Inventory Planning at Painting Section in the Indonesian Automotive Industry

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Abstract. An increase of competition in the Indonesian automotive industry due to an emergence of new products and the presence of new players has pushed the companies in this industry to have proper planning for inventory. Many models are available in the literature to support good planning for inventory, However, not all models are appropriate to be used in inventory planning for a specific department in the Automotive industry. Economic impacts such as cost can be used as consideration in selecting the appropriate model. This paper aims to compare models for inventory planning at painting section in one of the Indonesian automotive industry based on inventory cost. Economic Order Quantity (EOQ), Kanban and Economic Order Interval (EOI) are models compared in this study. The results of this study indicated that EOQ and EOI are the inventory model that produces the lowest inventory cost.

1. Introduction

Competition between companies in the Indonesian Automotive industry is increasing due to the emergence of new products and the presence of new players. With increasing competition between companies, it is necessary for those companies to have an appropriate model for managing activities in producing a product. Managing inventory is one important activity to ensure the product can be produced on schedule. To ensure raw materials are available when it is requested by the production line, it is important to determine the quantity of stock for each item requested by production line. Several factors such as demand of products, delivery time for each item to arrive in the warehouse and order cost are needed to consider in calculating the quantity of stock.

Several models are available in the literature to support the calculation of stock quantity. First is a traditional economic order quantity model (EOQ) that has been used for more than 100 years [1]. In this model, the quantity of stock is a function of product demand, order cost, and inventory holding cost. Economic order quantity model is good to be used if there are continues and constant demand, the cost for ordering is fixed and holding cost is calculated based on the number of stock [2]. Second is the Economic order interval (EOI). This model focuses on determining an optimal period between two stock replenishments [3]. In this model, the optimal period is influenced by ordering cost, holding cost and demand. Third is Kanban. This is a subsystem of the Toyota Production System that focuses to control materials flow (quantity and time) in the production line and between Departments (e.g. Procurement department and production department). Cards are used to manage these materials flow [4]. However, each model has a limitation, such as economic order quantity model lacks in consideration of interactions.
among the items [1], economy order interval model is difficult to use in stochastic environment [3], Kanban model is not adequate to be used while the demand is volatile, the operation is not standardized and the supply of raw materials is uncertain [4].

Suzuki Indomobil motor is one of the leading company in the Indonesian automotive industry. This company produces two and four-wheel vehicles. Currently, this company uses the Assembly to order production system where the production is started after an order from a customer is received. Following this system, the Kanban system is used as an inventory model. Discussion with production persons in this company indicated that there is a gap for improvement in inventory planning. This is due to materials overstock in some sections in the production line, particularly at the painting section. This section is a part of the production department that focuses on the finishing process. This paper aims to compare three inventory models (EOQ, EOI, and Kanban) based on inventory cost to support inventory planning in the painting section.

2. Methodology
A case study is used as a research methodology. Case study is good to use when the research focuses to investigate the phenomenon in real life context [5]. In this research, inventory planning in the painting section is a phenomenon that is observed. Material overstocks have occurred for several times becomes a reason to select this section as case study.

2.1. Research Process
To achieve the aim of the research, this research has been divided into three stages. Stages 1 focuses on collecting data and information required to develop inventory models. Secondary Data such as type of parts, demand for each part, order cost and variable cost for each part are collected and reviewed at this stage. In stage 2, the focus of the research is to define the quantity of stock and total inventory cost using economic order quantity, economy order interval and Kanban. Then, this is followed by stage 3 that is focused on comparing the inventory models based on the result from stage 2. Figure 1 displays the research process used in this research.
2.2. Inventory models

This section focuses to introduce the equations for each inventory model compared in this paper. Each inventory model has different formulation due to different factors that are considered in developing the models. Table 1 shows those equations for each inventory model.

Table 1. Equations for EOQ and EOI Models

| Inventory Models                                      | Equations                                                                 | Number of Equations |
|------------------------------------------------------|---------------------------------------------------------------------------|---------------------|
| Economy order quantity for Lots ordered independently| \( Q = \sqrt{\frac{DhC}{2S}} \)                                           | (1)                |
|                                                       | \( N = \frac{D}{Q} \)                                                   | (2)                |
|                                                       | \( TC = \left( \frac{D}{Q}S + \frac{D}{2} hC + +C_iD_i \right) \)      | (3)                |
| Economy order quantity for lots jointly ordered      | \( S^* = S + \sum_{i=1}^{k} S_i \)                                      | (4)                |
|                                                       | \( N = \sqrt{\frac{\sum_{i=1}^{k} D_i h_i}{2S^*}} \)                   | (5)                |
|                                                       | \( TC = (\sum_{i=1}^{k} D_i C_i) + \left( \frac{D}{2N} hC_i \right) + (N S^*) \) | (6)                |
| Economy order quantity for lots jointly ordered for subsequent product | \( \bar{n}_i = \sqrt{\frac{hC_i D_i}{2(S + s_i)}} \)                  | (7)                |
|                                                       | \( \bar{n} = \sqrt{\frac{hC_i D_i}{2S_1}} \)                          | (8)                |
|                                                       | \( m_i = [\bar{n} / \bar{n}] \)                                         | (9)                |
|                                                       | \( N = \sqrt{\frac{\sum_{i=1}^{k} hC_i m_i D_i}{2(S + \sum_{i=1}^{k} S_i/m_i)}} \) | (10)               |
|                                                       | \( TC = NS + \sum_{i=1}^{k} n_i s_i + \sum_{i=1}^{k} \frac{D_i}{2n_i} hC_i \) | (11)               |
| Economy order interval                                | \( T^* = \sqrt{\frac{2(S)}{\sum_{i=1}^{k} D_i h_i}} \)                 | (12)               |
|                                                       | \( Q_i = D_i T^* \)                                                   | (13)               |
|                                                       | \( TC = (\sum_{i=1}^{k} D_i C_i) + \left( \frac{D_i}{2} hC_i \right) + \frac{S^*}{T^*} \) | (14)               |
| Kanban                                               | \( N = \frac{d \ (c + Wp + \alpha)}{k} \)                             | (15)               |
|                                                       | \( TQ = Nk \)                                                          | (16)               |
|                                                       | \( SS = (Service Level) \times (Std) \times Lead time \)               | (17)               |
|                                                       | \( l = (Q + SS) / 2 \)                                                | (18)               |
|                                                       | \( TC = \left( \frac{D}{Q}S + hC_1 + +C_iD_i \right) \)               | (19)               |
Where:
TC is the total inventory cost, Q is the quantity of stock for part (i), Di is demand for part (i), Ci is unit price for part (i), N is the frequency of order for part (i), S is the total order cost for joint parts, Si is ordered cost for part (i), hi is holding cost for part (i), T* is interval of order, n̅ is to determine part with most order frequency, n̅̅̅ is order frequency for all parts, m is to evaluate order frequency part i with part with most order frequency, d is the daily demand, c is order cycle, Wp is order time, k is capacity of container, TQ is total stock in one period, SS is safety stock, Std is the standard deviation of demand and I is average inventory.

3. Result and Discussion
This section presents results from the implementation of three inventory models (EOQ, EOI, and Kanban) in determining the quantity of stock for each part used in the painting section. This section is divided into three subsections: Kanban result, economic order quantity result, and economic order interval result.

3.1. Kanban result
Inventory under Kanban system is designed based on a pull system where the stock of part is replenished whenever that part is taken by production line [6]. Kanban system focuses to supply the right quantity of parts in the right time for right production lines in order to minimize inventory level. The calculation of inventory is started by determining the number of Kanban card (order frequency) using Equation 15. Several factors such as daily demand, order cycle, order time, and capacity of containers affect the number of Kanban card. This is followed by calculating total stock in one year, safety stock and average inventory. Table 2 displays the total quantity of stock for 10 parts under Kanban system for August 2017 - July 2018 at painting section.

| Materials                        | Demand | Quantity (k) | Order Frequency (Kanban Cards) | Average Inventory (I) |
|----------------------------------|--------|--------------|--------------------------------|----------------------|
| AUTONET DISC 3” MIRKA # 320      | 5350   | 53.5         | 105                            | 3910                 |
| AUTONET DISC 5” MIRKA # 400      | 29350  | 294          | 107                            | 18980                |
| PRIMER K98 ZF1 DARK GREY         | 3420   | 8            | 463                            | 1991                 |
| NEO A’LAC DEEP BLACK             | 79660  | 166          | 537                            | 48874                |
| M’CRON 7100 CLEAR HG             | 19000  | 33           | 618                            | 10588                |
| M’CRON B/C THINNER               | 25560  | 47           | 579                            | 14464                |
| AMILAC I/M THINNER               | 20840  | 50           | 448                            | 11947                |
| MAG. 5500 RADIANT RED ZKB        | 1678   | 4            | 463                            | 976                  |
| NEO AMILAC SUPER.WHITE           | 65120  | 116          | 619                            | 38409                |
| AMILAC KP KAI THINNER            | 7880   | 14           | 613                            | 4438                 |

3.2. Economic order quantity result
Quantity of stock for each part can be calculated using economy order quantity under three conditions [7]. The first condition is a situation where each part is ordered independently. In the second condition, all part are joined in each order. The third condition is a situation wherein each order, there are multiple parts to be joined but not all parts. Equations 1 to 3 is used for the first condition while
Equations 4 to 6 is used for the second condition. The third condition is calculated using Equations 7 to 11. Table 3 shows the quantity of stock and order frequency under these three conditions.

Table 3. Quantity and Order Frequency of Parts Using EOQ

| Materials                  | Demand | Parts are ordered independently (First condition) | Parts are jointly ordered (Second condition) | Only certain part are jointly ordered (Third condition) |
|----------------------------|--------|--------------------------------------------------|---------------------------------------------|--------------------------------------------------------|
|                            |        | Quantity (Q) | Order Frequency (N) | Quantity (Q) | Order Frequency (N) | Quantity (Q) | Order Frequency (N) |
| AUTONET DISC 3"           | 5350   | 2182         | 2                   | 92           | 58                   | 206           | 26                   |
| MIRKA # 320               | 29350  | 4502         | 7                   | 506          | 58                   | 554           | 53                   |
| AUTONET DISC 5"           | 3420   | 353          | 10                  | 59           | 58                   | 132           | 26                   |
| MIRKA # 400               | 79660  | 2012         | 40                  | 1372         | 58                   | 1503          | 53                   |
| PRIMER K98 ZF1 DARK GREY  | 19000  | 1014         | 19                  | 327          | 58                   | 359           | 53                   |
| NEO ALAC DEEP BLACK BLACK | 25560  | 1854         | 14                  | 440          | 58                   | 483           | 53                   |
| MCRON 7100 CLEAR HG       | 20840  | 1651         | 13                  | 359          | 58                   | 394           | 53                   |
| MCRON B/C THINNER         | 1678   | 147          | 11                  | 29           | 58                   | 65            | 26                   |
| AMILAC I/M THINNER MAG. 5500 RADIANT RED ZKB   | 65120  | 1769         | 37                  | 1122         | 58                   | 1229          | 53                   |
| NEO AMILAC SUPER.WHIT E   | 7880   | 1011         | 8                   | 136          | 58                   | 303           | 26                   |
| AMILAC KP KAI THINNER     |        |              |                     |              |                      |               |                     |

It can be seen from table 3, a total of order frequency is higher for the first condition. This occurs because of only one type of material in each order. As a result, the order cost increases significantly following the number of order. An investment for buying the stock of part is lowest in the first condition. This is due to the low quantity of parts must be bought in each order comparing to other condition. In the second condition, all ten parts are combined in each order with different number of units for each part. As a result, a big quantity of parts should be bought in each order. This condition requires 58 orders to fulfill the quantity of all parts. The lowest order frequency can be observed in the third condition with only 53 orders. Four parts (AUTONET DISC 3”, PRIMER K98 ZF1 DARK GREY, MAG. 5500 RADIANT RED ZKB, and AMILAC KP KAI THINNER) are combined and ordered 26 times in one year.
3.3. Economic order interval result

Economic order interval model is started by calculating interval times between order using equation 10 (see table 2). Then this is followed by determining quantity for each part by using equation 11. From the calculation, it is found that the interval time between orders is 0.017 year or 6.2 days. This means that the company should orders all parts every 6 days. In total, to fulfill the demand of parts, 59 orders are required. Table 4 displays the quantity and order frequency for each part calculated using EOI.

It can be seen from table 4, order frequency calculated using EOI is similar with order frequency calculated using EOQ under the second condition. This is because the order cost for combining parts ($S'$) is not too big compared to the order cost for individual part (see Equation 5 in Table 2). Moreover, both models require combining all parts in each order. Hence, a big investment is required to buy total quantity of stock for all parts.

Table 4. Quantity and Order Frequency of Parts Using EOI

| Materials                          | Quantity | Order Frequency |
|-----------------------------------|----------|-----------------|
| AUTONET DISC 3" MIRKA # 320       | 91       | 59              |
| AUTONET DISC 5" MIRKA # 400       | 499      | 59              |
| PRIMER K98 ZF1 DARK GREY          | 58       | 59              |
| NEO A'LAC DEEP BLACK              | 1354     | 59              |
| MCRON 7100 CLEAR HG               | 323      | 59              |
| MCRON B/C THINNER                 | 435      | 59              |
| AMILAC I/M THINNER                | 354      | 59              |
| MAG. 5500 RADIANT RED ZKB         | 29       | 59              |
| NEO AMILAC SUPER.WHITE            | 1107     | 59              |
| AMILAC KP KAI THINNER             | 134      | 59              |

4. Comparison between inventory models based on inventory cost

Inventory cost consists of three types of cost including the cost of buying the parts, order cost and holding cost [7]. However, order frequency can be different for each inventory model. For example, order frequency for EOQ with lots ordered independently is influenced by the quantity of stock (Q) while order frequency for EOI is affected by the interval between orders. As a result, the equations for calculating inventory cost can be varied (see Table 2). Table 5 shows inventory cost for each inventory model.

Table 5. Comparison of Inventory Cost for Each Inventory Model

| Method                                    | Total Cost (IDR) |
|-------------------------------------------|------------------|
| EOQ Independent                           | 16,226,190,176   |
| **EOQ with lots jointly ordered**         | **16,174,770,877**|
| EOQ with lots selected jointly ordered    | 16,186,107,008   |
| EOI (Economic Order Interval)             | 16,174,952,195   |
| Kanban                                    | 17,121,778,890   |

The calculation of inventory cost in Table 5 shows that Kanban has the highest order cost compared to other models. This is due to the highest number of order frequency (Kanban cards) in this model. For purchasing cost, EOQ with lots jointly ordered and EOI has the highest purchasing cost due to the
highest quantity of parts in each order. EOQ with lots selected jointly ordered has the lowest order cost due to low order frequency. Based on the calculation of the inventory cost above, the EOQ model (Economic Order Quantity) with lots jointly ordered and EOI (Economic order interval) is suggested to adopt by the company due to lowest cost produced by these models.

5. Conclusion
Based on the results, some conclusions are obtained as follows.

- Inventory cost can be used to select appropriate inventory models to support inventory planning in business.
- The implementations of several inventory models could give new insight for inventory planner in managing inventory for their businesses.
- Inventory model based on Kanban system and EOQ with lots ordered independently might enhance the order cost due to high order frequency while EOQ with lots jointly ordered and EOI might increase the purchasing cost due to the high quantity of parts in each order.
- Based on the implementations of EOQ, EOI, and Kanban system in calculating the quantity of stock and order frequency, the EOQ method (Economic Order Quantity) with lots jointly ordered and EOI is suggested to use due to lowest inventory cost.

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