Model |
|---|---|---|---|---|
| 1 | Ordering Cost | Rp 431,034.48 | Rp 583,657.59 | Rp 583,657.59 |
| 2 | Holding Cost | Rp 431,174.71 | Rp 565,400.00 | Rp 563,986.50 |
| 3 | Stock Out Cost | Rp 1,900.14 | - | Rp 8.03 |
| 4 | Damage Cost | Rp 660,919.54 | - | Rp 275,000.00 |
| 5 | Fine Cost | - | Rp 10,056.97 | Rp 10,003.97 |
| 6 | Interest Revenue | - | Rp 684.82 | Rp 684.82 |
| 7 | Total inventory cost | Rp 1,525,028.87 | Rp 1,151,673.08 | Rp 1,431,971.26 |

Total inventory cost in the developed model is higher than Goyal (1985) by 23.6%, and lower by 6% than Limansyah (2011). Limansyah (2011) has the highest optimal order quantity. Both Goyal (1985) and developed model has the same amount of optimal order quantity. It can be seen in the Table 5 that Limansyah (2011) has the lowest ordering cost due to the higher amount of order quantity in each order. By ordering more products in each order, the amount of order needed will be lower, thus lower ordering cost. Limansyah (2011) also has the lowest holding cost even when having the highest order quantity between each order. This is the effect of having both highest damaged product and the assumption where after the good product is sold out in the warehouse the damaged product will be discarded thus no holding cost in the stock out period. The same reason is applied for the lower developed model holding cost compared to the Goyal (1985). Stock out cost in Limansyah (2011) model also has a higher amount proportional to a much higher amount of damaged product compared to the developed model. Damage cost in developed model has a lower amount compared to Limansyah (2011) model is proportional to the lower amount of damaged product in developed model. The damage cost difference between these two models is relatively small compared to the amount of damaged product difference. This is the result of adding the price of perishable product parameter when Limansyah (2011) model is used. Fine cost of the developed model is lower than Goyal (1985) model because of the 7 units damaged product in developed model that is discarded. Interest revenue between Goyal (1985) and developed model is same as it has the same amount of product price value used to generate extra profit. If we see the model on cost component view, developed model has a more complete cost component compared to both the previous model (Limansyah 2011; Gayol 1985). Developed model that has a lower amount of order quantity than Limansyah (2011) model shows the consideration to the possibility of fine cost in permissible delay in payment factor. The higher total inventory cost of the developed model compared to Goyal (1985) showed the damage factor influence. Based on this, the developed model is applicable in real situation where there is both the damage factor in product and payment delay factors.

## 4. Conclusions

In this paper, an economic order quantity model considering damage factor in product and permissible delay in payments has been developed. The developed model is more applicable in the real situation as it considers both the damage factor in product and permissible delay in payments. The model showed lower order quantity and higher inventory cost compared to the previous studies. Permissible delay in payment can be used by company to earn some extra profit, but the company can also be fined if the product stock has not been sold out. Further research can be done by considering other shape of damage product distribution, or using multi item products, or by considering a probabilistic demand.

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