Integration of deterministic and probabilistic inventory methods to optimize the balance between overstock and stockout

Z U Rizqi¹ and A Khairunisa²

¹,² Department of Industrial Engineering, Universitas Islam Indonesia, Yogyakarta, Indonesia

¹E-mail: ugihzakka@gmail.com

Abstract. In inventory management, stockout and overstock are problems that always occur in the inventory system. The limitations of the method make it difficult for companies to determine the level of inventory following probabilistic inventory conditions. Ajeng Gallery is a quality bag craft company that has problems in the supply of raw materials where there is always a large stockout and overstock. The research is limited to cow leather material which is the main material based on the results of ABC analysis. This research also integrates Min-Max method which is a deterministic method to determine the level of inventory then the results will be integrated with Monte Carlo simulation which is a probabilistic method so that it can evaluate the amount of stockout and overstock that occurs. The results showed that the company no longer experienced stockout for 1 month and the amount of overstock decreased by 0.42% of the actual system.

1. Introduction

Inventory is an interesting thing to talk about. By definition, inventory can be interpreted as an asset which includes goods belonging to the company to sell within a certain business period or inventory of goods that are still in the work or production process or inventory of raw materials awaiting their use in the production process [1]. Its presence is costly to the company, but without it, the company will find difficult to always meet the demands of dynamic customers.

Basically, inventory problems occur due to a lack of information obtained. Good information about the demand and time of arrival of the material is needed. If the supply of raw materials is less or exhausted (stockout), the company will lose because customer satisfaction will decrease [2]. Meanwhile, if the inventory is too much (overstock), it can increase the company's inventory costs. These costs arise due to warehouse rental fees, maintenance costs, warehouse worker salaries or possibly expired goods costs.

Ajeng Gallery is a quality handicraft bag company based on cow leather in Yogyakarta. The well known quality causes the demand for bags is quite high and probabilistic. However, the company often experience stockouts due to lack of good company in processing raw material inventory. The company also does not want to increase the high level of inventory because the quality of cow leather used is easily damaged if stored in a warehouse too long so that it will harm the company. Therefore,
the challenge is how companies determine the optimal level of inventory but with the lowest possible inventory costs.

The problem of overstock and stockout is a common problem faced by many companies in controlling inventory but it is still difficult to determine the optimal point [3]. One method that is widely used in inventory control is the Min-Max method. The min-max method is a method of controlling raw materials based on the assumption that raw material inventories are at two levels, namely the maximum level and the minimum level [4]. However, the method uses averages of probabilistic variables so that their use is assumed to be deterministic. Whereas the inventory environment is probabilistic so the method is less effective to use. With simulation, probabilistic conditions can be accommodated where a solution to a problem is given based on a randomization process [5]. By implementing simulation also the losses of money and time from experiments given can be minimized [6].

This study aims to integrate the min-max method with a Monte Carlo simulation in the Ajeng Gallery's raw material inventory where inventory levels obtained from the min-max method are included as input variables in the simulation. With the integration of the two methods, the evaluation of inventory levels can be optimized because it is carried out under probabilistic conditions following the actual inventory conditions.

2. Methods

2.1. Data collection
In this study, data collection was done by conducting interviews with warehousing managers from Ajeng Gallery. The interview was intended to collect historical company data regarding the type of material making up the product, material requirements per month, data on lead time from suppliers to the company, the amount of demand for raw materials, material prices, and the company's inventory management.

2.2. Data processing
Data processing in this study was carried out in 3 stages. The first will be done by material classification using ABC Analysis, determination of inventory levels using the min-max method, and evaluation with Monte Carlo simulation.

ABC analysis is done so that researchers focus only on the main material where the material is classified into 3 classes, namely A, B, and C. Materials that enter into class A are materials that provide high value, meaning that companies need to give focus and main control to for this material, class B is goods which provide a medium value represented by 30% of the total inventory and the value produced is 15%, and class C are goods that provide a low value represented by 50% of the total inventory exists and the resulting value is equal to 5% [7].

Furthermore, material entering into class A in ABC Analysis will be carried out inventory control is carried out using the Min-Max method. To avoid the amount of inventory that is too big or too small. The results of the Min-Max method are used to determine the minimum level or safety stock (SS), maximum level (Max), Reorder Point (ROP), and the number of materials ordered in a single order or Economic Order Quantity (EOQ) using equation 1, 2, 3, 4, and 5.

\[
Sdl = \sqrt{(d^2 \times Sl^2 + (l \times Sd^2))} \quad (1)
\]
\[
SS = Z \times Sdl \quad (2)
\]
\[
ROP = (d \times l) + SS \quad (3)
\]
\[
EOQ = 2 \times d \times l \quad (4)
\]
Max = SS + EOQ  \hspace{1cm} (5)

Where:
Z = proportion of demand to be fulfilled
Sdl = standard deviation of lead time and demand
SI = standard deviation of lead time/period
Sd = standard deviation of demand/period
d = average demand/period
l = average lead time/period

Then the researchers implemented the results of the Min-Max method calculation into the Monte Carlo simulation which estimated the company's inventory system to further evaluate the problems that occurred at Ajeng Gallery. Monte Carlo simulation is done using Excel software with the random number generation feature. The purpose of the simulation is to find out the effect that occurs if Ajeng Gallery applies the inventory level of the min-max method. Stockout and overstock variables will be used as parameters in this study.

3. Result and discussion

3.1. ABC analysis

ABC Analysis on Ajeng Gallery can be seen in Table 1 which explains the materials along with their prices and Table II which explains the calculation results of ABC Analysis. The standard unit between Ajeng Gallery and suppliers of cow leather is sheets, where for 1 sheet cow leather is equal to 1x2 meters.

| Item        | Needs/month | Price/unit (Rp) |
|-------------|-------------|-----------------|
| Cow leather | 125 sheet   | 425,000         |
| Suede fabric| 370 meter   | 35,000          |
| Kerinti handle | 400 pcs   | 13,500          |
| Ring D      | 500 pcs     | 1,000           |
| Zipper      | 300 meter   | 4,000           |
| Zipper slider | 750 pcs   | 1,500           |

Table 1. Materials in ajeng gallery warehouse.

| Item    | Needs (unit) | Statement of Unit | Price/unit (Rp) | Total Price (Rp) | Total Price (%) | Cumulative (%) | Class |
|---------|--------------|-------------------|-----------------|-----------------|----------------|----------------|-------|
| 1       | 125          | Sheet             | 425,000         | 53,125,000      | 71.50          | 71.50          | A     |
| 2       | 370          | Meter             | 35,000          | 12,950,000      | 17.43          | 88.93          | B     |
| 3       | 400          | Pcs               | 13,500          | 5,400,000       | 7.27           | 96.20          | B     |
| 4       | 300          | Meter             | 4,000           | 1,200,000       | 1.62           | 97.81          | C     |
| 5       | 750          | Pcs               | 1,500           | 1,125,000       | 1.51           | 99.33          | C     |
| 6       | 500          | Pcs               | 1,000           | 500,000         | 0.67           | 100            | C     |

Table 2. ABC analysis result.
Based on ABC analysis, the material that included in class A category is cow leather with total needs is 5.665 and total price is 71.5%, class B category are suede fabric and kerinti handle with total needs is 32.08% and total price is 24.7%, and for class C category are ring D, zipper and zipper slider with total needs is 62.26% and total price is 3.8%. Therefore, cow leather material will be carried out as an object to be evaluated in this study.

3.2. Min-max calculation

Before calculating using Min-Max, historical data regarding the lead time (day) and demand per day are required, which are shown in Table 3.

Table 3. Historical data for cow leather’s leadtime and demands.

| Lead time (Day) | Demand/Day |
|----------------|------------|
| 2              | 5          |
| 1              | 6          |
| 4              | 4          |
| 3              | 5          |
| 2              | 5          |

The results of calculations using equation 1, it obtained a value for Sd1 is 5.82. By using equation 2, we get 10 sheets for safety stock (min) of cow leather. Equation 3 is used to determine the reorder point (ROP), where the ROP for cow leather is 22 sheets. Economic order quantity (EOQ) is calculated using equation 4, which is 24 sheets. And the maximum (max) warehouse capacity for cow leather is calculated using equation 5, which is obtained as many as 34 sheets.

3.3. Implementation on simulation model

Monte Carlo simulation is done by imitating the real inventory system at Ajeng Gallery. Simulations were carried out specifically for cow leather material which included in classification A in the ABC analysis. The data that is used in the simulation is based on the leadtime and demand data in Table III, then the probability distribution of lead time is calculated first as shown in Table 4 and the probability distribution of demand in Table 5.

Table 4. Probabilistic distribution of lead time.

| Lead time (day) | Freq. | Prob. | Prob. Cum. | LL | UL |
|----------------|-------|-------|------------|----|----|
| 1              | 1     | 0.2   | 0.2        | 1  | 20 |
| 2              | 2     | 0.4   | 0.6        | 21 | 60 |
| 3              | 1     | 0.2   | 0.8        | 61 | 80 |
| 4              | 1     | 0.2   | 1          | 81 | 100|
| **Total**      | 5     | 1     |            |    |    |

Table 5. Probabilistic distribution of demand.

| Demand/day (sheet) | Freq. | Prob. | Prob. Cum. | LL | UL |
|--------------------|-------|-------|------------|----|----|
| 4                  | 1     | 0.2   | 0.2        | 1  | 20 |
| 5                  | 3     | 0.6   | 0.8        | 21 | 80 |
| 6                  | 1     | 0.2   | 1          | 81 | 100|
| **Total**          | 5     | 1     |            |    |    |
Simulation results for 1 month (26 days) can be seen in Figure 1.

| Day | R. N. Demand | R. N. Leadtime | Demand | Leadtime | Initial Inv. | End Inv. /Overstock | Stockout |
|-----|--------------|----------------|--------|----------|--------------|---------------------|----------|
| 1   | 50           | 15             | 5      | 0        | 50           | 45                  | 0        |
| 2   | 39           | 24             | 6      | 0        | 45           | 39                  | 0        |
| 3   | 21           | 45             | 5      | 0        | 39           | 34                  | 0        |
| 4   | 98           | 87             | 6      | 0        | 34           | 28                  | 0        |
| 5   | 47           | 91             | 2      | 0        | 28           | 23                  | 0        |
| 6   | 81           | 23             | 6      | 0        | 23           | 17                  | 0        |
| 7   | 46           | 64             | 5      | 3        | 17           | 12                  | 0        |
| 8   | 64           | 58             | 5      | 2        | 12           | 7                   | 0        |
| 9   | 86           | 15             | 6      | 1        | 7            | 1                   | 0        |
| 10  | 12           | 85             | 4      | Order Received | 25         | 21                  | 0        |
| 11  | 15           | 88             | 4      | 3        | 21           | 17                  | 0        |
| 12  | 71           | 94             | 5      | 2        | 17           | 12                  | 0        |
| 13  | 84           | 43             | 6      | 1        | 12           | 6                   | 0        |
| 14  | 80           | 98             | 5      | Order Received | 80         | 25                  | 0        |
| 15  | 73           | 82             | 5      | 0        | 25           | 20                  | 0        |
| 16  | 6            | 77             | 4      | 3        | 20           | 16                  | 0        |
| 17  | 65           | 52             | 5      | 2        | 16           | 11                  | 0        |
| 18  | 6            | 75             | 4      | 1        | 7            | 0                   | 0        |
| 19  | 34           | 58             | 5      | Order Received | 31         | 26                  | 0        |
| 20  | 95           | 42             | 6      | 0        | 26           | 20                  | 0        |
| 21  | 72           | 78             | 5      | 3        | 20           | 15                  | 0        |
| 22  | 38           | 63             | 5      | 2        | 15           | 10                  | 0        |
| 23  | 3            | 84             | 4      | 1        | 10           | 6                   | 0        |
| 24  | 76           | 89             | 5      | Order Received | 50         | 25                  | 0        |
| 25  | 2            | 93             | 4      | 0        | 25           | 21                  | 0        |
| 26  | 12           | 39             | 4      | 2        | 21           | 17                  | 0        |
| Total | 129          | Average       | 16.5   | 0        |              |                     |          |

**Figure 1.** Result of monte carlo simulation.

3.4. Analysis

Based on monte carlo simulation results that are integrated with the Min-Max method, the results of the number of stockouts and overstocks can be evaluated. It can be seen that the implementation of the Min-Max method does not produce a stockout at all which means that it is in accordance with the company’s objectives, which is always fulfilling the demand on time where the demand begins with the availability of raw materials. In terms of overstock, the average overstock per day that occurs is 19 sheets of cow leather per day. When compared to the real system, the average overstock per day that occurs is 33 sheets of cow leather per day. It means that there is a decrease in overstock per day by 0.42%. It also means that the application of Min-Max in Ajeng Gallery’s warehouse will giving benefit for company because with the decrease in the amount of overstock, the cost of maintaining materials at the warehouse will be reduced. In addition, in terms of the quality of cow leather, it will be better if it is processed immediately compared to one that has long been stored in a warehouse so that the quality of the final product can be maximized.

4. Conclusions

Based on the discussion, it can be concluded that based on ABC analysis, cow leather material is included in class A category so that priority is given to its control. Min-Max calculation results show that the number of Safety Stock (Min) is 10 sheets, ROP is 22 sheets, EOQ is 24 sheets and Max is 34 sheets. Evaluation using Monte Carlo simulation for one month showed that Ajeng Gallery did not experience any stockout at all and there was a decrease in overstock by 0.42% compared to the real system so that it would benefit the company because customer satisfaction would not decrease, inventory costs would decrease, and quality of raw materials would be maximized because raw materials are used faster.
References

[1] Lahu E P and Sumarauw J S B 2017 Analysis of raw material inventory control to minimize inventory cost on dunkin donuts Manado Jurnal EMBA 5 4175-4184

[2] Gavan J F 2000 Consumer response to stockouts Journal of Consumer Research 27 249-266

[3] Satibi, Fudholi A, Tuko E C, and Swastianadari G L 2019 The inventory control, storage facilities and distribution at pharmaceutical industry in supporting drugs availability of JKN era JMPF 9 27-37

[4] Kinanthi A P, Herlina D, and Mahardika F A 2016 Analisis pengendalian persediaan bahan baku menggunakan metode min-max (studi kasus PT.Djite Indonesia Tobacco) Performa 15 87-92

[5] Hutahaen H D 2018 Analisa simulasi monte carlo untuk memprediksi tingkat kehadiran mahasiswa dalam perkuliahan (studi kasus: STMIK pelita nusantara) Jurnal of Informatic Pelita Nusantara 3 41-45

[6] Rizqi Z U and Aulia R 2019 Evaluation of redesign layout using discrete event simulation (DES) Proceedings of the International Conference on Industrial Engineering and Operations Management 3203-3211

[7] Wahyuni T 2015 Penggunaan analisis abc untuk pengendalian persediaan barang habis pakai: studi kasus di program vakasi UI Jurnal Vokasi Indonesia 3 1-20

Acknowledgment

The authors also would express thanks to Ajeng Gallery company for allowing researchers to see the company's condition directly so that it can provide an opportunity for researchers to implement our knowledge.