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PERAMALAN DAN PENGENDALIAN PERSEDIAAN UNTUK PIPA *HIGH-DENSITY POLYETHYLENE* DI PT. MASPION UNIT-II

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FORECASTING AND INVENTORY CONTROL FOR HIGH-DENSITY POLYETHYLENE PIPES IN PT. MASPION UNIT-II

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PERAMALAN DAN PENGENDALIAN PERSEDIAAN UNTUK PIPA *HIGH-DENSITY POLYETHYLENE* DI PT MASPION UNIT-II

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ABSTRAK

PT. Maspion Unit-II bergerak di bidang manufaktur khususnya manufaktur pipa HDPE. Saat ini, perusahaan mengalami kendala pada proses peramalan dan pengendalian persediaan. Pada tahun 2019, peramalan yang dilakukan perusahaan pada penjualan aggregat memiliki *error* sebesar 87.66%. Disamping itu, pada bulan Desember 2019, perusahaan memegang lebih dari 11 miliar rupiah dari total persediaan. Menandakan perusahaan sering mengalami *overstock*. Walaupun tingkat persediaan seringkali tinggi, perusahaan masih mengalami *stockout* dimana perusahaan tidak mampu untuk memenuhi permintaan pembeli sehingga harus melakukan *backorder* dan mengurangi *fill rate*. Untuk mengatasi permasalahan tersebut, Tugas Akhir ini mengusulkan teknik peramalan dengan pendekatan *time series* untuk permintaan yang bersifat kontinyu dan metode Croston's dan SBA untuk permintaan yang *intermittent*. Dari hasil analisis, diperoleh bahwa teknik peramalan yang diusulkan dapat meningkatkan akurasi jika dibandingkan dengan teknik yang digunakan perusahaan saat ini. Untuk pengendalian persediaan diperlukan metode yang dapat meminimumkan *overstock* sekaligus *stockout.* Tugas akhir ini menggunakan klasifikasi ABC untuk mengorganisasikan multi produk. Setelah itu tiap produk dieksplorasi untuk diketahui sistem pengendalian terbaik dengan membandingkan metode *continuous review* dan *periodic review.* Simulasi Monte Carlo juga digunakan untuk mengeksplorasi lebih jauh kebijakan persediaan yang paling optimal untuk diterapkan pada perusahaan. Hasil yang didapatkan dari penelitian ini adalah metode peramalan yang banyak digunakan adalah metode *Winter's* untuk data yang *smooth* dan metode SBA untuk data yang *intermittent*, kebijakan persediaan yang optimal untuk produk A adalah *(s, S) system*, produk B adalah *(s, Q) system*, dan produk C adalah *(R, S) system*; dan untuk data kontinyu didominasi oleh *(s, Q)* dan *(s, S) system* dan data *intermittent* didominasi oleh *(s, Q)* dan *(R, S) system* yang dapat mengurangi total biaya sebesar Rp4,859,084,608 atau penurunan biaya sebesar 8.8% dari kondisi eksisting dengan tetap mempertahankan *fill rate* sebesar 97.8%.

Kata Kunci: *Klasifikasi Produk, Peramalan Permintaan, Pengendalian Persediaan, Simulasi Monte Carlo*

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FORECASTING AND INVENTORY CONTROL FOR HIGH-DENSITY POLYETHYLENE PIPES IN PT MASPION UNIT-II

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ABSTRACT

PT. Maspion Unit-II is a company engaged in manufacturing, especially manufacturing HDPE pipes. Currently, the company is experiencing problems in forecasting and controlling the inventory. in 2019, forecast conducted by the company on aggregate sales had an error of 87.66%. other than that, in December 2019, the company held more than 11 billion rupiah of total inventory. With the high value of inventory, the company often experience overstock. Despite inventory levels are often high, the company still experience stockouts where the company is unable to fulfill the demand so it must backorder and reduce the fill rate. To overcome these problems, this Final Project proposes the forecasting technique using time series approach for demand with continuous pattern and Croston's and SBA method for demand with intermittent pattern. From the analysis results, it was found that the proposed forecasting method can improve accuracy when compared to the techniques used by the company. For inventory control, it is required a method that can minimize overstock as well as stockout. This Final Project uses ABC classification to organize multiple products. Each item is explored to find out the best control system by comparing the continuous review and periodic review method. Monte Carlo simulation is also used to explore further the most optimal inventory policy to be applied to the company. The results obtained from this research are that the forecasting method that mostly used is Winter's method for smooth data and SBA method for intermittent data. The inventory policy that is optimal for product A is *(s, S)* system, product B is *(s, Q)* system, and product C is *(R, S)* system; for continuous item is dominated by *(s, Q)* and *(s, S)* system and intermittent item is dominated by *(s, Q)* and *(R, S)* system that can reduce the total cost for Rp4,859,084,608 or a reduce of 8.8% from the existing condition while keeping the fill rate by the level of 97.8%.

Keyword: *Product Classification, Demand Forecasting, Inventory Control, Monte Carlo Simulation*

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CHAPTER 1
INTRODUCTION

This chapter explains about the background of this final project, the problem formulation, objectives, benefits, scope of research that consists of limitations and assumptions, and research outline.

1.1 Background

HDPE (High Density Poly-Ethylene) pipe is a type of flexible plastic made from thermoplastic HDPE that can be used for transferring fluid and gas material. A high level of impermeability and strong molecular bond makes the material suitable for high-pressure pipelines. The size, thickness, and other dimensional attributes are regulated by dimensional standards and there are various standards such as SNI (Standar Nasional Indonesia) and JIS (Japanese Industrial Standards). According to the market research conducted by Adroit in 2019, the trend of the global HDPE pipe is increasing. In 2018 the market size was valued at US$14.35 billion and was expected to increase to US$19.7 billion by 2024. However, although the demand is expected to rise, there are always possibilities that fluctuation appears in the process. This condition becomes a challenge to the pipe industries. The industry must be able to satisfy the increasing and fluctuating demand of the market. If not, there will be a huge opportunity cost that will arise if demand is not fulfilled and huge inventory costs that will arise if the industry stock too many products. To overcome this problem, the industry must be able to formulate a proper strategy. One of the ways to optimize demand fulfillment is through the optimization of inventory.

Inventory is an essential asset for an organization. It is defined as items that are stored by an organization and the items are kept for future use (Waters, 2003). An organization can satisfy demand and improve their order fulfillment rate by providing and utilizing inventory effectively. Although the availability of inventory is beneficial to the organization, it can also be a burden to the organization. Inventory problems such as the abundance or too small quantities on hand can impact on the organization's failures (Sheakh, 2018). Inventories carry cost components such as holding cost, order/setup cost, and purchase cost. If the organization carries an excessive amount of inventory, it will generate cost to the organization. However, if the inventory level is too low and the organization experience shortage, it will impact on the fill rate provided by the organization. Fill rate is the probability of the demand that can be fulfilled by the available inventory and it can function as one of the performance measurements of an organization. Due to this condition, the organization must be able to optimize the inventory level. To optimize the level of inventory, an organization can implement inventory management in the field. The objective of inventory management is to keep the inventories at an optimal level.

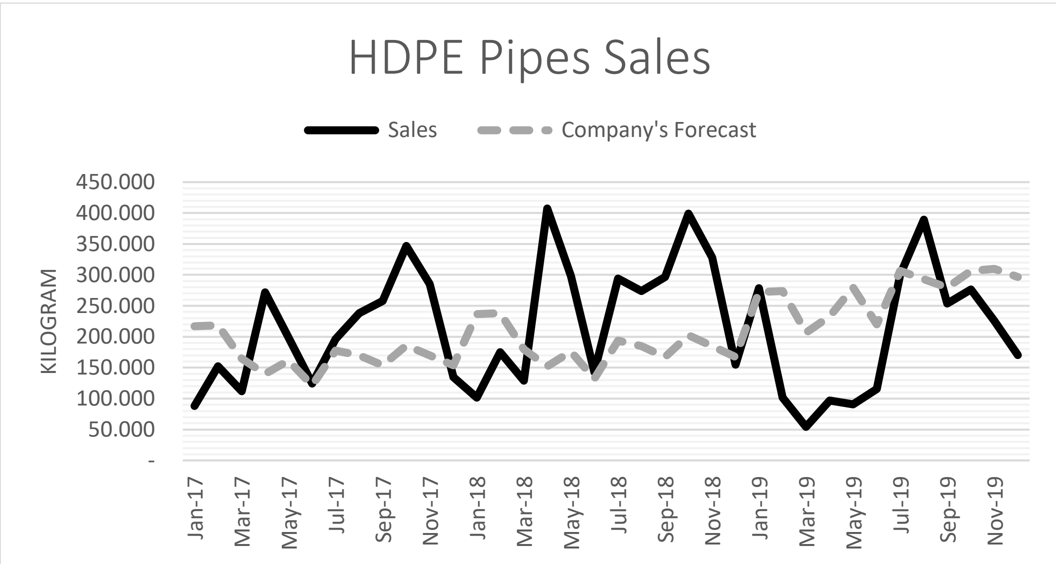

Figure 1. 1 Maspion HDPE Pipes Sales

One of the companies that produce HDPE pipes is PT Maspion Unit II. The pipes produced by Maspion have many variations of diameter, thickness, and length resulting in numerous types of products. Besides HDPE pipes, Maspion Unit II also produces styroforce and polycell. With the current condition of the increasing HDPE market, the company must be able to adapt with the available trend to capture the best profit possible. Nevertheless, the company also needs to adapt with the fluctuation that could happen. It can be seen from figure 1.1 that fluctuation of demand exists. Numerous problems also occur in the operations of the company. The company has difficulty in forecasting the demand of HDPE pipes. The company uses a conventional method in forecasting its demand by only increasing 10% from the previous year to forecast the future demand. In 2019 itself, the forecast error calculated using MAPE (Mean Absolute Percent Error) reach 87.66% of error, indicating a significant level of forecasting error. A high forecast error can give misleading information to other operations performed by the company. It can impact on inaccurate raw material replenishment quantity, high inventory level or even shortage, and other potential problems.

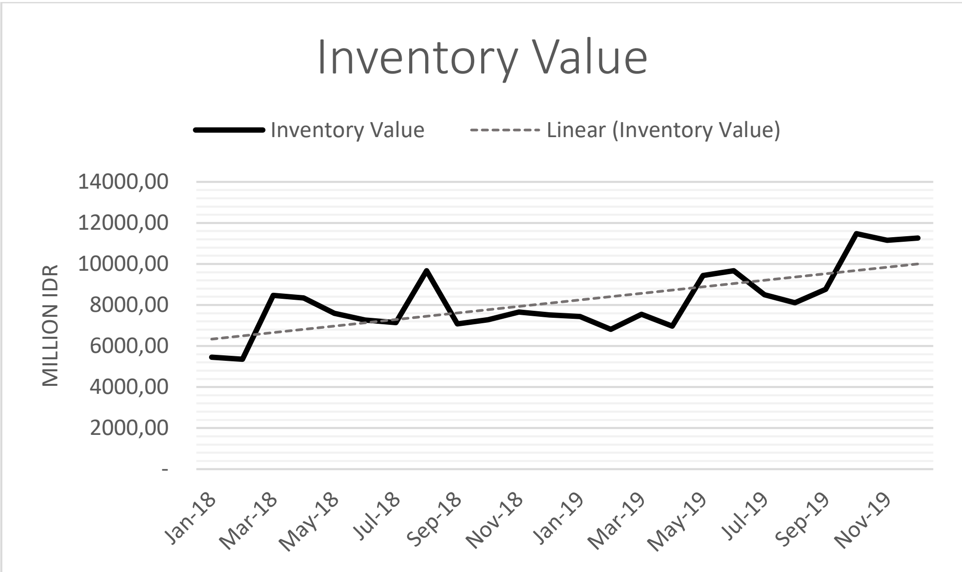

Figure 1. 2 Inventory Value

PT Maspion also encounters numerous amounts of product variety with more than 20 variation of HDPE pipes that have different standards and outside diameter. With the number of product variations, the company experience difficulties in managing its inventory. The company experienced a trend of increasing inventory level as shown in figure 1.2. In December 2019, the company hold more than 11 billion Rupiah of inventory which means an enormous amount of opportunity cost perceived by the company. This condition occurs due to the inaccuracy of demand forecast and the company still has not made classification on the product that makes them unable to determine the strategies best implemented to different characteristics of product. It has problems in determining which product to store making the inventory level to go high. With a large variety of products, some products with low demand are often not stored in the warehouse, increasing the probability of shortage and reduced service level to the customer. Although these conditions often arise, the company still did not have a proper method to control the inventory.

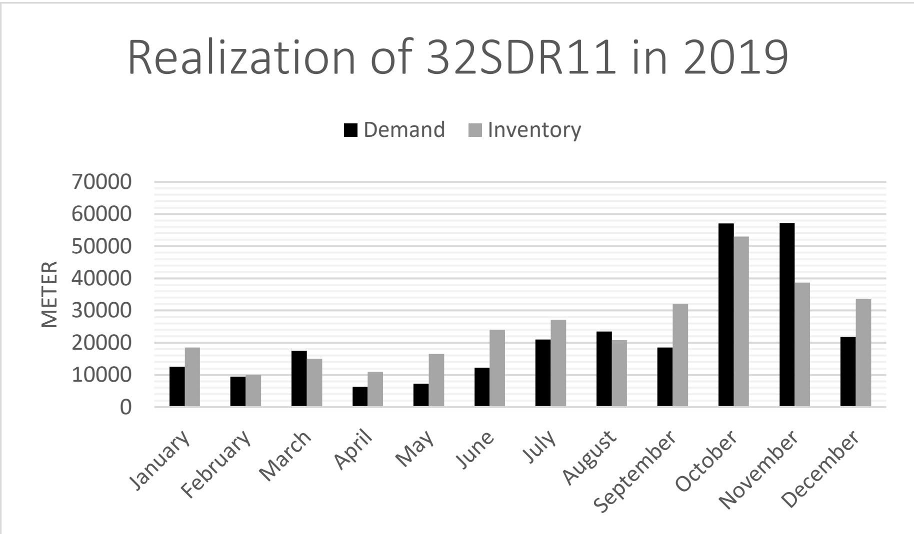

Figure 1. 3 Realization of 32SDR11 in 2019

Figure 1.3 shows about the realization graph of the 32SDR11 stock with the pipes demand in 2019. It is shown that in several periods such as in May and September 2019 there are overstock that occurs from the product because the demand is low compared to the stock item in the inventory. This condition generates cost to the company which can be reduced or avoided. In other side, there are also periods that experience understock such as in March and October. Because of the understock condition, some demand cannot be satisfied, causing the company not able to capture the potential profit generated from fulfilling the demand and reduced fill rate that is provided by the company. The condition of overstock and understock also happens in other products. The company still has not determined the optimal inventory level and optimal order quantity causing those conditions to appear. Since such conditions still arise at PT. Maspion, the company is eager to optimize the availability of inventory in order to have a lower inventory cost and a higher fill rate that can be offered to the customers.

This final project focuses on solving the problems of HDPE pipes. The methods that are used to minimize the forecasting error that is currently used by the company are using time series, Croston's method and Syntetos Boylan Approximation forecast. Even though forecast still has errors, the formulation of the proper forecast is expected to generate a lower level of error than the current method, giving the company the ability to make a more accurate decision. The HDPE pipe is also classified into different groups to map the product according to its characteristics and the inventory control policy that is used as an improvement to the company is continuous review and periodic review. By using continuous review, the optimal reorder point and maximum stock can be known. The continuous review can give a lower level of inventory if compared to periodic review; however, the continuous review requires more effort than the periodic review. By using periodic review, the coordination between other stakeholders can be improved because it can give a more predictable evaluation to the others. Each of the systems offers different advantages and disadvantages, resulting in a different outcome that can be evaluated and compared. The policy can give recommendation of the optimal inventory parameters that generate minimum total cost and optimal fill rate. Monte Carlo simulation is used in the final project to predict the level of demand based on a random number generated from the distribution of the existing data in order to imitate the real condition identically and to capture the randomness of the data. The simulation is used to measure the effectiveness of the inventory control policy.

1.2 Problem Formulation

Based on the problems stated in Section 1.1, the problems encountered are high forecasting error and poor inventory management. This final project aims to formulate a better forecasting method for the company and propose an inventory control strategy. The strategies are performed by formulating a forecast model and determining the optimal inventory parameters that can give the best fill rate and minimize total cost.

1.3 Objectives

The objectives that are going to be achieved by doing this final project are as follow.

1. To provide a forecasting method that generates the lowest error in accordance with product characteristics.
2. To classify HDPE pipes according to the percentage value from the total product and the data pattern.
3. To design the appropriate inventory control policy for the company using a periodic review system and continuous review system.
4. To analyze the impact of implementing inventory control policy in the company and to measure the inventory control policy performance using Monte Carlo simulation.

1.4 Benefits

The benefits that are expected to be obtained after conducting the final project are as follow.

1. This project can provide a recommendation to the company about the appropriate forecasting method to be implemented in accordance with the proper product classification.
2. This project provides recommendation to the company about the optimal inventory control policy to be implemented by the company.

1.5 Scope of Research

The scope of research in this final project consists of assumptions and limitations that will be explained as follow.

1.5.1 Assumptions

The assumption that will be used in this research is as follow:

1. The price for each product is the same and not affected by any external event.

2. No quantity discount is applied to the product.
3. The cost component that constructs the inventory cost is constant.
4. No *force majeure* circumstances that impact on the process and result of this research.

1.5.2 Limitations

The limitation that will be used in this research is as follow:

1. The observed finished goods are HDPE pipes.
2. The observed data are in the range of 2017 until 2019.

1.6 Research Outline

The research outline of this final project consists of six chapters that is interrelated which each other. The research outline is explained below.

CHAPTER 1 INTRODUCTION

This chapter explains about the background of the problem that is used as the topic for the research, problem formulation that will be solved, objectives of doing the research, benefits from doing the research, scope of research that consists of limitations and assumptions, and the research outline.

CHAPTER 2 LITERATURE REVIEW

This chapter explains about the theory and literature that is used in conducting the research. The theories are used as the basis in solving the problems that arise and as theoretical basis in constructing a conceptual framework. The theories are sourced from credible literature such as books, journals, and previous research. The literature review in this research consists of forecasting in operations management, inventory management, inventory classification method, inventory control model, Monte Carlo simulation in inventory management, and previous research.

CHAPTER 3 RESEARCH METHODOLOGY

This chapter explains about the methodology of the research. Methodology of the research work as the references in conducting experiment so the research can be performed in a systematic way and in accordance with the existing objectives. The methodology of the research will be shown in a form of a flowchart that represents the step in doing the research with detailed information of the steps taken.

CHAPTER 4 DATA COLLECTION AND PROCESSING

This chapter shows the data collection acquired from the company and other supporting data to enhance the validity of the research. The collected data will then be processed using a suitable methodology that has been formulated in the previous chapter.

CHAPTER 5 ANALYSIS AND INTERPRETATION

This chapter explains about the analysis and discussion of the results of data processing in the previous chapter. Furthermore, the results of the existing method with the proposed method will be compared so that the optimal method for controlling inventory can be known.

CHAPTER 6 CONCLUSION AND RECOMMENDATION

This chapter presents the conclusions from the results of data processing and proposing recommendations to the company and for further research.

CHAPTER 2
LITERATURE REVIEW

This chapter explains about the theoretical basis from the literatures that are used for the final project. The theoretical basis is used as guidelines in solving the problems in the final project. The literatures that are used in this final project are forecasting in operation management, inventory management, inventory classification method, inventory control model, Monte Carlo Simulation in Inventory Management, and previous research.

2.1 Forecasting in Operations Management

Forecasting is defined as the projection, prediction, or estimation of uncertain future events (Tersine, 1994). Forecast intends to use the available information to guide the organization about planning with the appropriate courses of action. According to Chopra (2016), forecast has several characteristics and organization should be aware of it such as it always inaccurate, longer-term forecast usually less accurate, and aggregate forecasts usually more accurate than disaggregate forecast. In operations management context, forecast is often used to estimate future demand. The basic approach to demand forecasting is as follows.

1. Understand the objective of forecasting
2. Integrate planning of demand and forecasting throughout the supply chain
3. Understand and identify customer segments
4. Identify the major factors that influence the forecast of demand
5. Determine the appropriate forecasting technique
6. Establish performance and error measures to the forecast

According to Chopra (2016), there are several forecasting models and one of the types is time series analysis. Time series analysis is a forecast that predicts the future using past data. By observing the variable to change over time, the relationship between the variable and time can be analyzed to predict future variable levels. In time series analysis, it may include components such as trends, level, seasonal variations, cyclical variations, and random variations. There are various methods to perform time series analysis. The methods are naïve model, moving average, exponential smoothing, Holt's method, and Winter method.

1. Naïve Model

   Naïve model forecasts the future period demand using the period previously. There is no calculation required. This method works well if there is little variation from one period to the next period.

$$\widehat{D}_t = D_{t-1} \tag{2.1}$$

   Description

   D_{t-1} = Actual demand in tge previous period

   $\widehat{D}_t$ = Forecasted demand for period t

2. Moving Average

   Moving average method generates future forecast using the average of actual demand from the last n time period. Moving average include enough period so that fluctuations can be neglected and few periods that are irrelevant from the distant past are ignored.

$$\widehat{D}_t = \frac{\sum_{i=1}^{n} D_{t-1}}{n} \tag{2.2}$$

   Description

   n = Number of time periods included in moving average

   D_{t-1} = Actual demand in period t – 1

   $\widehat{D}_t$ = Forecasted demand for period t

3. Exponential Smoothing

   Exponential smoothing does not require a long historical record and uses historical data as the basis for prediction. This method gives different weights to past data, where data is geometrically decreased with the increasing age of the data, therefore more recent data are weighted more heavily.

$$\widehat{D}_t = \alpha D_{t-1} + (1 - \alpha)\widehat{D}_{t-1} \tag{2.3}$$

Description

$\widehat{D}_t$ = Forecast for next period

D_{t-1} = Actual demand from the previous period

α = Smoothing factor

$\widehat{D}_{t-1}$ = Previously determined forecast from previous period

4. Holt's

Holt's two-parameter model is also known as linear exponential smoothing. Holt's method is suitable to forecast data with trend. This method involves one forecast equation and two smoothing equations.

$$\widehat{D}_{t+T} = (S_t + \tau G_t) \tag{2.4}$$

Description

S = Intercept (Level)

G = Slope (Trend)

τ = Amount of step ahead forecast

5. Winter's

Winter's is a model that considers three aspects of the time series, consisting of value (average), slope (trend), and cyclical repeating pattern (seasonality). Winter's is also called as triple exponential smoothing because it uses exponential smoothing to process data from the past and uses it to predict the future, and the three aspects of time series are expressed as three types of exponential smoothing.

$$\widehat{D}_{t+T} = (S_t + \tau G_t)(c_{t+1}) \tag{2.5}$$

Description

S = time series (Level)

G = Trend

c = Seasonal factor

Time series analysis is good to apply in a continuous demand pattern. In order to forecast data with intermittent demand pattern, there are other method that can be used such as Croston's methods and Syntetos-Boylan Approximation. Intermittent demand is characterized by occasional arrival of demand that are interspersed by time interval with no occurrence of demand (Babai, et al., 2017).

1. Croston's Method

   Croston's method is widely used to forecast intermittent demand. It is based on exponential smoothing. This method updates the interval and demand size only after the occurrence of positive demand; therefore, if there is a period t with demand is zero the method will only increment the count of time periods since the last occurrence of demand.

$$\hat{D}_t = \frac{\hat{z}_t}{\hat{n}_t} \quad (2.7)$$

If $x_{t-1} = 0$

$$\hat{z}_t = \hat{z}_{t-1} \quad (2.8)$$

$$\hat{n}_t = \hat{n}_{t-1} \quad (2.9)$$

If $x_{t-1} > 0$

$$\hat{z}_t = \alpha x_{t-1} + (1-\alpha)\hat{z}_{t-1} \quad (2.10)$$

$$\hat{n}_t = \alpha n_{t-1} + (1-\alpha)\hat{n}_{t-1} \quad (2.11)$$

Description:

x_t = Demand in period t

$\hat{D}_t$ = Forecast demand after period t

$\hat{z}_t$ = Estimation of demand size after period t

n_t = Interval of demand between period t with the previous period

$\hat{n}_t$ = Estimation of interval after period t

α = Smoothing factor

2. Syntetos and Boylan Approximation (SBA)

Syntetos and Boylan Approximation is the modification of Croston's method. Syntetos and Boylan showed that Croston's method is associated with positive bias causing over forecasting mean demand. SBA applies a deflating factor to Croston's method used for updating the interval of demand. SBA has shown in numerical studies to outperform Croston's method. However, some negative bias still remains which may lead to loss of performance.

$$\widehat{D}_t = \left(1 - \frac{\alpha}{2}\right)\frac{\hat{z}_t}{\hat{n}_t} \quad (2.12)$$

Description:

$\widehat{D}_t$ = Forecast demand after period t

$\hat{z}_t$ = Estimation of demand size after period t

$\hat{n}_t$ = Estimation of interval after period t

α = Smoothing factor

However, to predict events and activity in absolute accuracy is unachievable (Tersine, 1994). Forecasts always comprise of error, yet it is still desirable to do forecast because partial knowledge is better than no knowledge at all. Forecast error is defined as the difference between actual and forecast. What the organization can do is to use the most appropriate forecasting method with the least error. This way the organization can forecast more accurately. There are various metrics to summarize forecast errors in order to be able to provide useful information to the company (Swamidass, 2000). The metrics are mean absolute deviation (MAD), mean square error (MSE), and mean absolute percent error (MAPE).

1. Mean Absolute Deviation (MAD)

Mean absolute deviation is the average of the absolute deviation over all periods. It can be used to estimate the standard deviation from the random component. MAD can be a better measure of error than MSE if the forecast error does not possess a symmetric distribution.

$$MAD = \frac{\sum_{i=1}^{n}|A_t - F_t|}{n} \quad (2.13)$$

Description:

A_t = Actual demand in period t

A_t = Forecast demand in period t

n = Amount of data

2. Mean Square Error (MSE)

   Mean square error is related to the variance of the forecast error. MSE penalizes large errors more significantly because all errors are squared. This metric is suitable to use if the cost of a large error is larger than the gains from accurate forecasts.

$$MSE = \frac{\sum_{i=1}^{n}(A_t - F_t)^2}{n} \quad (2.14)$$

Description:

A_t = Actual demand in period t

A_t = Forecast demand in period t

n = Amount of data

3. Mean Absolute Percentage (MAPE)

   Mean absolute percentage error is the average absolute error as a percentage of demand. It gives a good measure of error when the forecast has significant seasonality and demand variation.

$$MAPE = \frac{100}{n}\sum_{i=1}^{n}\frac{|A_i - F_i|}{A_i} \quad (2.15)$$

Description

A_t = Actual demand in period t

A_t = Forecast demand in period t

n = Amount of data

2.2 Inventory Management

This subchapter explains about the basic concept of inventory, description of inventory management, and cost component that construct an inventory system.

2.2.1 Basic Concept of Inventory

Inventory is defined as on- hand materials and supplies that an organization carries that can be used for sale or to provide inputs to the production process (Arnold, et al., 2008). Inventory is classified into four categories which are supplies, raw materials, in-process goods, and finished goods. Each of the inventory types serves different purposes towards the organization. Supplies are defined as items consumed for the use of the organization that not construct the final product, such as pencil, paper, and light bulb. Raw materials are defined as items that are used as input to the production process and will be transformed into finished goods. In-process goods are defined as partially completed final products that still require further production process. Finished goods are defined as the final products that are available for sale, distribution, or storage.

In any type of organization, there is always problem in matching the demand and supplies. As a solution, inventory is created because it can help the organization to match the supply and demand (Tersine, 1994). Several factors support the existence of inventory which are time, discontinuity, uncertainty, and economic factors. These factors show that it is beneficial to hold inventory even though inventory generates cost to the organization. In time factor, the existence of inventory helps the organization by enabling it to reduce lead time in meeting demand. In the discontinuity factor, inventory helps to free one stage in the supply-production-distribution process with the next stages, allowing each to operates more economically. In the uncertainty factor, inventory helps to function as protection from unplanned occurrences such as equipment breakdown, strikes, and delays. In the economy factor, inventory allows the organization to produce or purchase items in economic quantities because bulk purchases can acquire quantity discounts, and therefore reduce cost.

Inventory can be utilized in various forms to help the organization reach optimization. Inventory can be categorized again based on the utilization which are working stock, safety stock, anticipation stock, pipeline stock, decoupling stock, and psychic stock. Working stock is inventory acquired in advance of the usage so that ordering can be done more economically. Safety stock is inventory held to give protection against the uncertainties of supply and demand. Anticipation stock or also known as seasonal stock is inventory used to cope with the seasonal demand, promotional programs, or deficiencies in production capacity. Pipeline stock or in transit stock is inventory that is still being processed or being moved. Decoupling stock is the inventory between dependent processes to reduce the requirement for synchronized operations. Psychic stock is inventory displayed in retail to stimulate demand and function as a silent salesperson.

2.2.2 Inventory Management

Inventory management is a method that covers the planning, control, and replenishment of the inventory (Yeh, 2016). The main objective of inventory management is to keep the inventories at an optimal level, which means without stockouts and excesses. To achieve the optimal level of inventory, an effective inventory management is crucial to the performance of most organizations because it handles the flow of materials within the organization (Tersine, 1994). In inventory management, two mutually dependent objectives should be achieved, which are to have adequate inventories to fulfill demand and to minimize the inventory carrying cost (Kiisler, 2014). These two objectives often contradict each other due to the different nature of each objectives. Good inventory management can balance the stock availability with the cost of carrying inventory.

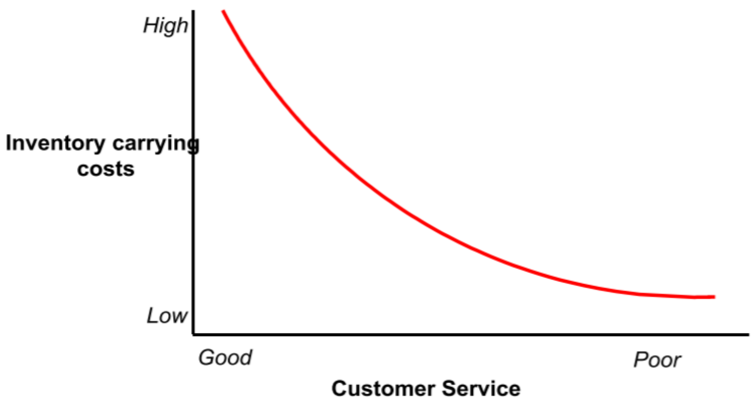

Figure 2. 1 Trade-offs Between Inventory Management Objectives
(Kiisler, 2014)

The objectives of inventory management are to reach the desired level of customer service, improve operating efficiency, and minimize inventory cost (Yeh, 2016). In customer service, it is defined as the ability of the company to fulfill the customer's demand. In the scope of inventory management, customer service is defined as the availability of items when required, and it is one of the aspects to measure inventory management effectiveness. There are many ways to measure customer service such as the percentage of line items shipped on schedule, the percentage of order shipped on schedule, and order days out of stock. The availability of inventory is to help maximize the customer service level by protecting against the uncertainty of demand and supply. In order to improve operating efficiency, inventories can help to establish a more productive manufacturing process because inventory allows production operations to operate at different rates to achieve economy. Inventory also allows manufacturing to execute longer production runs and to purchase in greater quantities, which result in lower setup and ordering cost. In inventory cost, it is the consequence of providing proper customer service and operational efficiency. There are cost that appears when the organization carries inventory. Therefore, the inventory cost must be minimized.

2.2.3 Inventory Cost Component

One of the objectives of inventory management is to have inventory at the right time, right place, and at the right amount with the lowest cost as possible. Inventory is associated with the cost acquired from the operation of the inventory system. According to Tersine (1994), there are four types of inventory costs which are purchase cost, order/setup cost, holding cost, and stockout cost.

1. Purchase cost

   Purchase cost is defined as the unit purchase price to acquire an item if the item comes from external sources, or the unit production cost if the item is acquired from an internal source. For purchased items, the cost consists of the purchase price added with any distribution cost. For manufactured items, the cost consists of direct labor, direct material, factory overhead, and any other cost related to production.

2. Order/setup cost

   Order/setup cost is defined as the cost to issue a purchase order to the outside supplier or from internal production. Order cost consists of making requisitions, vendor analysis, writing purchase orders, receiving materials, materials inspection, and other activities related to complete the transactions. Setup cost consists of cost acquired from changing the production process to produce the ordered items such as work scheduling, preproduction setup, expediting, and quality acceptance.

3. Holding Cost

   Holding cost or also known as carrying cost is defined as the cost related to investment for inventory and cost related to maintaining the physical investment in storage. It consists of capital costs, taxes, insurance, storage, shrinkage, and obsolescence. Usually, holding costs takes around 20%-40% of the inventory value.

4. Stockout cost

   Stockout cost is defined as the economic consequences of experiencing a shortage. Based on the source, there are two kinds of shortages which are internal and external shortage. An internal shortage occurs when order from inside the organization is not fulfilled while external shortage occurs when a customer's order is not fulfilled. Internal shortage can cause lost production, while external shortage can cause backorder costs and potential profit loss.

2.3 Inventory Classification Methods

Inventory classification is classifying the inventory product as per their demand, value, revenue, criticality, cost, and other (Orderhive, 2017). Inventory classification can aid a company to control its inventory by reducing the amount of stock on hand and by increasing the turnover ratio. There are several methods in classifying inventory, which are ABC, ADI-CV, FSN, and VED classification.

2.3.1 ABC Classification

Most companies carry a large variety of products in stock. It is preferable to classify the item according to the products' importance to have better inventory control at a reasonable cost (Arnold, et al., 2008). Usually, the importance is based on the money value, but other criteria can also be desirable. ABC classification principle is based on the observation at a small number of items that construct most of the results achieved in any situation. The observation was first conducted by an Italian economist called Vilfredo Pareto and the principle is often called Pareto's law. In ABC classification, the products are classified into three groups which are:

1. Group A : About 20% of items account for 80% of the money value.
2. Group B : About 30% of items account for 15% of the money value.
3. Group C : About 50% of items account for 5% of the money value.

The percentages are taken as an approximation and should not be taken as an absolute value. The steps in classifying the product using ABC classification is as follow:

1. Determine the annual usage of each product.
2. Multiply the annual usage of each product by its cost to get the annual money usage.
3. List the items according to their annual money usage.
4. Measure the cumulative annual money and the cumulative percentage of the product.
5. Evaluate the annual usage distribution and classify the products into A, B, and C group based on the percentage of annual usage

2.3.2 ADI-CV Classification

ADI (Average inter-Demand Interval) - CV (Coefficient of Variation) is a method to classify products according to the demand characteristics based on the inter-arrival of demand and the variation of the demand. The products are classified into four categories which are smooth, intermittent, erratic, and lumpy (Syntetos, 2001). The parameters to classify the product according to the demand pattern are ADI and CV with the formula as shown below.

$$ADI = \frac{Total\ Number\ of\ Periods}{Number\ of\ Demand\ Buckets}$$

$$ADI = \frac{\sum_{n=1}^{N_{pi}} t_i^n}{N_{pi}} \qquad (2.16)$$

$$CV = \frac{Standard\ Deviation\ of\ Population}{Average\ value\ of\ a\ Population}$$

$$CV = \frac{\sqrt{\frac{\sum_{n=1}^{N_{pi}}\left(d_i^n - d_i\right)^2}{N_{pi}}}}{d_i} \tag{2.17}$$

Where:

$$d_i = \frac{\sum_{n=1}^{N_{pi}} d_i^n}{N_{pi}} \tag{2.18}$$

Using ADI-CV classification the products are classified into four categories, which are smooth, intermittent, erratic, and lumpy.

1. Smooth (ADI < 1.32 and $CV^2 < 0.49$)
   Smooth demand has a very regular demand in terms of time and quantity. It is easy to forecast and can generate a low forecast error.
2. Intermittent (ADI ≥ 1.32 and $CV^2 < 0.49$)
   Intermittent demand shows very little variation in demand but high variation in the interval between demands. The forecast error is considerably higher than the smooth demand.
3. Erratic (ADI < 1.32 and $CV^2 \geq 0.49$)
   Erratic demand shows regular occurrences of demand but high variations in the quantity. The forecast accuracy remains shaky in this type of pattern.
4. Lumpy (ADI ≥ 1.32 and $CV^2 \geq 0.49$)
   Lumpy demand shows a large variation in quantity and time. The forecast error is high compared to the other pattern of demand.

2.3.3 FSN (Fast Moving, Slow Moving, Non-Moving)

In this classification, inventory is grouped into three different categories, which are fast-moving, slow-moving, and non-moving products. This analysis considers the quantity, consumption rate, and how often the product is issued and used (Chan, 2018). Using FSN analysis can be beneficial because it can show which products are active in the inventory. The active products that are fast-moving need to be reviewed on a regular basis. This helps to make smarter supply or production decisions and keep inventory conform to demand. This analysis also shows which products are no longer necessary to keep in stock. Therefore, FSN analysis can give information on which product that should have priority in the warehouse and which product that doesn't need to be stored. However, this analysis can be inaccurate depending on the fluctuations in demand. In one period, a particular product can be very popular classified as fast-moving, but then it can be turned into a non-moving product in another period of time, causing an error in inventory control strategies.

2.3.4 VED Analysis

VED (Vital, Essential, and Desirable) is an inventory classification that is dependent on the user's experience and perception. It is a classification based on the importance or criticality of the part towards the operation (Brindha, 2014). It takes a more qualitative approach that is able to consider crucial factors, which are nuisance value, or how much it will cost to the organization if a particular product is not in stock. Therefore, the analysis encourages the organization to classify inventory into three groups, which are vital products, essential products, and desirable products. Vital products are considered critical to keep the organization running. Essential products are items that are needed in the organization, and without it, the quality, speed, or cost of service will be damaged. Desirable products are items that without it the organization can still run normally but may incur minor costs or short-term disruption.

2.4 Inventory Control Model

In inventory control, there is two major models that illustrates the concept of inventory control. According to Tersine (1994), the models are deterministic and probabilistic model.

2.4.1 Deterministic Model

Deterministic model has characteristics such as all the parameters and variables are known and can be calculated with certainty (Tersine, 1994). It is assumed that the rate of demand and inventory costs are known with assurance. The lead time is also assumed to be constant and independent of demand. Since all parameters are assumed to be known, the same number of products are ordered and the lead time between orders is expected not to vary significantly.

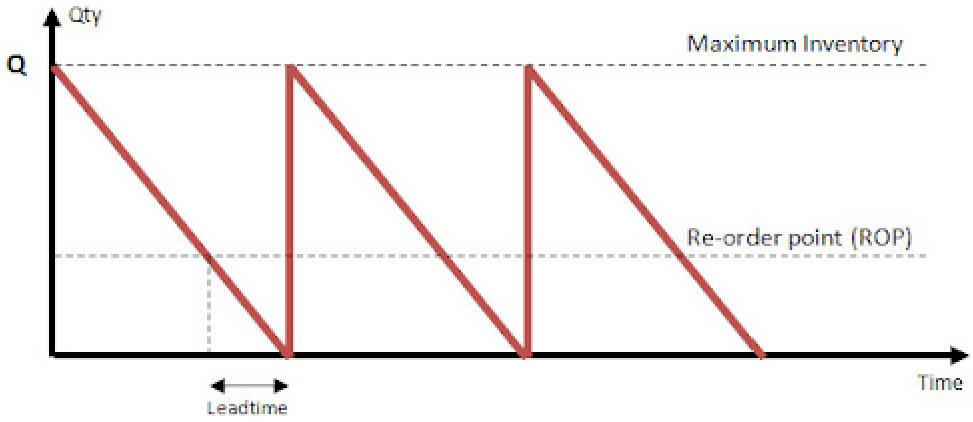

Figure 2. 2 Classic Inventory Model
(Tersine, 1994)

In the deterministic model, the order size that gives the minimum value of inventory cost is known as the economic order quantity (EOQ). The classical inventory model assumed the ideal condition as shown in Figure 2.2. If stockouts are not allowed, the total inventory cost is visualized by figure 2.3 and calculated using the following formula:

$$Total\ Annual\ Cost = Purchase\ Cost + Order\ Cost + Holding\ Cost$$

$$TC(Q) = PR + \frac{CR}{Q} + \frac{HQ}{2} \quad (2.19)$$

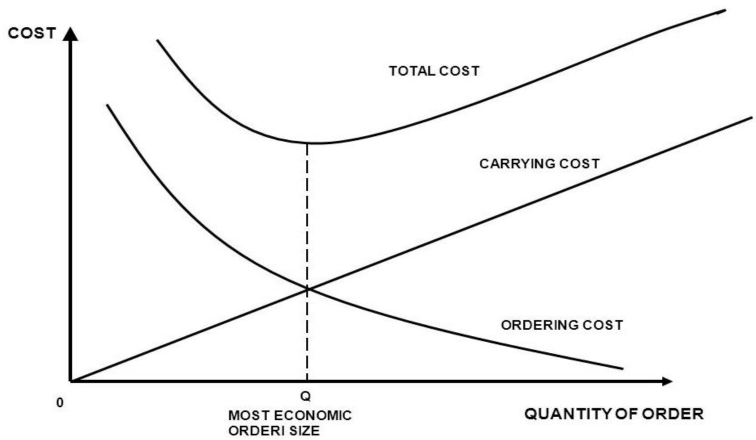

Figure 2. 3 Inventory Cost Curve
(Tersine, 1994)

In order to obtain the optimal order size that gives the minimum inventory cost, economic order quantity is used. Economic order quantity is calculated using the following formula:

$$EOQ = \sqrt{\frac{2CR}{PF}} \tag{2.20}$$

To calculate the order interval and reorder point, the formula below is used.

$$Order\ Interval = T = \sqrt{\frac{2C}{HR}} \tag{2.21}$$

$$Reorder\ Point = B = \frac{RL}{12} \tag{2.22}$$

Description:

R = Annual demand in units

P = Purchase cost of an item

C = Ordering cost per order

H = PF = Holding cost per unit per year

Q = Lot size or order quantity in units

F = Annual holding cost as a fraction of unit cost

2.4.2 Probabilistic Model

Probabilistic models have characteristics that demand and lead time are treated as random variables (Tersine, 1994). The availability of inventory in this model can be categorized as working stock and safety stock, where working stock is expected to be used during a given period while safety stock is stored because of the probability that it might be used. The availability of safety stocks is necessary because of the existence of risk and uncertainty in the model, therefore it can work as a cushion against the uncertainty of the environment. Probabilistic model is seen as more representative to models the real-life than deterministic model, because in reality, the pattern of demand over time will be irregular and discrete. There could be a possibility when the demand during lead time is so great that it causes stockout or when the demand during lead time is not as what is expected which causes excessive stock in the warehouse. The visualization of the realistic inventory model is shown in Figure 2.4.

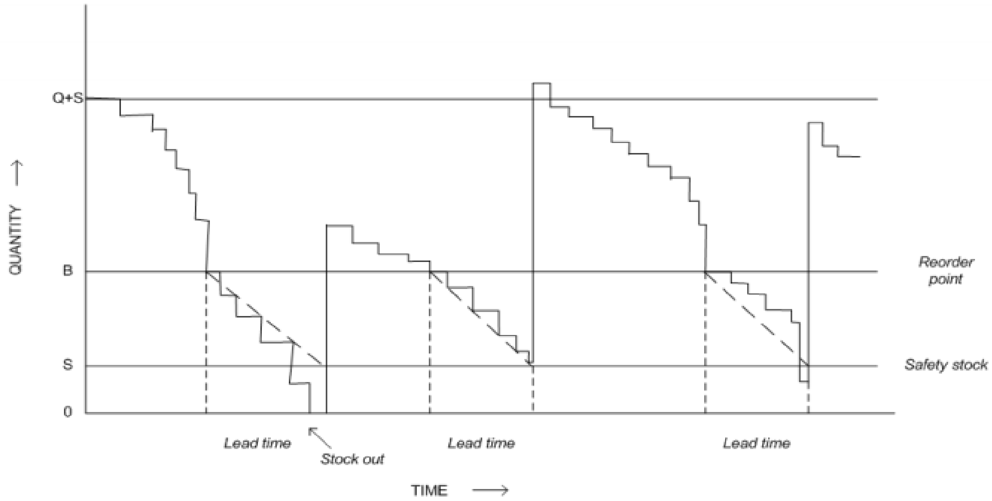

Figure 2. 4 Realistic Inventory Model
(Tersine, 1994)

According to Silver (2016), probabilistic inventory control is classified into two systems which are continuous review and periodic review system.

1. Periodic Review

In periodic review, the quantity on hand of a particular product is observed at specified time intervals, and the amount of replenishment is ordered (Arnold, et al., 2008). Between the reviewing interval, there may be uncertainties in the value of the stock level. In some cases, periodic review is appealing because all items from the same group can be given a similar review interval (ex: items from a particular supplier will be reviewed every Monday). Periodic review also gives a reasonable prediction of the involved staff's workload. There are two systems in periodic review which are (*R, S*) system and (*R, s, S*) system.

a. (R, S) System

The (R, S) system is also known as the replenishment cycle system. The system procedure is that every review interval (*R*) the replenishment is ordered to achieve the inventory position to the level *S* (Silver, et al., 2016).

This system offers regular opportunity (Every *R* period) to adjust the order level (*S*). The disadvantages of this system are that the replenishment amount varies and the carrying cost will be higher than continuous review systems. The steps in conducting the periodic review *(R, S)* according to Smith (1989) are as follows:

$$t^* = \sqrt{\frac{2k}{rh}} \qquad (2.23)$$

$$F_{L+tp}(K^*) = \frac{\pi - ht_p}{\pi} \qquad (2.24)$$

$$S = \mu_{L+tp} + K\sigma_{L+tp} \qquad (2.25)$$

Description

t* = Order cycle

r = Amount of demand

k = Order cost

h = Holding cost

π = Shortage cost

K = Safety factor

σ = Standard deviation of demand

μ = Average demand

L = Lead time

b. (*R, s, S*) System

The (R, s, S) system is a combination of the (*s, S*) and (*R, S*) system. The system procedure is that every *R* units of time the inventory position is checked (Silver, et al., 2016). If the inventory position is below the reorder point (*s*) then replenishment is done to the level *S,* and if the inventory position is above *s* then nothing is done until the next period of review. This system can produce a lower total of carrying, replenishment, and shortage cost than any system. However, the computational effort is more intense than the other system. The steps in conducting the periodic review *(R, s, S)* according to Smith (1989) are as follows:

$$q_w = \sqrt{\frac{2kr}{h}} \tag{2.26}$$

$$F_{L+W}(K) = \frac{\pi r - hq}{\pi r} \tag{2.27}$$

$$SS = K \times \sigma_{L+W} \tag{2.28}$$

$$s = \mu_{L+w} + SS + \frac{rw}{2} \tag{2.29}$$

$$S = q_w + s - \frac{rw}{2} \tag{2.30}$$

Description:

q_w = order quantity

r = Amount of Demand

k = Order cost

h = Holding cost

π = Shortage cost

K = Safety factor

σ = Standard deviation of demand

μ = Average demand

L = Lead time

2. Continuous Review

In continuous review, the quantity on hand of a product is calculated every time the product moves in or moves out from the system. The advantages of using the continuous review system are that to provide the same level of customer service with periodic review requires less level of safety stock therefore requires lower carrying costs. However, the reviewing cost will be higher than periodic review, and the number of workforces can change anytime because it depends on the material requirement (Chopra & Meindl, 2016). There are two systems in continuous review which are (*s*, *Q*) system and (*s*, *S*) system.

a. (*s*, *Q*) System

In this system, a fixed quantity *Q* is ordered every time the inventory position drops until the reorder point *s* or lower. This system is often called as a two-bin system because it is similar by having two bins for storage of items (Silver, et al., 2016). As long as units filled the first bin, demand is able to be satisfied. The second bin represents the order point. When the second bin is opened, replenishment is triggered. The advantages of the system are that it is quite simple and the production requirement for the supplier is predictable. The disadvantage of the system is that it may not be able to be implemented effectively if the individual transactions are large. The steps in conducting the continuous review *(s, Q)* according to Smith (1989) are as follows:

1. Calculate the value of q & q_w

   $$q = q_w = \sqrt{\frac{2kr}{h}} \tag{2.37}$$

2. Calculate F(K)

   $$F(K) = \frac{\pi r - hq}{\pi r} \tag{2.38}$$

3. Calculate the value of K from the safety factor table.
4. Calculate N_k

   $$N_k = \sigma_L \times E(K) \tag{2.39}$$

5. Calculate the new q

   $$q = \sqrt{\frac{2r(k + \pi N_k)}{h}} \tag{2.40}$$

   If $|q_{new} - q_{old}| < \varepsilon$ calculate $s = \mu + K\sigma_L$ and finish the iteration. If not iterate from step 2.

Description:

q = order quantity

r = Amount of Demand

k = Order cost

h = Holding cost

π = Shortage cost

K = Safety factor

σ = Standard deviation of demand

μ = Average demand

L = Lead time

b. (*s*, *S*) System

In this system, a variable replenishment quantity is ordered to raise the inventory position up to level *S* every time the inventory position drops until the reorder point *s* or lower (Silver, et al., 2016). This system is similar to the min-max system because the inventory position is always between the minimum value of *s* and maximum value of *S*. the advantage of the system is that it can generate a lower total cost of replenishment, carrying inventory, and shortage than the (*s*, *Q*) system. Nevertheless, the computational effort is substantially greater than the (*s*, *Q*) system. The disadvantage of the system is the variable order quantity that can cause errors more frequently. The steps in conducting the continuous review *(s*, *S)* are as follows:

$$q = \sqrt{\frac{2kr}{h}} \quad (2.41)$$

$$F'(K) = \frac{q}{r} \quad (2.42)$$

$$s = \mu + K\sigma_L \quad (2.43)$$

$$S = q + s \quad (2.44)$$

Description:

q = order quantity

r = Amount of Demand

k = Order cost

h = Holding cost

π = Shortage cost

K = Safety factor

σ_L = Standard deviation of demand during lead time

μ = Average demand

L = Lead time

s = Order point

2.5 Monte Carlo Simulation in Inventory Management

Monte Carlo simulation is a probabilistic simulation that estimates the solution to a problem by sampling from a random process (Tersine, 1994). This method is widely used in inventory management scope. Several final projects, thesis, national journals, and international journals use Monte Carlo simulation as a method to generate a large amount of numbers to obtain numerical results. Several work of literature that implement Monte Carlo simulation in inventory management are Solikhah (2017), Ardiansyah (2018), Widyadana et al.2017), and Leepaiton et al. (2019).

This method involves the probability distribution of the studied variable, which will then randomly take a sample from the distribution to obtain data. The number of random numbers is used to describe the movement of each random variable over a certain period and allow for an artificial but realistic sequence of events to take place. Monte Carlo simulation allows the company to determine the level of variety for policies or organizational conditions that will be affected by the behavior of random influences. This simulation establishes a stochastic model of an existing situation and then undergo sampling experiments on the model. The steps to perform Monte Carlo simulation are as follows:

1. Determine the known probability distributions of particular key variables.
2. Change the frequency distributions to cumulative probability distributions so the variable value will be associated with the random number.
3. Sample randomly from the cumulative probability distributions to determine the value of certain variables to be used in the simulation.
4. Perform simulation to the operation under analysis for a large number of observations

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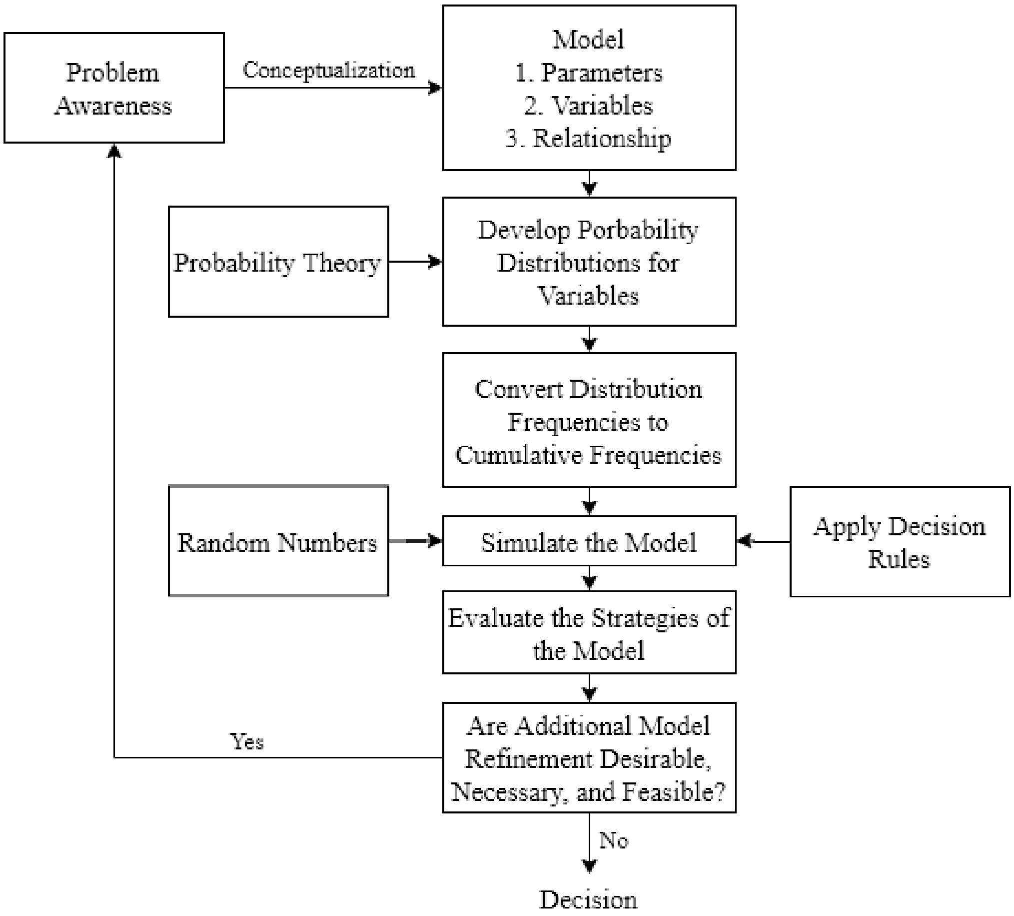

Figure 2. 5 Monte Carlo Simulation
(Tersine, 1994)

In doing Monte Carlo Simulation, several actions such as determining the number of replications is required in order to test whether the simulation is adequate to give information. The formula used to measure the required number of replications are as follow:

$$hw = t_{\frac{\alpha}{2},n,1} \times \frac{s}{\sqrt{n}} \tag{2.45}$$

If the half-width that is obtained is adequate, the first number of replications is used. However, if it is still not adequate further calculation of the number of replications is required using the formula as follow:

$$n' = \left[\frac{t_{\frac{\alpha}{2},n-1}\,s}{hw'}\right]^2 \tag{2.46}$$

2.6 Previous Research

There are many researches in the inventory management field that have been conducted before. In the research that was conducted by Solikhah (2017) with the title of "Determining of Fertilizer Supplies and Inventory Policy with Continuous Review *(s, S)* System Approach and Monte Carlo Simulation" describes the formulation of inventory control policy to provide a certain level of service level. The object that is observed is fertilizer that is produced and stored by the company. The method used by the author is continuous review *(s, S)* method with the combination of Monte Carlo simulation to obtain the optimal reorder point (ROP) and maximum stock (*S*) that generate a low inventory level with considering the service level provided by the company.

Research conducted by Prarayendra (2019) with the title of "Design of Demand Forecasting Method and Determination of Inventory Control Policy in Ship Maintenance Services using Monte Carlo Simulation" describes the formulation of accurate forecasting method and inventory control policy, especially for lumpy demand. The methods used by the author are ABC analysis and ADI-CV to classify the product according to its characteristics, Croston's and SBA method to forecast the lumpy demand, and continuous review *(s, S)* and continuous review *(s, S)* for lumpy demand with the combination of Monte Carlo simulation to obtain the optimal service level with the lowest total cost.

Research conducted Pan & Hui (2017) with the title of "Inventory Control System for a Healthcare Apparel Service Centre with Stockout Risk: A Case Analysis" describes the formulation of inventory control policy to minimize the inventory cost and achieve low stockout risk under capacity constraint. The method used by the author is the continuous review *(Q, r)* method. From the research, it is obtained that the expected total cost on an order cycle is reduced around 20% by using the method proposed in the research.

Research conducted by Caessarramzy et al. (2017) with the title of "Usulan Kebijakan Persediaan Produk Kategori Suplemen dan Kebutuhan Harian di BM PT XYZ untuk Mengurangi Total Biaya Persediaan Mengginuakan Metode Periodic Review (R, s, S)" describes the formulation of inventory control policy to minimize the total cost. The object that is observed is medicine that are supplied by the company. The method used by the authors is periodic review *(R, s, S)* with the combination of Monte Carlo simulation to obtain the optimal policy's parameter which are reviewing period (R), reorder point (s), and maximum stock (S) that generate the lowest inventory cost compared to the existing system. The result of the research is cost savings up to 47% from the actual condition.

Research conducted by Hidayat (2012) with the title of "Material Inventory Control Approach to Continuous Review *(s, S)* (Case Study: PT PLN Persero APJ Gresik)" describes the optimization of consumable goods inventory parameters such as s and S to fulfill the service level with minimum cost. The method used by the author is the continuous review (s, S) method complemented with Monte Carlo simulation to obtain the optimal value of the parameters. From the research, it is obtained that the total cost from the analyzed material is reduced by around 1.01%, and the service level increased around 3.10%.

Research conducted by Tirkeş et al. (2017) with the title of "Demand Forecasting: A Comparison Between the Holt-Winter's, Trend Analysis, and Decomposition Models" describes about the optimization of forecasting models in the food industry. This research aims to compare the performance between trend analysis, Holt-Winter method, and decomposition method in forecasting future demand. From the research, it is shown that Holt-Winter Method and decomposition method is successful to forecast data with trend, seasonal, and cyclic behavior while trend analysis is only successful for data with only trend behavior.

The comparison with the previous research is shown in Table 2.1. This final project is the development from the previous research with the object is HDPE pipes. Several methods are used in this final project. The methods to classify the products are ABC analysis and ADI-CV. Method to forecast the demand are time series forecast, Croston's method and SBA. The method for inventory control policy is periodic review system and continuous review system with the combination of Monte Carlo simulation to obtain the optimal service level and minimize total cost.

Table 3. 1 Previous Research

No	Author	Object	Classification	Forecasting Method	Inventory Control Model	Inventory Control Policy	Simulation
1	Solikhah (2017)	Fertilizer	-	-	Probabilistic	Continuous review (s, S)	Monte Carlo
2	Prarayendra (2019)	Spare part	ABC and ADI-CV	Croston's method and Syntetos Boylan Approximation	Probabilistic	Continuous review (s, S) and (s, S) for lumpy demand	Monte Carlo
3	Pan & Hui (2017)	Healthcare apparel	-	-	Probabilistic	Continuous review (Q, r)	-
4	Caesarramzy et. al. (2017)	Medicine	ADI-CV	-	Probabilistic	Periodic review (R, s, S)	Monte Carlo
5	Hidayat (2012)	Consumable goods	ADI-CV	-	Probabilistic	Continuous review (s, S)	Monte Carlo
6	Tirkeş et al. (2017)	Food and Beverage Industry	-	Trend Analysis, Decomposition, Holt-Winter's	-	-	-
7	This Research	HDPE pipe	ABC and ADI-CV	Time Series Forecast, Croston's method and Syntetos Boylan Approximation	Probabilistic	Continuous review (s, Q) and (s, S); Periodic review (R, s, S) and (R, S)	Monte Carlo

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CHAPTER 3
RESEARCH METHODOLOGY

This chapter explains about the systematical procedure that is used in this final project. The final project consists of several steps which are data collection stage, data processing stage, and analysis and interpretation stage. The project steps are defined in the following sections as illustrated in Figure 3.1.

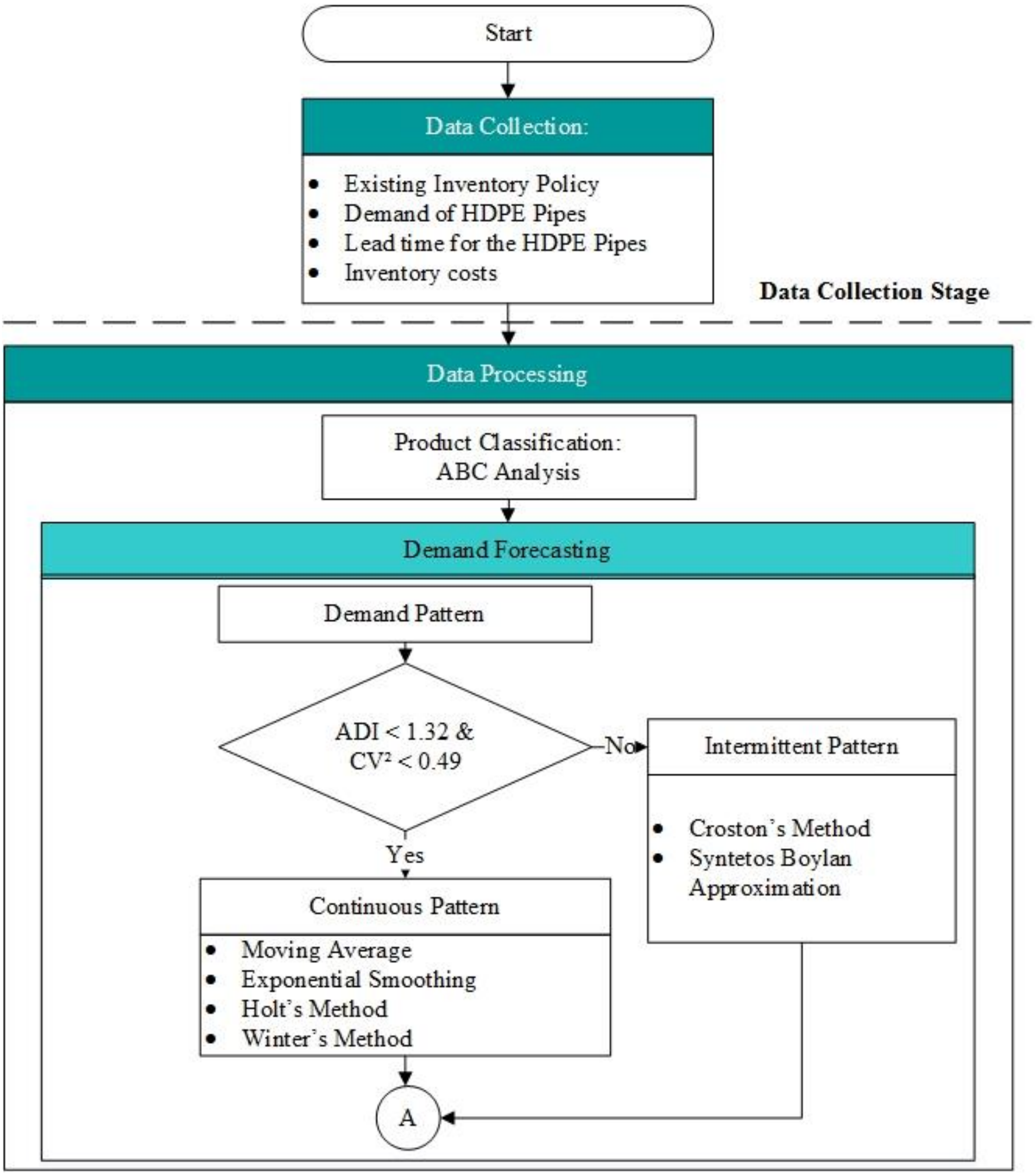

Figure 3. 1 Research Methodology

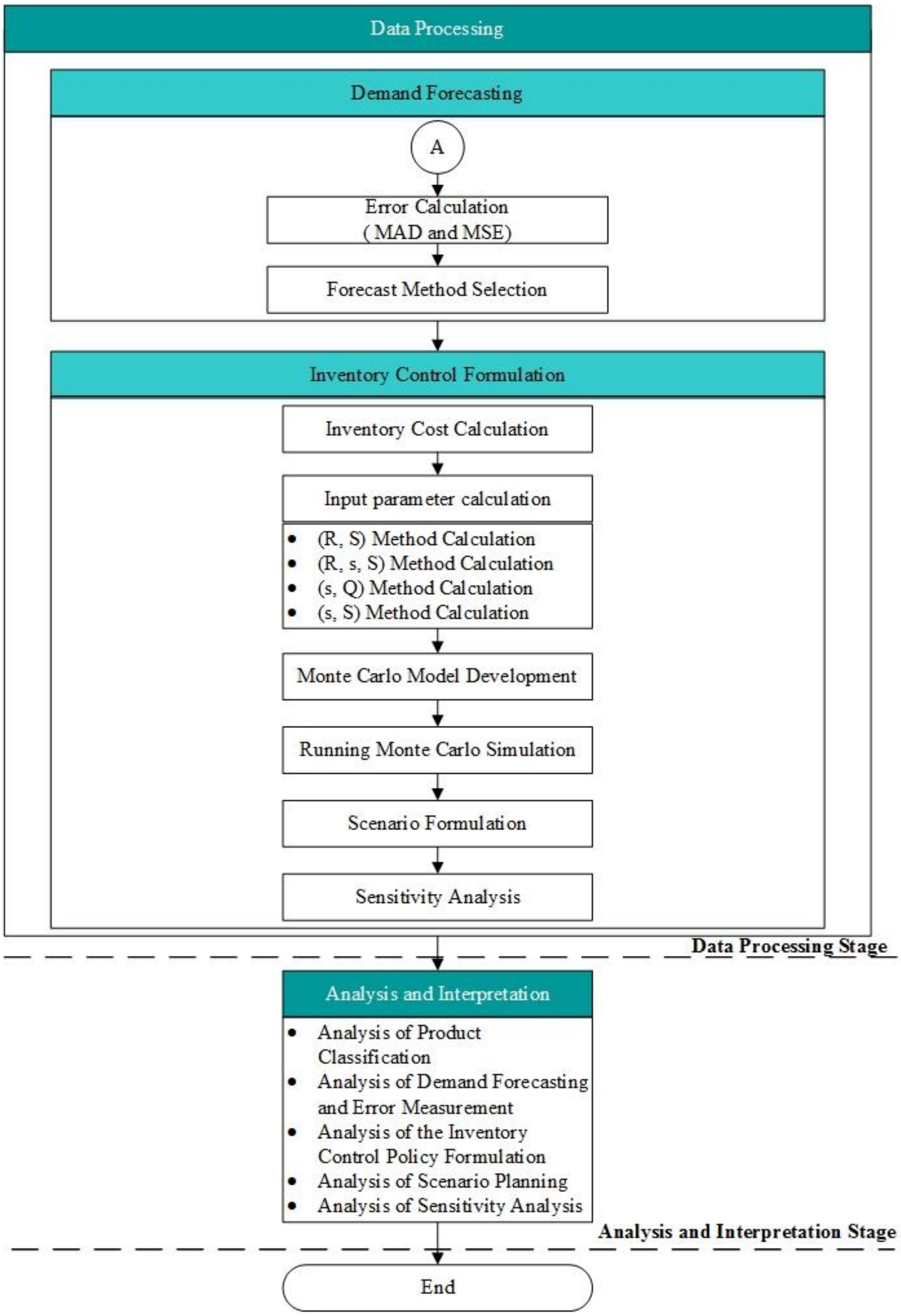

Figure 3. 1 Research Methodology (Con't)

3.1 Data Collection Stage

In this stage, the collection of the required and related data with the object is conducted. To understand more on the related data, field study is conducted by doing direct observation in the company. It is intended to obtain the existing condition of the demand forecasting and inventory management in PT. Maspion Unit-II. Literature review is also gathered to understand more on the existing condition and related data by using the available theories.

The data that are collected consists of primary data that are obtained from field study and interview with the stakeholders and secondary data that are obtained from the historical data of the company and other data that supports the problem-solving framework in the final project. The collected data for the final project are as follow:

1. HDPE pipes product specification and description.
2. Demand of HDPE pipes from 2017 to 2019.
3. Inventory related costs such as holding cost, setup cost, and stockout cost.
4. Lead time for HDPE pipes.

3.2 Data Processing Stage

The collected data that are obtained from the previous stage are then processed so it can be a useful information to the company. the steps for data processing are as follows.

3.2.1 Product Classification

The classification of the product in this final project is conducted using ABC analysis and ADI-CV^2 analysis. In this analysis, the items are classified based on the money value of the items towards the company. The items are classified into three different categories which are class A, class B, and class C items. ABC analysis is used to help directing response of the management in managing the items based on the importance. After the items are classified using ABC analysis, the items are classified again in accordance with the demand pattern using ADI-CV^2. In ADI-CV^2 the demand is classified into four characteristics which are continuous, lumpy, erratic, or intermittent. ADI-CV^2 analysis is conducted due to the different pattern that the data exhibited that requires different treatment.

3.2.2 Demand Forecasting and Forecast Error Calculation

After the products are classified, the demand is forecasted using the time series forecast, Croston's method, and Sythetos Boylan Approximation. Time series forecast consists of moving average, exponential smoothing, Holt's, and Winter's. Before the forecast is calculated, the trend is analyzed using trend analysis in Minitab Software. Time series forecast is better used in a continuous demand pattern, while Croston's method and Synthetos Boylan Approximation are better used in an intermittent demand pattern. The accuracy of the forecasts is compared using the value of forecast error. Forecast error is measured using MAD and MSE with the most accurate forecast generate the lowest value of error.

3.2.3 Inventory Control Policy Formulation

In this stage, the inventory control policy parameters are formulated. The calculation requires the calculation of inventory costs such as setup cost, holding cost, and stockout cost. After the inventory costs are obtained, the value of the parameters is calculated using the formula mentioned in chapter two. The inventory control policy that are used are periodic review and continuous review that consists of *(R, S)* system, *(R, s, S)* system, *(s, Q)* system, and *(s, S)* system. In periodic review (*R, S),* the parameters that are searched are the maximum level of inventory *(S)* and the optimal reviewing period *(R).* In periodic review *(R, s, S),* the parameters that are searched are the reorder point (*s*) and maximum level of inventory (*S*) with a certain reviewing period (*R*). In continuous review *(s, Q),* the parameters that are searched are the reorder point *(s)* and the optimal order quantity *(Q).* In continuous review *(s, S),* the parameters that are searched are the reorder point *(s)* and the maximum level of inventory *(S).* The parameters are then used as input for the simulation.

3.2.4 Monte Carlo Simulation Formulation

The formulation of the Monte Carlo Simulation using Microsoft Excel to generate random number that corresponds with the existing distribution in order to simulate the performance of the inventory control policy. Monte Carlo simulation is conducted in order to be able to capture the random probability in the data. The simulation is used to measure the effectiveness of the inventory control policy if faced with random data that follows a specific distribution pattern. The model element in the simulation are initial inventory, incoming order, available inventory, demand, fulfilled demand, ending inventory, stockout, review period, order decision, lead time, order release, order receipt, order arrival period, fill rate, and total cost. The simulation is based on the input from the inventory control policy parameters obtained from the previous calculation. Scenarios are also formulated to obtain the most optimal parameters. Scenarios are conducted by changing the value of the inventory control policy parameters. After scenarios are conducted, sensitivity analysis is performed to understand the impact of changing the independent variables towards the performance of the inventory control policy.

3.3 Analysis and Interpretation

In this stage, the result of the data processing from the previous chapter is analyzed and interpreted. Analysis and interpretation of the information is used to gather knowledge from doing this final project. The analysis that are conducted are analysis of product classification, analysis of demand forecasting and error measurement, analysis of the inventory control policy formulation, analysis of scenario planning, and analysis of sensitivity analysis. After the information is analyzed, the conclusion from this final project is drawn.

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CHAPTER 4
DATA COLLECTION AND PROCESSING

This chapter explains about the data collection that is required in this research and data processing. collected data are processed using the methodology explained from the previous chapter.

4.1 Data Collection

This sub-chapter explains about the data collection required in this final project in accordance with the previous chapter. The collected data are the demand of HDPE pipes, unit cost, and lead time of HDPE pipes.

The demand of HDPE pipes data is for 3 years that ranged from January 2017 until December 2019. The HDPE pipes that are observed are 36 types of HDPE pipes with different diameters and standards. Each of the items have different values and characteristics of pattern and this data is used for the input in the next sub-chapter. Detail information of the demand data is shown in Attachment A and the sample of demand data can be seen in the Table 4.1.

Table 4. 1 Demand of HDPE Pipes

No	Item	Month						Total (m)
		1	2	3	4	…	36	
1	110SDR17	1250	2000	525	2750	…	5800	139641
2	160SDR17	556	0	1090	0	…	0	23238
3	20SDR11	44525	51250	78512	64315	…	32576	2134130
4	20SDR13.6	14250	18025	11240	15510	…	30025	718179
5	25SDR11	4225	5005	6225	4910	…	7250	229191
6	25SDR13.6	1995	2105	2450	2300	…	4250	105000
7	32SDR11	25110	21450	21100	28550	…	21756	653733
8	32SDR13.6	1000	1250	1450	1800	…	2000	76150
9	75SDR11	375	380	0	0	…	0	8710
10	90SDR11	2850	2450	3005	0	…	2200	47965
…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…
36	40SDR17	1100	1350	1210	0	…	3850	47200

The unit cost and lead-time are from the observed 36 types of HDPE pipes. Each of the items have different values of unit cost ranging from Rp5,360 as the lowest cost of pipe per meter until Rp517,250 as the highest cost of pipe per meter. This is caused by the different specifications required for each meter of pipe. While for the lead time for each product have an average of 2 weeks. Detail information of the unit cost and lead time is shown in Attachment B and the sample of unit cost can be seen in the Table 4. 2.

Table 4. 2 Sample of Unit Cost

No	Item	Unit Cost
1	110SDR17	Rp108,010.00
2	160SDR17	Rp226,010.00
3	200SDR17	Rp351,870.00
4	90SDR17	Rp 72,250.00
5	63SDR17	Rp 35,860.00
6	20SDR17	Rp 5,360.00
7	25SDR11	Rp 8,550.00
8	25SDR13.6	Rp 6,323.00
9	32SDR11	Rp 13,780.00
10	25SDR17	Rp 7,610.00

4.2 Classification of HDPE Pipes

This sub-chapter explains about the classification of HDPE pipes. The products are classified to give insight on handling different characteristics of products. The classification is conducted using ABC analysis and ADI-CV analysis.

4.2.1 ABC Analysis

ABC analysis is classifying the item according to the importance of the item towards the company. The objectives of this analysis are to help the company to focus on the important item that contributes the most for the company. It can give insight on the decision for prioritizing efforts and resources of the items. The example of ABC analysis calculation for 20SDR17 is shown below.

1. %Value

$$\%Value = \frac{Demand \times Unit\ Cost}{Total\ Value}$$

$$\%Value = \frac{3,506,053 \times 5,360}{151,223,038,561}$$

$$\%Value = 12.43\%$$

2. Unit Fraction

$$Unit\ Fraction = \frac{1}{Number\ of\ Item}$$

$$Unit\ Fraction = \frac{1}{36}$$

$$Unit\ Fraction = 0.028$$

The recapitulation of HDPE pipes classification using ABC analysis is shown in the Table 4. 3.

Table 4. 3 ABC Classification of HDPE Pipes

No	Item	Value	%Value	Cum. Unit Fraction	Cum. Value	Class
1	20SDR17	Rp18,792,444,080	12.427%	0.028	0.1243	A
2	110SDR17	Rp15,082,624,410	9.974%	0.028	0.2240	A
3	63SDR17	Rp13,481,244,260	8.915%	0.028	0.3132	A
4	25SDR17	Rp12,641,009,050	8.359%	0.111	0.3967	A
5	20SDR11	Rp12,143,307,600	8.030%	0.139	0.4770	A
…	…	…	…	…	…	…
8	90SDR17	Rp9,908,943,000	6.553%	0.222	0.6755	B
9	50SDR11	Rp7,173,600,000	4.744%	0.250	0.7229	B
10	200SDR17	Rp5,391,879,945	3.566%	0.278	0.7586	B
11	63SDR11	Rp5,321,833,440	3.519%	0.306	0.7938	B
12	160SDR17	Rp5,252,020,380	3.473%	0.333	0.8285	B
…	…	…	…	…	…	…
19	50SDR17	Rp1,505,533,120	0.996%	0.528	0.9611	C
20	110SDR11	Rp1,092,133,900	0.722%	0.556	0.9683	C
21	25SDR13.6	Rp754,333,900	0.499%	0.583	0.9733	C

Table 4. 3 ABC Classification of HDPE Pipes (Con't)

No	Item	Value	%Value	Cum. Unit Fraction	Cum. Value	Class
22	40SDR17	Rp691,952,000	0.458%	0.611	0.9779	C
23	75SDR11	Rp638,007,500	0.422%	0.639	0.9821	C
…	…	…	…	…	…	…
36	125SDR17	Rp10,924,875	0.007%	1.000	1.0000	C

4.2.2 ADI-CV Analysis

ADI-CV analysis is classifying the item according to the pattern of the data. The objectives of this analysis are to determine the pattern of the demand so the company can implement an appropriate strategy in managing the products. To conduct ADI-CV analysis, the average inter-demand arrival (ADI) and coefficient of variation (CV) must be calculated. The example of ADI and CV calculation for 160SDR17 is shown below.

1. ADI

$$ADI = \frac{Total\ Number\ of\ Periods}{Number\ of\ Demand\ Buckets}$$

$$ADI = \frac{36}{26} = 1.38$$

2. CV^2

$$CV = \frac{Standard\ Deviation\ of\ Population}{Average\ value\ of\ a\ Population}$$

$$CV^2 = \left(\frac{260}{893}\right)^2 = 0.085$$

Because the value of ADI > 1.32 and the value of $CV^2 < 0.49$, then 160SDR17 is classified to have an intermittent pattern. The recapitulation of the ADI-CV analysis is shown in the Table 4. 4.

Table 4. 4 ADI-CV Classification of HDPE Pipes

No	Item	ADI	CV	Classification
1	110SDR17	1	0.188037	smooth
2	160SDR17	1.384615	0.085193	intermittent
3	200SDR17	1.5	0.289309	intermittent
4	20SDR11	1	0.070409	smooth
5	20SDR13.6	1	0.118536	smooth
6	20SDR17	1	0.048747	smooth
7	25SDR11	1	0.047184	smooth
8	25SDR13.6	1	0.049977	smooth
9	32SDR11	1	0.143765	smooth
10	25SDR17	1	0.023698	smooth
11	32SDR13.6	1	0.095497	smooth
12	32SDR17	1	0.305765	smooth
13	40SDR17	1.636364	0.114736	intermittent
14	50SDR11	1	0.115171	smooth
15	50SDR17	1.44	0.390174	intermittent
16	63SDR11	1	0.302619	smooth
17	63SDR17	1	0.136143	smooth
18	63SDR21	1	0.046491	smooth
19	75SDR11	1.8	0.015645	intermittent
20	90SDR11	1.894737	0.038484	intermittent
21	90SDR17	1	0.063067	smooth
22	90SDR21	1.894737	0.155802	intermittent
23	200SDR11	2.117647	0.049736	intermittent
24	110SDR11	2.25	0.021875	intermittent
25	250SDR17	2.4	0.110003	intermittent
26	40SDR11	1	0.181768	smooth
27	40SDR13.6	1	0.075238	smooth
28	50SDR13.6	1	0.111199	smooth
29	60SDR17	1	1	smooth
30	63SDR13.6	1.44	1.44	intermittent
31	110SDR13.6	6	6	intermittent
32	125SDR11	9	9	intermittent
33	125SDR17	9	9	intermittent
34	125SDR21	12	0.067867	intermittent
35	160SDR11	4.5	0.116959	intermittent
36	160SDR13.6	6	0.358015	intermittent

4.3 HDPE Pipes Demand Forecasting

This sub-chapter explains about the comparison between forecasting methods that can give the most accurate result. Forecasting is used to predict the upcoming event using historical data. Forecasting methods generate error and forecast with the lowest error are chosen as a recommendation. The first step in forecast is to estimates the level and trend. After level and trend is plotted, the calculation of forecast can be conducted and finally the error of the forecast is calculated. If there is a trend in the data, method such as moving average and exponentially smoothing is not used because these methods are unable to follow the trend of the data. The Identification of trend in this research is conducted using trend analysis in Minitab Software. The example of trend identification in item 20SDR11 is shown in Figure 4. 1.

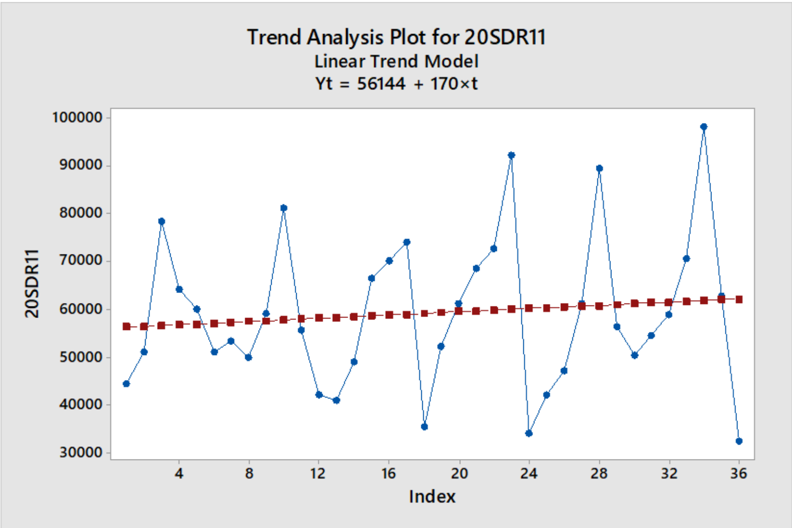

Figure 4. 1 Trend Analysis in 20SDR11

The value of level for 20SDR11 is 56,144 and the value of the trend is 170. It is shown that the trend in this data is not significantly visible, therefore all of the forecasting methods is calculated. The example of forecast calculation in smooth data pattern in item 20SDR11 is shown below. The α, β, γ that are used in the calculation are obtained from optimization using Excel data solver.

1. Moving Average

$$\widehat{D}_t = \frac{\sum_{i=1}^{n} D_{t-1}}{n}$$

$$\widehat{D}_4 = \frac{44{,}525 + 51{,}250 + 78{,}512}{3} = 58{,}095$$

2. Exponential Smoothing

$$\widehat{D}_t = \alpha D_{t-1} + (1-\alpha)\widehat{D}_{t-1}$$

$\widehat{D}_4 = 0.07\ x\ 78{,}512 + (1 - 0.07)\ x\ 45{,}012 = 47{,}439$

3. Holt's Method

$\widehat{D}_{t+T} = (S_t + \tau G_t)$

$\widehat{D}_4 = (56{,}701 + 1\ x\ 170) = 56{,}871$

4. Winter's Method

$\widehat{D}_{t+T} = (S_t + \tau G_t)(c_{t+1})$

$\widehat{D}_4 = (56{,}314 + 1\ x\ 209)(1.26) = 71512$

The recapitulation of the forecast calculation for 20SDR11 is shown in Table 4. 5.

Table 4. 5 Recapitulation of 20SDR11 Forecast Calculation

Period	Actual Demand	Existing Forecast	MA	ES	Holt	Winter
Jan-17	44,525	42,250	-	44,525	56,314	40,858
Feb-17	51,250	45,554	-	44,525	56,364	47,260
Mar-17	78,512	65,000	-	45,012	56,481	66,275
Apr-17	64,315	75,025	58,096	47,439	56,871	71,512
May-17	60,125	55,000	64,692	48,661	57,117	61,157
Jun-17	51,250	50,000	67,651	49,491	57,318	44,002
Jul-17	53,500	51,250	58,563	49,619	57,428	51,421
Aug-17	49,900	45,540	54,958	49,900	57,559	54,535
Sep-17	59,125	60,150	51,550	49,900	57,651	63,527
Oct-17	81,256	80,000	54,175	50,568	57,836	80,678
Nov-17	55,640	50,005	63,427	52,791	58,242	67,502
Dec-17	42,250	45,000	65,340	52,997	58,387	35,030
Jan-18	41,075	48,978	59,715	52,219	58,396	42,874
Feb-18	49,125	56,375	46,322	51,412	58,391	49,516
Mar-18	66,542	86,363	44,150	51,246	58,466	69,433
Apr-18	70,150	70,747	52,247	52,354	58,715	74,528
May-18	74,050	66,138	61,939	53,643	58,998	63,805
Jun-18	35,500	56,375	70,247	55,121	59,319	46,064
Jul-18	52,200	58,850	59,900	53,700	59,250	53,544
Aug-18	61,250	54,890	53,917	53,591	59,347	56,669
Sep-18	68,500	65,038	49,650	54,146	59,534	66,122
Oct-18	72,700	89,382	60,650	55,186	59,792	84,112
Nov-18	92,150	61,204	67,483	56,454	60,091	70,136
Dec-18	34,100	46,475	77,783	59,040	60,585	36,709
Jan-19	42,200	45,183	66,317	57,234	60,491	44,688
Feb-19	47,240	54,038	56,150	56,145	60,477	51,614

Table 4. 5 Recapitulation of 20SDR11 Forecast Calculation (Con't)

Period	Actual Demand	Existing Forecast	MA	ES	Holt	Winter
Mar-19	61,250	73,196	41,180	55,500	60,512	72,285
Apr-19	89,550	77,165	50,230	55,916	60,687	77,477
May-19	56,520	81,455	66,013	58,352	61,146	66,607
Jun-19	50,500	39,050	69,107	58,220	61,270	47,744
Jul-19	54,500	57,420	65,523	57,660	61,331	55,762
Aug-19	59,000	67,375	53,840	57,432	61,431	59,071
Sep-19	70,750	75,350	54,667	57,545	61,574	68,827
Oct-19	98,174	79,970	61,417	58,502	61,835	87,385
Nov-19	62,880	101,365	75,975	61,375	62,371	73,370
Dec-19	32,576	37,510	77,268	61,484	62,549	38,076

For intermittent demand pattern, the calculation of forecast is using Croston's method and Syntetos Boylan Approximation. the value of α is obtained from optimization using Excel data solver. The example of forecast calculation in item 90SDR11 is shown below.

1. Croston's Method

- If $x_{t-1} = 0$

  $\hat{z}_t = \hat{z}_{t-1}$

  $\hat{n}_t = \hat{n}_{t-1}$

- If $x_{t-1} > 0$

  $\hat{z}_t = \alpha x_{t-1} + (1-\alpha)\hat{z}_{t-1}$

  $\hat{n}_t = \alpha n_{t-1} + (1-\alpha)\hat{n}_{t-1}$

- $x_{3-1} = 2850 > 0$

  $\hat{z}_3 = 0.18\ x\ 2850 + (1-0.18)\ x\ 0 = 514$

  $\hat{n}_3 = 0.18\ x\ 2 + (1-0.18)\ x\ 1 = 1.18$

- $\hat{D}_3 = \frac{514}{1.18} = 435$

2. Syntetos Boylan Approximation

$$\hat{D}_t = \left(1 - \frac{\alpha}{2}\right)\frac{\hat{z}_t}{\hat{n}_t}$$

$$\hat{D}_3 = \left(1 - \frac{0.18}{2}\right) x \frac{514}{1.18} = 396$$

The recapitulation of the calculation for 90SDR11 using Croston's and Syntetos Boylan Approximation method is shown in the Table 4. 6.

Table 4. 6 Croston and SBA Forecast Calculation for 90SDR11

Period	xt	Zt'	n_t	$\hat{n}_t$	Croston's	SBA
Jan-17	0	0	1	1.00	-	-
Feb-17	2850	0	2	1.00	-	-
Mar-17	2450	514.0	1	1.18	435	396
Apr-17	3005	863.1	1	1.15	752	684
May-17	0	1,249.4	1	1.12	1,114	1,014
Jun-17	0	1,249.4	2	1.12	1,114	1,014
Jul-17	2050	1,249.4	3	1.12	1,114	1,014
Aug-17	0	1,393.8	1	1.46	955	869
Sep-17	0	1,393.8	2	1.46	955	869
Oct-17	2405	1,393.8	3	1.46	955	869
Nov-17	2175	1,576.1	1	1.74	907	825
Dec-17	0	1,684.1	1	1.60	1,050	955
Jan-18	2000	1,684.1	2	1.60	1,050	955
Feb-18	2050	1,741.1	1	1.68	1,039	945
Mar-18	3100	1,796.8	1	1.55	1,156	1,052
Apr-18	0	2,031.8	1	1.45	1,397	1,271
May-18	0	2,031.8	2	1.45	1,397	1,271
Jun-18	0	2,031.8	3	1.45	1,397	1,271
Jul-18	2200	2,031.8	4	1.45	1,397	1,271
Aug-18	2400	2,062.2	1	1.91	1,078	981
Sep-18	2325	2,123.1	1	1.75	1,214	1,105
Oct-18	0	2,159.5	1	1.61	1,338	1,218
Nov-18	0	2,159.5	2	1.61	1,338	1,218
Dec-18	2100	2,159.5	3	1.61	1,338	1,218
Jan-19	0	2,148.8	1	1.86	1,153	1,049
Feb-19	2300	2,148.8	2	1.86	1,153	1,049
Mar-19	0	2,176.0	1	1.89	1,152	1,049
Apr-19	0	2,176.0	2	1.89	1,152	1,049
May-19	0	2,176.0	3	1.89	1,152	1,049
Jun-19	2500	2,176.0	4	1.89	1,152	1,049
Jul-19	3450	2,234.5	1	2.27	985	896
Aug-19	0	2,453.7	1	2.04	1,203	1,094
Sep-19	0	2,453.7	2	2.04	1,203	1,094
Oct-19	3855	2,453.7	3	2.04	1,203	1,094
Nov-19	2550	2,706.4	1	2.21	1,223	1,113
Dec-19	2200	2,678.2	1	1.99	1,343	1,222

Error in forecast is inevitable. To obtain the best forecasting method to be implemented, the error can be measured. Various ways to measure the error is using mean absolute deviation and mean square error. The best forecast generates the lowest value of error. The example of MAD and MSE calculation in Winter's forecast for 25SDR13.6 is shown below.

1. MAD

$$MAD = \frac{\sum_{i=1}^{n} |A_t - F_t|}{n}$$

$$MAD = \frac{|1995 - 1837| + |2105 - 2157| + \cdots + |4250 - 3524|}{36}$$

$$MAD = 247.829$$

2. MSE

$$MSE = \frac{\sum_{i=1}^{n} (A_t - F_t)^2}{n}$$

$$MSE = \frac{(1995 - 1837)^2 + (2105 - 2157)^2 + \cdots + (4250 - 3524)^2}{36}$$

$$MSE = 110{,}352.4$$

After the MAD and MSE calculated using the formula above, other product forecast error is calculated. The recapitulation of error calculation using MAD and MSE in smooth pattern and the chosen method to forecast is shown in Table 4. 7.

Table 4. 7 Forecast Error with Smooth Pattern

No	Item	Existing		MA (3)		ES		Holt’s		Winter		Chosen Method
		MAD	MSE	MAD	MSE	MAD	MSE	MAD	MSE	MAD	MSE	
1	110SDR17	1,315	321,751,634	-	-	-	-	1,059	1,739,011	960	1,401,824	Winter's
2	20SDR11	9,575	165,605,721	17,365	436,327,910	13,245	300,969,885	12,411	246,826,113	5,933	57,905,689	Winter's
3	20SDR13.6	5,470	59,692,026	-	-	-	-	4,410	31,840,858	3,165	22,051,110	Winter's
4	20SDR17	11,333	282,524,891	-	-	-	-	10,667	157,568,111	4,780	37,533,479	Winter's
5	25SDR11	1,384	2,931,618	-	-	-	-	909	1,338,159	919	1,255,252	Winter's
6	25SDR13.6	381	209,099	-	-	-	-	332	177,589	248	110,352	Winter's
7	32SDR11	6,920	70,183,466	-	-	-	-	5,281	41,750,115	4,196	34,303,606	Winter's
8	25SDR17	9,531	119,052,492	-	-	-	-	1,889	7,486,674	1,969	5,786,868	Winter's
9	32SDR13.6	686	685,475	-	-	-	-	458	305,514	460	273,648	Winter's
10	32SDR17	10,215	298,316,816	-	-	-	-	9,164	167,156,027	8,760	151,044,831	Winter's
11	50SDR11	1,550	3,884,147	-	-	-	-	1,171	2,706,230	1,097	1,697,691	Winter's
12	63SDR11	1,114	1,970,521	-	-	-	-	938	1,422,818	837	1,450,812	Holt’s
13	63SDR17	3,474	20,821,007	-	-	-	-	3,237	14,521,066	2,904	11,851,335	Winter's
14	63SDR21	464	354,832	-	-	-	-	448	324,688	196	52,030	Winter's
15	90SDR17	1,026	1,456,610	-	-	-	-	638	652,841	575	559,298	Winter's
16	40SDR11	15	400	-	-	-	-	86	10,250	42	3,010	Winter's
17	40SDR13.6	127	27,133	68	8,321	57	6,204	55	5,645	45	3,400	Winter's
18	50SDR13.6	93	18,960	-	-	-	-	132	28,368	98	14,504	Winter's
19	60SDR17	249	90,606	-	-	-	-	18	517	21	733	Holt's

Intermittent pattern uses the same formula to calculate the value of MAD and MSE. The recapitulation of error calculation using MAD and MSE in intermittent pattern and the chosen method to forecast is shown in the Table 4. 8.

Table 4. 8 Forecast Error with Intermittent Pattern

No	Item	Existing		Croston		SBA		Chosen Method
		MAD	MSE	MAD	MSE	MAD	MSE	
1	160SDR17	433	370,028	415	218,746	419	221,492	Croston
2	200SDR17	417	263,916	334	153,925	323	145,683	SBA
3	40SDR17	1,202	2,365,398	1,039	1,419,899	1,110	1,537,095	Croston
4	50SDR17	1,796	6,290,583	1,477	3,468,029	1,485	6,290,583	Croston
5	75SDR11	153	57,003	204	62,406	204	61,999	Existing
6	90SDR11	1,479	3,484,602	1,316	2,102,453	1,317	2,130,612	Croston
7	90SDR21	811	1,153,394	772	894,428	773	905,635	Croston
8	200SDR11	164	56,783	143	24,080	140	22,930	SBA
9	110SDR11	248	109,263	211	55,542	203	53,317	SBA
10	250SDR17	15	400	13	249	12	237	SBA
11	63SDR13.6	21	753	19	472	18	431	SBA
12	110SDR13.6	146	71,572	132	34,059	105	33,276	SBA
13	125SDR11	5	163	8	293	8	293	Existing
14	125SDR17	3	62	3	29	3	29	SBA
15	125SDR21	11	689	10	355	9	354	SBA
16	160SDR11	79	15,753	87	11,562	67	8,292	SBA
17	160SDR13.6	44	6,750	26	2,110	25	2,107	SBA

4.4 Calculation of Inventory Cost

Inventory costs are related with the operation of an inventory system. It is the basic economic parameter to any decision model. According to Tersine (1994), the most relevant inventory costs are unit cost, setup cost, holding cost, and stockout cost. The costs are used to calculate the inventory control policy parameter.

4.4.1 Setup Cost

Setup cost covers the cost of changing the production process to produce the required item (Tersine, 1994). The observed setup cost consists of three components such as cost of the related worker, cost of asset related to setup, and cost of setup operational. The setup related worker consists of setup operator, PPIC staff, and quality assurance staff. Setup operator is in charge of setting up the machine for the new batch, PPIC staff are in charge of scheduling the work, and QA staff are in charge of assuring the products after setup conforms with the requirement. The calculation of cost of worker is shown in Table 4. 9.

Table 4. 9 Cost of Setup Related Worker

Worker	Quantity	Yearly Unit Cost	Total Cost
Setup Operator	2	Rp41,456,354.40	Rp82,912,708.80
PPIC Staff	1	Rp41,456,354.40	Rp41,456,354.40
QA Staff	1	Rp41,456,354.40	Rp41,456,354.40
Total			Rp165,825,417.60

Setup operational cost is the cost to perform the setup activities. The cost in performing the setup activities is calculated and shown in Table 4. 10.

Table 4. 10 Setup Operational Cost

Component	Quantity	Unit Cost	Cost
Paper	6 Box	Rp167,500	Rp1,005,000
Electricity	10080 KWH	Rp1,036	Rp10,440,662
Total			Rp11,445,662

The cost of asset is the cost that appears in the asset related with setup activities. The cost is calculated based on the depreciation using straight-line method. The calculation of cost of asset and the total cost per setup is shown in Table 4. 11.

Table 4. 11 Order Preparation Equipment Depreciation

Equipment Depreciation	Unit	Price	Life Time	Depreciation
Hopper Drier	15	Rp90,000,000	5 Years	Rp18,000,000
Water Cooler	4	Rp11,600,000	5 Years	Rp2,320,000
Air Compressor	6	Rp7,722,000	5 Years	Rp1,544,400
Total				Rp21,864,400
Total Setup Cost				Rp199,135,480.00
Total Cost / Setup				Rp2,074,327.92

4.4.2 Holding Cost

Holding cost is associated with inventory investment and cost related to maintain the physical investment in storage. Holding cost consists of obsolescence, cost of assets, operational cost, and cost of capital. The holding cost calculation in this research is shown below.

$$Obsolescence\ Cost = \frac{Item\ Value}{Lifetime} \quad (4.\ 1)$$

$$Obsolescence\ Cost\ (110SDR17) = \frac{108{,}010}{50\ years}$$

$$Obsolescence\ Cost\ (110SDR17) = Rp2{,}160.2$$

Table 4. 12 Cost of Asset

Asset	Unit	Price	Life Time	Depreciation
Warehouse Building	5000	Rp11,000,000,000	30	Rp366,666,667
Fork lift 3 ton	1	Rp174,000,000	5	Rp 34,800,000
Fork lift 3 ton	1	Rp174,000,000	5	Rp 34,800,000
Fork lift 2 ton	1	Rp125,000,000	5	Rp 25,000,000
Crane Hoist 5 ton	2	Rp128,700,000	5	Rp 25,740,000
Hand lift 1 ton	4	Rp33,200,000	5	Rp 6,640,000
Total/year				Rp458,846,667

The yearly operational cost for maintaining the inventory is shown in Table 4. 13.

Table 4. 13 Operational Cost

Operational Cost	**Cost per Month**	**Cost per Year**
Electricity and Water	Rp88,600,000.00	Rp1,063,200,000
Indirect Labour	Rp72,400,000.00	Rp868,800,000
Overhead Cost	Rp58,200,000.00	Rp698,400,000
Direct Labor	Rp134,200,000.0	Rp1,610,400,000
PBB	-	Rp37,250,000.0
Total		Rp4,278,050,000
(Operational Cost+Depreciation)/kg		Rp 4,791.74

Cost of capital is considered in the calculation of holding cost. Cost of capital is the cost that is used to generate capital. WACC (Weighted Average Cost of Capital) is used to calculate the cost of capital of the firm. The formula of WACC is shown in Formula 4.2.

$$WACC = Cost\ of\ Equity \times \%Equity + Cost\ of\ Debt \times \%Debt \times 1(-Tax\ Rate) \quad (4.\ 2)$$

To calculate the WACC, the value of beta stock from a similar firm must be known. In this research, the firms that are used as the reference for beta stock is firm that runs in the field of pipe manufacturing. The data of beta stock value are shown in Table 4. 14.

Table 4. 14 Pefindo Beta Stock (29 December 2019)

Code	Company	Adjusted Beta
ALMI	Alumindo Light Metal Industry Tbk.	1.173
INAI	Indal Aluminium Industry Tbk.	0.525
ISSP	Steel Pipe Industry of Indonesia Tbk.	1.04
LMPI	Langgeng Makmur Industri Tbk.	0.545
Average		0.82075

The cost of equity is the rate of return a company requires to specify if an investment meets the capital return requirements. The cost of equity is calculated using Formula 4.3.

$$Cost\ of\ Equity = Rf + (Rm - Rf) \times \beta \tag{4. 3}$$

Description:

Rf: = Risk of free

Rm = Average expected rate of return on the market

β = Relative market risk

The value of Rf is obtained from risk-free asset such as Bank Indonesia Certificate (SBI) with the value of Rf is 5.96%. the value of Rm is obtained from the rate of IHSG from the year 2010-2019 with the value of Rm is 10.59%. the β is obtained from Pefindo Beta Stock for a related firm and the value of β is 0.82. The calculation of the cost equity is shown below.

$$Cost\ of\ Equity = 5.96\% + (10.59\% - 5.96\%) \times 0.82$$
$$Cost\ of\ Equity = 9.76\%$$

The cost of debt is the rate of return that the company must provide to its creditors. The cost of debt after tax is calculated using Formula 4. 4.

$$Cost\ of\ Debt\ (After\ Tax) = Interest \times (1 - Tax) \tag{4. 4}$$

One of the loans that the company use is from PT. Bank Mandiri Tbk. which is used to fund the operation inside the company. The interest rate given by the bank is 9.95% per year. The tax rate for a corporation is 20% per year. The calculation of the cost of debt after tax is shown below.

$$Cost\ of\ Debt\ (After\ Tax) = Interest \times (1 - Tax)$$
$$Cost\ of\ Debt\ (After\ Tax) = 9.95\% \times (1 - 20\%)$$
$$Cost\ of\ Debt\ (After\ Tax) = 7.96\%$$

After the cost of equity and cost of debt is known, the WACC calculation can be completed. The proportion of equity and debt is assumed to be 50:50. The calculation of WACC is shown below.

$$WACC = 9.76\% \times 50\% + \%Equity + 7.96\% \ \times 50\%$$
$$WACC = 8.86\%$$

After the obsolescence cost, asset cost, operational cost, and capital cost calculated, the holding cost can be calculated. The recapitulation of the holding cost is shown in Table 4. 15.

Table 4. 15 Recapitulation of Holding Cost

No	Item	Obsolescence Cost	Asset + Operational Cost	Cost of Capital	Holding Cost
1	110SDR17	Rp 2,160.20	Rp10,398	Rp9,570	Rp22,128
2	160SDR17	Rp 4,520.20	Rp21,755	Rp20,025	Rp46,300
3	200SDR17	Rp 7,037.40	Rp33,878	Rp31,177	Rp72,092
4	20SDR11	Rp 111.60	Rp527	Rp494	Rp1,133
5	20SDR13.6	Rp 110.60	Rp527	Rp490	Rp1,128
6	20SDR17	Rp 107.20	Rp479	Rp475	Rp1,061
7	25SDR11	Rp 171.00	Rp815	Rp758	Rp1,743
8	25SDR13.6	Rp 126.46	Rp719	Rp560	Rp1,405
9	32SDR11	Rp 275.60	Rp1,294	Rp1,221	Rp2,790
10	25SDR17	Rp 152.20	Rp719	Rp674	Rp1,545
11	32SDR13.6	Rp 161.00	Rp1,102	Rp713	Rp1,976
12	32SDR17	Rp 212.80	Rp1,006	Rp943	Rp2,162
13	40SDR17	Rp 293.20	Rp1,390	Rp1,299	Rp2,982
14	50SDR11	Rp 672.00	Rp3,210	Rp2,977	Rp6,860
15	50SDR17	Rp 459.20	Rp2,204	Rp2,034	Rp4,698
16	63SDR11	Rp 1,046.40	Rp5,031	Rp4,636	Rp10,713
17	63SDR17	Rp 717.20	Rp3,450	Rp3,177	Rp7,345
18	63SDR21	Rp 567.40	Rp2,779	Rp2,514	Rp5,860
19	75SDR11	Rp 1,465.00	Rp7,044	Rp6,490	Rp14,999
20	90SDR11	Rp 2,106.80	Rp10,158	Rp9,334	Rp21,599
21	90SDR17	Rp 1,445.00	Rp6,948	Rp6,402	Rp14,795

Table 4. 15 Recapitulation of Holding Cost (Con't)

No	Item	Obsolescence Cost	Asset + Operational Cost	Cost of Capital	Holding Cost
22	90SDR21	Rp 1,190.00	Rp5,654	Rp5,272	Rp12,116
23	200SDR11	Rp 10,345.00	Rp49,834	Rp45,830	Rp106,009
24	110SDR11	Rp 3,146.00	Rp15,142	Rp13,937	Rp32,225
25	250SDR17	Rp 10,934.40	Rp52,661	Rp48,441	Rp112,037
26	40SDR11	Rp 430.20	Rp2,060	Rp1,906	Rp4,397
27	40SDR13.6	Rp 357.00	Rp1,725	Rp1,582	Rp3,664
28	50SDR13.6	Rp 558.00	Rp2,635	Rp2,472	Rp5,665
29	60SDR17	Rp 459.20	Rp3,450	Rp2,034	Rp5,944
30	63SDR13.6	Rp 881.20	Rp4,217	Rp3,904	Rp9,002
31	110SDR13.6	Rp 2,654.40	Rp12,506	Rp11,759	Rp26,920
32	125SDR11	Rp 4,062.20	Rp19,550	Rp17,996	Rp41,609
33	125SDR17	Rp 3,735.00	Rp13,177	Rp16,547	Rp33,459
34	125SDR21	Rp 3,590.00	Rp10,877	Rp15,904	Rp30,372
35	160SDR11	Rp 6,646.00	Rp32,057	Rp29,443	Rp68,146
36	160SDR13.6	Rp 5,614.40	Rp26,450	Rp24,873	Rp56,938

4.4.3 Stockout Cost

Stockout cost is the economic consequences of experiencing shortage. The stockout cost is assumed to be 20% from the price of the item. The assumption is based on the discount given from the company if the order is backordered which are 17% added with other cost related to stockout. The stockout cost in this research is shown in Table 4. 16.

Table 4. 16 Stockout Cost Recapitulation

No	Item	Stockout Cost
1	110SDR17	Rp 2,160,200.00
2	160SDR17	Rp 1,130,050.00
3	200SDR17	Rp 1,759,350.00
4	20SDR11	Rp 279,000.00
5	20SDR13.6	Rp 276,500.00
6	20SDR17	Rp 268,000.00
7	25SDR11	Rp 427,500.00
8	25SDR13.6	Rp 316,150.00

Table 4. 16 Stockout Cost Recapitulation (Con't)

No	Item	Stockout Cost
9	32SDR11	Rp 689,000.00
10	25SDR17	Rp 380,500.00
11	32SDR13.6	Rp 402,500.00
12	32SDR17	Rp 532,000.00
13	40SDR17	Rp 733,000.00
14	50SDR11	Rp 1,680,000.00
15	50SDR17	Rp 1,148,000.00
16	63SDR11	Rp 1,046,400.00
17	63SDR17	Rp 717,200.00
18	63SDR21	Rp 567,400.00
19	75SDR11	Rp 1,465,000.00
20	90SDR11	Rp 2,106,800.00
21	90SDR17	Rp 1,445,000.00
22	90SDR21	Rp 1,190,000.00
23	200SDR11	Rp 2,586,250.00
24	110SDR11	Rp 786,500.00
25	250SDR17	Rp 2,733,600.00
26	40SDR11	Rp 1,075,500.00
27	40SDR13.6	Rp 892,500.00
28	50SDR13.6	Rp 1,395,000.00
29	60SDR17	Rp 459,200.00
30	63SDR13.6	Rp 881,200.00
31	110SDR13.6	Rp 663,600.00
32	125SDR11	Rp 4,062,200.00
33	125SDR17	Rp 3,735,000.00
34	125SDR21	Rp 3,590,000.00
35	160SDR11	Rp 6,646,000.00
36	160SDR13.6	Rp 5,614,400.00

4.5 Inventory Control Parameter Calculation

This sub-chapter explains about the calculation of the inventory control parameter that will be used in the Monte Carlo Simulation.

4.5.1 Parameter for Existing Condition

The current inventory control policy in the company is a min-max system where the minimum level of inventory and the maximum level of inventory is stated. However, the value of the minimum and maximum level inventory is only based on intuition and has not been updated. Due to this situation, the existing policy is still not optimized, therefore further development is available. The sample of the existing parameter are shown in Table 4. 17.

Table 4. 17 Recapitulation of Existing Condition Parameter

No	Item	Min (m)	Max (m)
1	20SDR17	40,000	90,000
2	110SDR17	1,000	5,500
3	63SDR17	5,000	10,000
4	90SDR17	5,500	8,500
5	50SDR11	7,000	15,000
6	200SDR17	100	500
7	50SDR17	5,000	10,000
8	110SDR11	25	125
9	25SDR13.6	6000	8000
10	40SDR17	4000	5000

4.5.2 Parameter for (R, S) System

Inventory control policy using periodic review (R, S) system considers parameters such as the replenishment period (R) and maximum inventory level (S). The example of the calculation for 20SDR17 is shown below.

Table 4. 18 Data for (R, S) Parameter Calculation of 20SDR17

Data for 20SDR17	
Average demand / year (r)	1,168,684
Setup Cost (k)	Rp 2,074,328
Holding Cost (h)	Rp 1,061
Stockout cost (π)	Rp 268,000.00
Average demand (μ_{L+tp})	112,373
Standard Deviation (σ_{L+tp})	1869

$$t^* = \sqrt{\frac{2k}{rh}}$$

$$t^* = \sqrt{\frac{2\ x\ 2{,}074{,}328}{1{,}168{,}684.3\ x\ \ 1{,}061}}$$

$$t^* = 0.057\ years = 2.85\ weeks\ \ \approx 3\ weeks$$

$$F_{L+tp}(K^*) = \frac{\pi - ht_p}{\pi}$$

$$F_{L+tp}(K^*) = \frac{268{,}000 - \ 1{,}061\ \times\ 3}{268{,}000} = 0.988$$

From the safety factor table, the value of K is 2.2.

$$S = \mu_{L+tp} + K\sigma_{L+tp}$$

$$S = 112{,}373 + 2.2\ x\ 1869.4$$

$$S = 116{,}486\ m$$

The sample of the (R, S) parameter recapitulation for the observed item is shown in Table 4. 19. The table shows information about the item, reviewing period, and maximum inventory level parameter.

Table 4. 19 Recapitulation of (R, S) parameter

No	Item	R (weeks)	S (m)
1	20SDR17	3	116,486
2	110SDR17	3	4740
3	63SDR17	3	12800
4	90SDR17	4	5450
5	50SDR11	5	10018
6	200SDR17	6	705
7	50SDR17	10	5488
8	110SDR11	12	623
9	25SDR13.6	15	11,600
10	40SDR17	15	5,464

4.5.3 Parameter for (R, s, S) System

Inventory control policy using periodic review (R, s, S) system considers parameters such as the reviewing period (R), reorder point (s), and maximum inventory level (S). The example of the calculation for 20SDR17 is shown below.

Table 4. 20 Data for (R, s, S) Parameter Calculation of 20SDR17

Data for 20SDR17	
Average demand / year (r)	1,168,684
Setup Cost (k)	Rp 2,074,328
Holding Cost (h)	Rp 1,061
Stockout cost (π)	Rp 268,000.00
Average demand (μ_{L+w})	112,373
Standard Deviation (σ_{L+w})	1,425

$$q_w = \sqrt{\frac{2kr}{h}}$$

$$q_w = \sqrt{\frac{2\ x\ 2{,}074{,}328\ x\ 1{,}168{,}684.3}{1{,}061}}$$

$$q_w = 67{,}590\ m$$

$$F_{L+w}(K^*) = \frac{\pi r - hq}{\pi r}$$

$$F_{L+w}(K^*) = \frac{268{,}000\ \times\ 1{,}168{,}684.3\ -\ 1{,}061\ \times\ 67{,}590}{268{,}000x1{,}168{,}684.3}$$

$$F_{L+w}(K^*) = 0.999$$

From the safety factor table, the value of K is 3.

$$s = \mu_{L+w} + K\sigma_{L+w} + \frac{rw}{2}$$

$$s = 89{,}899 + 3\ x\ 1{,}425 + \frac{28972.75\ \times\ 2}{2}$$

$$s = 116{,}650$$

$$S = q_w + s - \frac{rw}{2}$$

$$S = 67{,}590 + 161{,}765 - \frac{28972.75\ x\ 2}{2}$$

$$S = 67{,}590 + 161{,}765 - \frac{28972.75\ x\ 3}{2}$$

$$S = 161{,}765$$

The sample of the (R, s, S) parameter recapitulation for the observed item is shown in Table 4. 21. The table shows information about the item, reviewing period, minimum inventory level, and maximum inventory level parameter.

Table 4. 21 Recapitulation of (R, s, S) parameter

No	Item	R (weeks)	s (m)	S (m)
1	20SDR17	2	116,650	161,765
2	110SDR17	2	4,811	6,870
3	63SDR17	2	13,005	19,009
4	90SDR17	3	5,975	8,237
5	50SDR11	4	13,659	16,455
6	200SDR17	5	886	1,178
7	50SDR17	9	7,298	9,800
8	110SDR11	11	928	1,229
9	25SDR13.6	14	15,791	21,243
10	40SDR17	14	7,590	10,151

4.5.4 Parameter for (s, Q) System

Inventory control policy using continuous review (s, Q) system considers parameters such as the minimum inventory level (s) and optimal order quantity (Q). The example of the calculation for 20SDR17 is shown below.

Table 4. 22 Data for (s, Q) Parameter Calculation of 20SDR17

Data for 20SDR17	
Average demand / year (r)	1,168,684
Setup Cost (k)	Rp 2,074,328
Holding Cost (h)	Rp 1,061
Stockout cost (π)	Rp 268,000.00
Standard Deviation (σ_L)	5765

$$q = q_w = \sqrt{\frac{2kr}{h}}$$

$$q_w = \sqrt{\frac{2 \times 2{,}074{,}328 \times 1{,}168{,}684.3}{1{,}061}}$$

$$q_w = 67{,}590\, m$$

$$F(K^*) = \frac{\pi r - hq}{\pi r}$$

$$F(K^*) = \frac{268{,}000\ x\ 1{,}168{,}684 - 1{,}061 \times 67{,}590}{268{,}000\ x\ 1{,}168{,}684}$$

$$F(K^*) = 0.999$$

From the safety factor table, the value of K is 3 and E(K) is 0.0004

$$N_k = \sigma_L \times E(K)$$

$$N_k = 5765 \times 0.0004$$

$$N_k = 2.3$$

Calculate the new value of q using the formula below.

$$q = \sqrt{\frac{2r(k + \pi N_k)}{h}}$$

$$q = \sqrt{\frac{2 \times 1{,}168{,}684 \times (2{,}074{,}328 + 268{,}000 \times 2.3)}{1{,}061}}$$

$q = 77{,}003\ m$

The value of $|q_{new} - q_{old}|$ is equal to |77,003 – 67,590| = 9413, the value is larger than 0.05, therefore iterate the process again.

$$F(K^*) = \frac{268{,}000 \times 1{,}168{,}684 - 1{,}061 \times 77{,}003}{268{,}000 \times 1{,}168{,}684}$$

$F(K^*) = 0.999$

From the safety factor table, the value of K is 3 and E(K) is 0.0004

$N_k = \sigma_L \times E(K)$

$N_k = 5765 \times 0.0004$

$N_k = 2.3$

Calculate the new value of q using the formula below.

$$q = \sqrt{\frac{2r(k + \pi N_k)}{h}}$$

$$q = \sqrt{\frac{2 \times 1{,}168{,}684\ x\ (2{,}074{,}328 + 268{,}000 \times 2.3)}{1{,}061}}$$

$q = 77{,}003\ m$

The value of $|q_{new} - q_{old}|$ is equal to |77,003 – 77,003| which is smaller than 0.05, therefore stop the iteration process and calculate the value of s.

$s = \mu + K\sigma_L$

$s = 22{,}475 + 3\ x\ 5765$

$s = 39{,}769$

The sample of the (s, Q) parameter recapitulation for the observed item is shown in Table 4. 23. The table shows information about the item, minimum inventory level, and order quantity parameter.

Table 4. 23 Recapitulation of (s, Q) parameter

No	Item	s (m)	Q (m)
1	20SDR17	39,769	77,003
2	110SDR17	2,112	3,194
3	63SDR17	5,028	8,906
4	90SDR17	1,612	3,700
5	50SDR11	2833	7,060
6	200SDR17	264	537
7	50SDR17	1,632	4,585
8	110SDR11	161	564
9	25SDR13.6	1,178	10,216
10	40SDR17	1,134	4,769

4.5.5 Parameter for (s, S) System

Inventory control policy using continuous review (s, S) system considers parameters such as the minimum inventory level (s) and maximum inventory level (S). The example of the calculation for 20SDR17 is shown below.

Table 4. 24 Data for (s, S) Parameter Calculation of 20SDR17

Data for 20SDR17	
Average demand / year (r)	1,168,684
Setup Cost (k)	Rp 2,074,328
Holding Cost (h)	Rp 1,061
Stockout cost (π)	Rp 268,000.00
Standard Deviation (σ_L)	5,765

$$q = \sqrt{\frac{2kr}{h}}$$

$$q = \sqrt{\frac{2\ x\ 2{,}074{,}328\ x\ 1{,}168{,}684}{1{,}061}}$$

$$q = 67{,}590\ m$$

$$F(K^*) = \frac{q}{r}$$

$$F'(K^*) = \frac{67{,}590}{1{,}168{,}684}$$

$$F'(K^*) = 0.057$$

From the safety factor table, the value of K is 1.6.

$$s = \mu + K\sigma_L$$

$$s = 22{,}475 + 1.6\ x\ 5{,}765$$

$$s = 31{,}699$$

$$S = q + s$$

$$S = 67{,}590 + 31{,}699$$

$$S = 99{,}289\ m$$

The sample of the (s, S) parameter recapitulation for the observed item is shown in Table 4. 25. The table shows information about the item, minimum inventory level, and maximum inventory level parameter.

Table 4. 25 Recapitulation of (s, S) parameter

No	Item	s (m)	S (m)
1	20SDR17	31,699	99,289
2	110SDR17	1,545	4,499
3	63SDR17	3,719	12,132
4	90SDR17	1,245	4,826
5	50SDR11	2,052	8,612
6	200SDR17	179	685
7	50SDR17	784	5,177
8	110SDR11	85	630
9	25SDR13.6	775	10,938
10	40SDR17	469	5,148

4.6 MRP and Inventory Control Policy Simulation

The simulation of MRP and inventory control policy is conducted using Monte Carlo simulation with 52 weeks of period. The element in the simulation is shown below.

1. Initial Inventory

   Initial inventory is the inventory on hand at the beginning of the period. The value of the initial inventory is from ending inventory from the previous period.

   $$Initial\ Inventory_{(t)} = Ending\ Inventory_{(t-1)} \quad (4.5)$$

2. Order Receipt

   Order Receipt is the amount of item received from the previous order. The initial order receipt in the first period is assumed to be 0. The order receipt amount is adjusted with the inventory control policy parameters.

   - (R, S) → $Order\ Receipt_{(t)} = Max\ Inventory\ Level - Ending\ Inventory_{(t-LT)}$ (4. 6)
   - (R, s, S) → $Order\ Receipt_{(t)} = Max\ Inventory\ Level - Ending\ Inventory_{(t-LT)}$ (4. 7)
   - (S, Q) → $Order\ Receipt_{t} = Order\ Quantity$ (4. 8)
   - (S, S) → $Order\ Receipt_{(t)} = Max\ Inventory\ Level - Ending\ Inventory_{(t-LT)}$ (4. 9)

3. Available Inventory

   Available inventory is the inventory on hand after receiving the order receipt. The value of available inventory must not exceed the maximum inventory level.

   $$Available\ Inventory_{(t)} = Initial\ Inventory_{(t)} + Order\ Receipt_{(t)} \quad (4.10)$$

4. Demand

   The demand data is the result of generating random numbers using the probability of the actual demand.

5. Fulfilled Demand

Fulfilled demand is the demand that can be satisfied using the available inventory on hand. If the demand is larger than the available inventory, there will be some demand that are not fulfilled therefore causing stockout.

$$Fulfilled\ Demand_{(t)} = Min(Demand_{(t)}; Available\ Inventory_{(t)}) \quad (4.\ 11)$$

6. Ending Inventory

Ending inventory is the inventory on hand after the available inventory subtracted with the demand in the period. Ending inventory is used as initial inventory in the next period.

$$Ending\ Inventory_{(t)} = Available\ Inventory_{(t)} - Fulfilled\ Demand_{(t)} \quad (4.\ 12)$$

7. Stockout

Stockout occurs when the company is not able to fulfill the demand. if the demand is bigger than the available inventory, stockout occurs.

$$Stockout_{(t)} = Demand_{(t)} - Fulfilled\ Demand_{(t)} \quad (4.\ 13)$$

8. Order Release

Order release is the amount of items that are ordered to make the available inventory reaching a certain level.

- (R, S) → $Order\ Release_{(t)} = Max\ Inventory\ Level - Ending\ Inventory_{(t)}$ (4. 14)
- (R, s, S) → $Order\ Release_{(t)} = Max\ Inventory\ Level - Ending\ Inventory_{(t)}$ (4. 15)
- (S, Q) → $Order\ Release_{t} = Order\ Quantity$ (4. 16)
- (S, S) → $Order\ Release_{(t)} = Max\ Inventory\ Level - Ending\ Inventory_{(t)}$ (4. 17)

9. Lead Time

Lead time is the time required from ordering an item until the item is ready to be used. The lead time in this research is assumed to be in uniform distribution.

10. Review Period

    Review period is the certain time to review the inventory level. in periodic review, order is only permitted to be requested in the review period.

11. Total Inventory Cost

    Total inventory cost is the calculation of the total cost acquired from holding, setup, and shortage of inventory.

$$Total\ Inventory\ Cost = Unit\ Cost + Holding\ Cost + Setup\ Cost + Stockout\ Cost \quad (4.\ 18)$$

12. Fill Rate

    Fill rate is the fraction of demand that is met by the stock available and without backorders or lost sales. The fill rate is measured by calculating the fulfilled demand over the total number of demands.

4.6.1 Random Number Generation

Random number generation is conducted as the input for the simulation. The random numbers are generated using sample at random from the cumulative probability distributions then the values of the specific variables can be obtained. The cumulative probability distribution is used to assure that only one variable value will be associated with a given random number. The example of cumulative probability distribution in 20SDR17 is shown below.

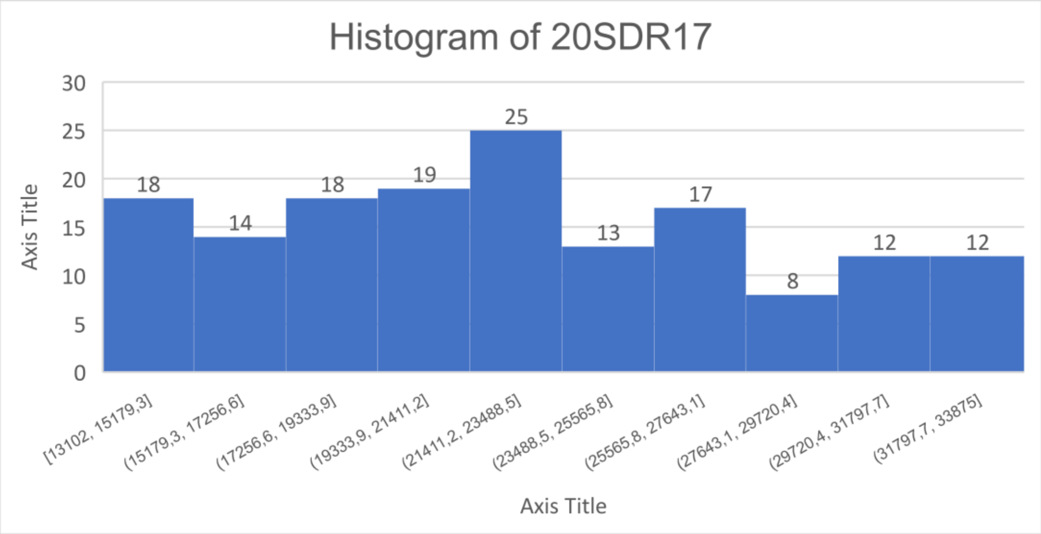

Figure 4. 2 Histogram of 20SDR17

Table 4. 26 Cumulative Probability Distribution

No	Range		Frequency	Probability	Cum. Probability
1	13102	15179.3	18	0.115384615	0
2	15179.3	17256.6	14	0.08974359	0.115384615
3	17256.6	19333.9	18	0.115384615	0.205128205
4	19333.9	21411.2	19	0.121794872	0.320512821
5	21411.2	23488.5	25	0.16025641	0.442307692
6	23488.5	25565.5	13	0.083333333	0.602564103
7	25565.5	27643.1	17	0.108974359	0.685897436
8	27643.1	29720.4	8	0.051282051	0.794871795
9	29720.4	31797.7	12	0.076923077	0.846153846
10	31797.7	33875	12	0.076923077	0.923076923

The output that are observed in the simulation are the stockout, fill rate, and total cost. In order to make the simulation sufficient to be the basis in decision making, replication is required in a certain amount. The initial number of replications required is 10 times. The halfwidth of the simulation is calculated to determine whether the replication is sufficient to generate a representative result. The value of α is 5%, and the initial n value is 10 replications. The example of HW calculation using the total cost parameter in 20SDR17 is shown in Table 4.27.

Table 4. 27 Replication Calculation

Replication	Total Cost
1	Rp 5,942,661,694
2	Rp 6,750,845,335
3	Rp 5,512,294,576
4	Rp 6,281,312,479
5	Rp 6,224,968,696
6	Rp 6,190,970,609
7	Rp 6,322,816,912
8	Rp 6,164,167,846
9	Rp 6,209,948,994
10	Rp 6,046,302,536
$\frac{hw}{\lvert x \rvert}$	3%

From the calculation, it is shown that the value is below the relative error of 5%. It indicates that 10 replications are sufficient to make the simulation to be the basis of decision making. After the number of replications is sufficient, the Monte Carlo simulation is conducted.

Table 4. 28 Generated Random Number

No	Generated Random Number
1	18,677
2	32,558
3	27,908
4	22,212
5	13,809
6	22,159
7	32,455
…	…
…	…
52	22,786

4.6.2 Existing Condition Simulation

This sub-chapter explains about the Monte Carlo simulation using the existing policy. The existing policy use a min-max system. The input parameter that is used for the simulation is shown in Table 4. 29.

Table 4. 29 Input Parameter for 20SDR17

20SDR17	
Input Parameter	
Minimum Stock	40,000
Maximum Stock	90,000
Lead Time (Week)	2
Unit Cost	Rp5,360
Holding Cost	Rp1,061
Setup Cost	Rp2,074,327
Stockout Cost	Rp268,000

Monte Carlo simulation is used to generate the demand based on the cumulative probability. The MRP then response according to the input parameters. The result of the simulation is shown in the Table 4. 30.

Table 4. 30 Monte Carlo Simulation for Existing Condition in 20SDR17

Period	Initial Inventory	Order Receipt	Available Inventory	Demand	Fulfilled Demand	Ending Inventory	Stockout	Order Release	Production Decision	Lead Time
(I)	(a) = $(f)_{t-1}$	(b) = S – $(f)_{t-LT}$	(c) = (a) + (b)	(d)	(e)= (d) - (c)	(f) = (c) – (e)	(g) = (d) – (e)	(h) = S – (f)	(i)	(j)
1	40,000	0	40,000	18,677	18,677	21,323	0	68,677	Yes	2
2	21,323	0	21,323	32,558	21,323	0	11,235	0	No	2
3	0	68,677	68,677	39,143	39,143	29,534	0	60,466	Yes	2
4	29,534	0	29,534	22,212	22,212	7,322	0	0	No	2
5	7,322	60,466	67,788	13,809	13,809	53,979	0	0	No	2
6	53,979	0	53,979	22,159	22,159	31,820	0	58,180	Yes	2
7	31,820	0	31,820	32,455	31,820	0	635	0	No	2
8	0	58,180	58,180	23,784	23,784	34,396	0	55,604	Yes	2
9	34,396	0	34,396	22,644	22,644	11,752	0	0	No	2
10	11,752	55,604	67,356	29,621	29,621	37,735	0	52,265	Yes	2
11	37,735	0	37,735	27,199	27,199	10,536	0	0	No	2
12	10,536	52,265	62,801	33,134	33,134	29,667	0	60,333	Yes	2
13	29,667	0	29,667	28,415	28,415	1,252	0	0	No	2
14	1,252	60,333	61,585	15,339	15,339	46,246	0	0	No	2
15	46,246	0	46,246	17,028	17,028	29,218	0	60,782	Yes	2
16	29,218	0	29,218	16,892	16,892	12,326	0	0	No	2
17	12,326	60,782	73,108	17,768	17,768	55,340	0	0	No	2

Table 4. 30 Monte Carlo Simulation for Existing Condition in 20SDR17 (Con't)

Period	Initial Inventory	Order Receipt	Available Inventory	Demand	Fulfilled Demand	Ending Inventory	Stockout	Order Release	Production Decision	Lead Time
18	55,340	0	55,340	21,006	21,006	34,334	0	55,666	Yes	2
19	34,334	0	34,334	21,804	21,804	12,530	0	0	No	2
20	12,530	55,666	68,196	25,157	25,157	43,039	0	0	No	2
21	43,039	0	43,039	27,585	27,585	15,454	0	74,546	Yes	2
22	15,454	0	15,454	20,365	15,454	0	4,911	0	No	2
23	0	74,546	74,546	28,515	28,515	46,031	0	0	No	2
24	46,031	0	46,031	33,022	33,022	13,009	0	76,991	Yes	2
25	13,009	0	13,009	28,292	13,009	0	15,283	0	No	2
26	0	76,991	76,991	33,998	33,998	42,993	0	0	No	2
27	42,993	0	42,993	16,423	16,423	26,570	0	63,430	Yes	2
28	26,570	0	26,570	23,989	23,989	2,581	0	0	No	2
29	2,581	63,430	66,011	30,935	30,935	35,076	0	54,924	Yes	2
30	35,076	0	35,076	18,133	18,133	16,943	0	0	No	2
31	16,943	54,924	71,867	17,310	17,310	54,557	0	0	No	2
32	54,557	0	54,557	14,983	14,983	39,574	0	50,426	Yes	2
33	39,574	0	39,574	13,996	13,996	25,578	0	0	No	2
34	25,578	50,426	76,004	13,185	13,185	62,819	0	0	No	2
35	62,819	0	62,819	20,149	20,149	42,670	0	0	No	2
36	42,670	0	42,670	22,366	22,366	20,304	0	69,696	Yes	2
37	20,304	0	20,304	27,540	20,304	0	7,236	0	No	2
38	0	69,696	69,696	23,284	23,284	46,412	0	0	No	2
39	46,412	0	46,412	25,064	25,064	21,348	0	68,652	Yes	2
40	21,348	0	21,348	16,784	16,784	4,564	0	0	No	2
41	4,564	68,652	73,216	25,290	25,290	47,926	0	0	No	2
42	47,926	0	47,926	24,125	24,125	23,801	0	66,199	Yes	2

Table 4. 30 Monte Carlo Simulation for Existing Condition in 20SDR17 (Con't)

Period	Initial Inventory	Order Receipt	Available Inventory	Demand	Fulfilled Demand	Ending Inventory	Stockout	Order Release	Production Decision	Lead Time
43	23,801	0	23,801	24,166	23,801	0	365	0	No	2
44	0	66,199	66,199	29,653	29,653	36,546	0	53,454	Yes	2
45	36,546	0	36,546	20,334	20,334	16,212	0	0	No	2
46	16,212	53,454	69,666	25,401	25,401	44,265	0	0	No	2
47	44,265	0	44,265	29,651	29,651	14,614	0	75,386	Yes	2
48	14,614	0	14,614	18,755	14,614	0	4,141	0	No	2
49	0	75,386	75,386	23,492	23,492	51,894	0	0	No	2
50	51,894	0	51,894	32,019	32,019	19,875	0	70,125	Yes	2
51	19,875	0	19,875	28,696	19,875	0	8,821	0	No	2
52	0	70,125	70,125	31,607	31,607	38,518	0	0	Yes	2

4.6.3 Periodic Review (R, S) System Simulation

This sub-chapter explains about the simulation of material requirement planning framework combined with the (R, S) system parameters. It simulates the MRP response when using the (R, S) system parameters such as the review period and maximum inventory level. The response from the parameters are production is triggered when in the reviewing period and the production size is adjusted to the maximum inventory level. The response of the MRP that is combined with (R, S) system can be used to measure the total cost and fill rate generated from the simulation. The value of the parameter that is used for the simulation is shown in Table 4. 31.

Table 4. 31 Input Parameter for 20SDR17

20SDR17	
Input Parameter (R, S) System	
Review Period (R)	3 weeks
Maximum inventory level (S)	116,486
Lead Time (Week)	2
Unit Cost	Rp5,360
Holding Cost	Rp1,061
Setup Cost	Rp2,074,327
Stockout Cost	Rp268,000

Monte Carlo simulation is used to generate the demand based on the cumulative probability. The MRP then response according to the input parameters. The result of the simulation is shown in Table 4. 32.

Table 4. 32 Monte Carlo Simulation for (R, S) system in 20SDR17

Period	Initial Inventory	Order Receipt	Available Inventory	Demand	Fulfilled Demand	Ending Inventory	Stockout	Order Release	Production Decision	Lead Time	Review Period
(l)	(a) = $(f)_{t-1}$	(b) = S – $(f)_{t-LT}$	(c) = (a) + (b)	(d)	(e)= (d) - (c)	(f) = (c) – (e)	(g) = (d) – (e)	(h) = S – (f)	(i)	(j)	(k)
1	40,000	0	40,000	18,677	18,677	21,323	0	95,163	Yes	2	Yes
2	21,323	0	21,323	32,558	21,323	0	11,235	0	No	2	No
3	0	95,163	95,163	39,143	39,143	56,020	0	0	No	2	No

Table 4. 32 Monte Carlo Simulation for (R, S) system in 20SDR17 (Con't)

Period	Initial Inventory	Order Receipt	Available Inventory	Demand	Fulfilled Demand	Ending Inventory	Stockout	Order Release	Production Decision	Lead Time	Review Period
4	56,020	0	56,020	22,212	22,212	33,808	0	82,678	Yes	2	Yes
5	33,808	0	33,808	13,809	13,809	19,999	0	0	No	2	No
6	19,999	82,678	102,677	22,159	22,159	80,518	0	0	No	2	No
7	80,518	0	80,518	32,455	32,455	48,063	0	68,423	Yes	2	Yes
8	48,063	0	48,063	23,149	23,149	24,914	0	0	No	2	No
9	24,914	68,423	93,337	22,644	22,644	70,693	0	0	No	2	No
10	70,693	0	70,693	29,621	29,621	41,072	0	75,414	Yes	2	Yes
11	41,072	0	41,072	27,199	27,199	13,873	0	0	No	2	No
12	13,873	75,414	89,287	33,134	33,134	56,153	0	0	No	2	No
13	56,153	0	56,153	28,415	28,415	27,738	0	88,748	Yes	2	Yes
14	27,738	0	27,738	15,339	15,339	12,399	0	0	No	2	No
15	12,399	88,748	101,147	17,028	17,028	84,119	0	0	No	2	No
16	84,119	0	84,119	16,892	16,892	67,227	0	49,259	Yes	2	Yes
17	67,227	0	67,227	17,768	17,768	49,459	0	0	No	2	No
18	49,459	49,259	98,718	21,006	21,006	77,712	0	0	No	2	No
19	77,712	0	77,712	21,804	21,804	55,908	0	60,578	Yes	2	Yes
20	55,908	0	55,908	25,157	25,157	30,751	0	0	No	2	No
21	30,751	60,578	91,329	27,585	27,585	63,744	0	0	No	2	No
22	63,744	0	63,744	20,365	20,365	43,379	0	73,107	Yes	2	Yes
23	43,379	0	43,379	23,604	23,604	19,775	0	0	No	2	No
24	19,775	73,107	92,882	33,022	33,022	59,860	0	0	No	2	No
25	59,860	0	59,860	28,292	28,292	31,568	0	84,918	Yes	2	Yes
26	31,568	0	31,568	18,715	18,715	12,853	0	0	No	2	No
27	12,853	84,918	97,771	16,423	16,423	81,348	0	0	No	2	No
28	81,348	0	81,348	23,989	23,989	57,359	0	59,127	Yes	2	Yes

Table 4. 32 Monte Carlo Simulation for (R, S) system in 20SDR17 (Con't)

Period	Initial Inventory	Order Receipt	Available Inventory	Demand	Fulfilled Demand	Ending Inventory	Stockout	Order Release	Production Decision	Lead Time	Review Period
29	57,359	0	57,359	30,935	30,935	26,424	0	0	No	2	No
30	26,424	59,127	85,551	18,133	18,133	67,418	0	0	No	2	No
31	67,418	0	67,418	17,310	17,310	50,108	0	66,378	Yes	2	Yes
32	50,108	0	50,108	14,983	14,983	35,125	0	0	No	2	No
33	35,125	66,378	101,503	13,996	13,996	87,507	0	0	No	2	No
34	87,507	0	87,507	13,185	13,185	74,322	0	42,164	Yes	2	Yes
35	74,322	0	74,322	20,149	20,149	54,173	0	0	No	2	No
36	54,173	42,164	96,337	22,366	22,366	73,971	0	0	No	2	No
37	73,971	0	73,971	27,540	27,540	46,431	0	70,055	Yes	2	Yes
38	46,431	0	46,431	16,048	16,048	30,383	0	0	No	2	No
39	30,383	70,055	100,438	25,064	25,064	75,374	0	0	No	2	No
40	75,374	0	75,374	16,784	16,784	58,590	0	57,896	Yes	2	Yes
41	58,590	0	58,590	25,290	25,290	33,300	0	0	No	2	No
42	33,300	57,896	91,196	24,125	24,125	67,071	0	0	No	2	No
43	67,071	0	67,071	24,166	24,166	42,905	0	73,581	Yes	2	Yes
44	42,905	0	42,905	29,288	29,288	13,617	0	0	No	2	No
45	13,617	73,581	87,198	20,334	20,334	66,864	0	0	No	2	No
46	66,864	0	66,864	25,401	25,401	41,463	0	75,023	Yes	2	Yes
47	41,463	0	41,463	29,651	29,651	11,812	0	0	No	2	No
48	11,812	75,023	86,835	18,755	18,755	68,080	0	0	No	2	No
49	68,080	0	68,080	19,351	19,351	48,729	0	67,757	Yes	2	Yes
50	48,729	0	48,729	32,019	32,019	16,710	0	0	No	2	No
51	16,710	67,757	84,467	28,696	28,696	55,771	0	0	No	2	No
52	55,771	0	55,771	22,786	22,786	32,985	0	0	Yes	2	Yes

4.6.4 Periodic Review (R, s, S) System Simulation

This sub-chapter explains about the simulation of material requirement planning framework combined with the (R, s, S) system parameters. It simulates the MRP response when using the (R, s, S) system parameters such as the review period, reorder point, and maximum inventory level. The response from the parameters are production is triggered when in the reviewing period and the inventory level is below reorder point and the production size is adjusted to the maximum inventory level. The response of the MRP that is combined with (R, s, S) system can be used to measure the total cost and fill rate generated from the simulation. The value of the parameter that is used for the simulation is shown in Table 4. 33.

Table 4. 33 Input Parameter for 20SDR17

20SDR17	
Input Parameter (R, s, S) System	
Review Period (R)	2 weeks
Reorder Point (s)	116,650
Maximum inventory level (S)	161,765
Lead Time (Week)	2
Unit Cost	Rp5,360
Holding Cost	Rp1,061
Setup Cost	Rp2,074,327
Stockout Cost	Rp268,000

Monte Carlo simulation is used to generate the demand based on the cumulative probability. The MRP then response according to the input parameters. The result of the simulation is shown in Table 4. 34.

Table 4. 34 Monte Carlo Simulation for (R, s, S) system in 20SDR17

Period	**Initial Inventory**	**Order Receipt**	**Available Inventory**	**Demand**	**Fulfilled Demand**	**Ending Inventory**	**Stockout**	**Order Release**	**Production Decision**	**Lead Time**	**Review Period**
(l)	**(a) = $(f)_{t-1}$**	**(b) = S – $(f)_{t-LT}$**	**(c) = (a) + (b)**	**(d)**	**(e)= (d) - (c)**	**(f) = (c) – (e)**	**(g) = (d) – (e)**	**(h) = S – (f)**	**(i)**	**(j)**	**(k)**
1	40,000	0	40,000	18,677	18,677	21,323	0	140,442	Yes	2	Yes
2	21,323	0	21,323	32,558	21,323	0	11,235	0	No	2	No
3	0	140,442	140,442	39,143	39,143	101,299	0	60,466	Yes	2	Yes
4	101,299	0	101,299	22,212	22,212	79,087	0	0	No	2	No
5	79,087	60,466	139,553	13,809	13,809	125,744	0	0	No	2	Yes
6	125,744	0	125,744	22,159	22,159	103,585	0	0	No	2	No
7	103,585	0	103,585	32,455	32,455	71,130	0	90,635	Yes	2	Yes
8	71,130	0	71,130	23,149	23,149	47,981	0	0	No	2	No
9	47,981	90,635	138,616	22,644	22,644	115,972	0	45,793	Yes	2	Yes
10	115,972	0	115,972	29,621	29,621	86,351	0	0	No	2	No
11	86,351	45,793	132,144	27,199	27,199	104,945	0	56,820	Yes	2	Yes
12	104,945	0	104,945	33,134	33,134	71,811	0	0	No	2	No
13	71,811	56,820	128,631	28,415	28,415	100,216	0	61,549	Yes	2	Yes
14	100,216	0	100,216	15,339	15,339	84,877	0	0	No	2	No
15	84,877	61,549	146,426	17,028	17,028	129,398	0	0	No	2	Yes
16	129,398	0	129,398	16,892	16,892	112,506	0	0	No	2	No

Table 4. 34 Monte Carlo Simulation for (R, s, S) system in 20SDR17 (Con't)

Period	Initial Inventory	Order Receipt	Available Inventory	Demand	Fulfilled Demand	Ending Inventory	Stockout	Order Release	Production Decision	Lead Time	Review Period
17	112,506	0	112,506	17,768	17,768	94,738	0	67,027	Yes	2	Yes
18	94,738	0	94,738	21,006	21,006	73,732	0	0	No	2	No
19	73,732	67,027	140,759	21,804	21,804	118,955	0	0	No	2	Yes
20	118,955	0	118,955	25,157	25,157	93,798	0	0	No	2	No
21	93,798	0	93,798	27,585	27,585	66,213	0	95,552	Yes	2	Yes
22	66,213	0	66,213	20,365	20,365	45,848	0	0	No	2	No
23	45,848	95,552	141,400	23,604	23,604	117,796	0	0	No	2	Yes
24	117,796	0	117,796	33,022	33,022	84,774	0	0	No	2	No
25	84,774	0	84,774	28,292	28,292	56,482	0	105,283	Yes	2	Yes
26	56,482	0	56,482	18,715	18,715	37,767	0	0	No	2	No
27	37,767	105,283	143,050	16,423	16,423	126,627	0	0	No	2	Yes
28	126,627	0	126,627	23,989	23,989	102,638	0	0	No	2	No
29	102,638	0	102,638	30,935	30,935	71,703	0	90,062	Yes	2	Yes
30	71,703	0	71,703	18,133	18,133	53,570	0	0	No	2	No
31	53,570	90,062	143,632	17,310	17,310	126,322	0	0	No	2	Yes
32	126,322	0	126,322	14,983	14,983	111,339	0	0	No	2	No
33	111,339	0	111,339	13,996	13,996	97,343	0	64,422	Yes	2	Yes
34	97,343	0	97,343	13,185	13,185	84,158	0	0	No	2	No
35	84,158	64,422	148,580	20,149	20,149	128,431	0	0	No	2	Yes
36	128,431	0	128,431	22,366	22,366	106,065	0	0	No	2	No
37	106,065	0	106,065	27,540	27,540	78,525	0	83,240	Yes	2	Yes
38	78,525	0	78,525	16,048	16,048	62,477	0	0	No	2	No
39	62,477	83,240	145,717	25,064	25,064	120,653	0	0	No	2	Yes
40	120,653	0	120,653	16,784	16,784	103,869	0	0	No	2	No
41	103,869	0	103,869	25,290	25,290	78,579	0	83,186	Yes	2	Yes

Table 4. 34 Monte Carlo Simulation for (R, s, S) system in 20SDR17 (Con't)

Period	Initial Inventory	Order Receipt	Available Inventory	Demand	Fulfilled Demand	Ending Inventory	Stockout	Order Release	Production Decision	Lead Time	Review Period
42	78,579	0	78,579	24,125	24,125	54,454	0	0	No	2	No
43	54,454	83,186	137,640	24,166	24,166	113,474	0	48,291	Yes	2	Yes
44	113,474	0	113,474	29,288	29,288	84,186	0	0	No	2	No
45	84,186	48,291	132,477	20,334	20,334	112,143	0	49,622	Yes	2	Yes
46	112,143	0	112,143	25,401	25,401	86,742	0	0	No	2	No
47	86,742	49,622	136,364	29,651	29,651	106,713	0	55,052	Yes	2	Yes
48	106,713	0	106,713	18,755	18,755	87,958	0	0	No	2	No
49	87,958	55,052	143,010	19,351	19,351	123,659	0	0	No	2	Yes
50	123,659	0	123,659	32,019	32,019	91,640	0	0	No	2	No
51	91,640	0	91,640	28,696	28,696	62,944	0	0	Yes	2	Yes
52	62,944	0	62,944	22,786	22,786	40,158	0	0	No	2	No

4.6.5 Continuous Review (s, Q) System Simulation

This sub-chapter explains about the simulation of material requirement planning framework combined with the (s, Q) system parameters. It simulates the MRP response when using the (s, Q) system parameters such as the reorder point and order quantity. The response from the parameters are production is triggered when the inventory level is below reorder point and the production size is based on the order quantity. The response of the MRP that is combined with (s, Q) system can be used to measure the total cost and fill rate generated from the simulation. The value of the parameter that is used for the simulation is shown in Table 4. 35.

Table 4. 35 Input Parameter for 20SDR17

20SDR17	
Input Parameter (s, Q) System	
Reorder Point (s)	39,770
Order Quantity (Q)	77,003
Lead Time (Week)	2
Unit Cost	Rp5,360
Holding Cost	Rp1,061
Setup Cost	Rp2,074,327
Stockout Cost	Rp268,000

Monte Carlo simulation is used to generate the demand based on the cumulative probability. The MRP then response according to the input parameters. The result of the simulation is shown in Table 4. 36.

Table 4. 36 Monte Carlo Simulation for (s, Q) system in 20SDR17

Period	**Initial Inventory**	**Order Receipt**	**Available Inventory**	**Demand**	**Fulfilled Demand**	**Ending Inventory**	**Stockout**	**Order Release**	**Production Decision**	**Lead Time**
(l)	**(a) = $(f)_{t-1}$**	**(b) = S – $(f)_{t-LT}$**	**(c) = (a) + (b)**	**(d)**	**(e)= (d) - (c)**	**(f) = (c) – (e)**	**(g) = (d) – (e)**	**(h) = S – (f)**	**(i)**	**(j)**
1	40,000	0	40,000	18,677	18,677	21,323	0	77,004	Yes	2
2	21,323	0	21,323	32,558	21,323	0	11,235	0	No	2
3	0	77,004	77,004	39,143	39,143	37,861	0	77,004	Yes	2

Table 4. 36 Monte Carlo Simulation for (s, Q) system in 20SDR17 (Con't)

Period	Initial Inventory	Order Receipt	Available Inventory	Demand	Fulfilled Demand	Ending Inventory	Stockout	Order Release	Production Decision	Lead Time
4	37,861	0	37,861	22,212	22,212	15,649	0	0	No	2
5	15,649	77,004	92,653	13,809	13,809	78,844	0	0	No	2
6	78,844	0	78,844	22,159	22,159	56,685	0	0	No	2
7	56,685	0	56,685	32,455	32,455	24,230	0	77,004	Yes	2
8	24,230	0	24,230	23,149	23,149	1,081	0	0	No	2
9	1,081	77,004	78,084	22,644	22,644	55,440	0	0	No	2
10	55,440	0	55,440	29,621	29,621	25,819	0	77,004	Yes	2
11	25,819	0	25,819	27,199	25,819	0	1,380	0	No	2
12	0	77,004	77,004	34,514	34,514	42,490	0	0	No	2
13	42,490	0	42,490	28,415	28,415	14,075	0	77,004	Yes	2
14	14,075	0	14,075	15,339	14,075	0	1,264	0	No	2
15	0	77,004	77,004	18,292	18,292	58,712	0	0	No	2
16	58,712	0	58,712	16,892	16,892	41,820	0	0	No	2
17	41,820	0	41,820	17,768	17,768	24,052	0	77,004	Yes	2
18	24,052	0	24,052	21,006	21,006	3,046	0	0	No	2
19	3,046	77,004	80,050	21,804	21,804	58,246	0	0	No	2
20	58,246	0	58,246	25,157	25,157	33,089	0	77,004	Yes	2
21	33,089	0	33,089	27,585	27,585	5,504	0	0	No	2
22	5,504	77,004	82,507	20,365	20,365	62,142	0	0	No	2
23	62,142	0	62,142	23,604	23,604	38,538	0	77,004	Yes	2
24	38,538	0	38,538	33,022	33,022	5,516	0	0	No	2
25	5,516	77,004	82,520	28,292	28,292	54,228	0	0	No	2
26	54,228	0	54,228	18,715	18,715	35,513	0	77,004	Yes	2
27	35,513	0	35,513	16,423	16,423	19,090	0	0	No	2
28	19,090	77,004	96,094	23,989	23,989	72,105	0	0	No	2

Table 4. 36 Monte Carlo Simulation for (s, Q) system in 20SDR17 (Con't)

Period	Initial Inventory	Order Receipt	Available Inventory	Demand	Fulfilled Demand	Ending Inventory	Stockout	Order Release	Production Decision	Lead Time
29	72,105	0	72,105	30,935	30,935	41,170	0	0	No	2
30	41,170	0	41,170	18,133	18,133	23,037	0	77,004	Yes	2
31	23,037	0	23,037	17,310	17,310	5,727	0	0	No	2
32	5,727	77,004	82,731	14,983	14,983	67,748	0	0	No	2
33	67,748	0	67,748	13,996	13,996	53,752	0	0	No	2
34	53,752	0	53,752	13,185	13,185	40,567	0	0	No	2
35	40,567	0	40,567	20,149	20,149	20,418	0	77,004	Yes	2
36	20,418	0	20,418	22,366	20,418	0	1,948	0	No	2
37	0	77,004	77,004	29,488	29,488	47,515	0	0	No	2
38	47,515	0	47,515	16,048	16,048	31,467	0	77,004	Yes	2
39	31,467	0	31,467	25,064	25,064	6,403	0	0	No	2
40	6,403	77,004	83,407	16,784	16,784	66,623	0	0	No	2
41	66,623	0	66,623	25,290	25,290	41,333	0	0	No	2
42	41,333	0	41,333	24,125	24,125	17,208	0	77,004	Yes	2
43	17,208	0	17,208	24,166	17,208	0	6,958	0	No	2
44	0	77,004	77,004	36,246	36,246	40,758	0	0	No	2
45	40,758	0	40,758	20,334	20,334	20,424	0	77,004	Yes	2
46	20,424	0	20,424	25,401	20,424	0	4,977	0	No	2
47	0	77,004	77,004	34,628	34,628	42,376	0	0	No	2
48	42,376	0	42,376	18,755	18,755	23,621	0	77,004	Yes	2
49	23,621	0	23,621	19,351	19,351	4,270	0	0	No	2
50	4,270	77,004	81,273	32,019	32,019	49,254	0	0	No	2
51	49,254	0	49,254	28,696	28,696	20,558	0	0	Yes	2
52	20,558	0	20,558	22,786	20,558	0	2,228	0	No	2

4.6.6 Continuous Review (s, S) System Simulation

This sub-chapter explains about the simulation of material requirement planning framework combined with the (s, S) system parameters. It simulates the MRP response when using the (s, S) system parameters such as the reorder point and maximum inventory level. The response from the parameters are production is triggered when the inventory level is below reorder point and the production size is adjusted to the maximum inventory level. The response of the MRP that is combined with (s, S) system can be used to measure the total cost and fill rate generated from the simulation. The value of the parameter that is used for the simulation is shown in Table 4. 37.

Table 4. 37 Input Parameter for 20SDR17

20SDR17	
Input Parameter (s, S) System	
Reorder Point (s)	31,699
Maximum inventory level (S)	99,289
Lead Time (Week)	2
Unit Cost	Rp5,360
Holding Cost	Rp1,061
Setup Cost	Rp2,074,327
Stockout Cost	Rp268,000

Monte Carlo simulation is used to generate the demand based on the cumulative probability. The MRP then response according to the input parameters. The result of the simulation is shown in Table 4. 38.

Table 4. 38 Monte Carlo Simulation for (s, S) system in 20SDR17

Period	Initial Inventory	Order Receipt	Available Inventory	Demand	Fulfilled Demand	Ending Inventory	Stockout	Order Release	Production Decision	Lead Time
(l)	**(a) = $(f)_{t-1}$**	**(b) = S – $(f)_{t-LT}$**	**(c) = (a) + (b)**	**(d)**	**(e)= (d) - (c)**	**(f) = (c) – (e)**	**(g) = (d) – (e)**	**(h) = S – (f)**	**(i)**	**(j)**
1	40,000	0	40,000	18,677	18,677	21,323	0	77,966	Yes	2
2	21,323	0	21,323	32,558	21,323	0	11,235	0	No	2
3	0	77,966	77,966	39,143	39,143	38,823	0	0	No	2
4	38,823	0	38,823	22,212	22,212	16,611	0	82,678	Yes	2
5	16,611	0	16,611	13,809	13,809	2,802	0	0	No	2
6	2,802	82,678	85,480	22,159	22,159	63,321	0	0	No	2
7	63,321	0	63,321	32,455	32,455	30,866	0	68,423	Yes	2
8	30,866	0	30,866	23,149	23,149	7,717	0	0	No	2
9	7,717	68,423	76,140	22,644	22,644	53,496	0	0	No	2
10	53,496	0	53,496	29,621	29,621	23,875	0	75,414	Yes	2
11	23,875	0	23,875	27,199	23,875	0	3,324	0	No	2
12	0	75,414	75,414	36,458	36,458	38,956	0	0	No	2
13	38,956	0	38,956	28,415	28,415	10,541	0	88,748	Yes	2
14	10,541	0	10,541	15,339	10,541	0	4,798	0	No	2
15	0	88,748	88,748	21,826	21,826	66,922	0	0	No	2
16	66,922	0	66,922	16,892	16,892	50,030	0	0	No	2
17	50,030	0	50,030	17,768	17,768	32,262	0	0	No	2
18	32,262	0	32,262	21,006	21,006	11,256	0	88,033	Yes	2
19	11,256	0	11,256	21,804	11,256	0	10,548	0	No	2
20	0	88,033	88,033	35,705	35,705	52,328	0	0	No	2
21	52,328	0	52,328	27,585	27,585	24,743	0	74,546	Yes	2

Table 4. 38 Monte Carlo Simulation for (s, S) system in 20SDR17 (Con't)

Period	Initial Inventory	Order Receipt	Available Inventory	Demand	Fulfilled Demand	Ending Inventory	Stockout	Order Release	Production Decision	Lead Time
22	24,743	0	24,743	20,365	20,365	4,378	0	0	No	2
23	4,378	74,546	78,924	23,604	23,604	55,320	0	0	No	2
24	55,320	0	55,320	33,022	33,022	22,298	0	76,991	Yes	2
25	22,298	0	22,298	28,292	22,298	0	5,994	0	No	2
26	0	76,991	76,991	24,709	24,709	52,282	0	0	No	2
27	52,282	0	52,282	16,423	16,423	35,859	0	0	No	2
28	35,859	0	35,859	23,989	23,989	11,870	0	87,419	Yes	2
29	11,870	0	11,870	30,935	11,870	0	19,065	0	No	2
30	0	87,419	87,419	37,198	37,198	50,221	0	0	No	2
31	50,221	0	50,221	17,310	17,310	32,911	0	0	No	2
32	32,911	0	32,911	14,983	14,983	17,928	0	81,361	Yes	2
33	17,928	0	17,928	13,996	13,996	3,932	0	0	No	2
34	3,932	81,361	85,293	13,185	13,185	72,108	0	0	No	2
35	72,108	0	72,108	20,149	20,149	51,959	0	0	No	2
36	51,959	0	51,959	22,366	22,366	29,593	0	69,696	Yes	2
37	29,593	0	29,593	27,540	27,540	2,053	0	0	No	2
38	2,053	69,696	71,749	16,048	16,048	55,701	0	0	No	2
39	55,701	0	55,701	25,064	25,064	30,637	0	68,652	Yes	2
40	30,637	0	30,637	16,784	16,784	13,853	0	0	No	2
41	13,853	68,652	82,505	25,290	25,290	57,215	0	0	No	2
42	57,215	0	57,215	24,125	24,125	33,090	0	0	No	2
43	33,090	0	33,090	24,166	24,166	8,924	0	90,365	Yes	2
44	8,924	0	8,924	29,288	8,924	0	20,364	0	No	2
45	0	90,365	90,365	40,698	40,698	49,667	0	0	No	2
46	49,667	0	49,667	25,401	25,401	24,266	0	75,023	Yes	2

Table 4. 38 Monte Carlo Simulation for (s, S) system in 20SDR17 (Con't)

Period	Initial Inventory	Order Receipt	Available Inventory	Demand	Fulfilled Demand	Ending Inventory	Stockout	Order Release	Production Decision	Lead Time
47	24,266	0	24,266	29,651	24,266	0	5,385	0	No	2
48	0	75,023	75,023	24,140	24,140	50,883	0	0	No	2
49	50,883	0	50,883	19,351	19,351	31,532	0	67,757	Yes	2
50	31,532	0	31,532	32,019	31,532	0	487	0	No	2
51	0	67,757	67,757	29,183	29,183	38,574	0	0	No	2
52	38,574	0	38,574	22,786	22,786	15,788	0	0	Yes	2

4.6.7 Inventory Control Policy Comparison

Each policy used can generate different output. To know which is best to be implemented, the output from each of the policy must be compared. The total cost and fill rate from implementing the inventory control policy are calculated and compared with each other. The recapitulation of the inventory control policy comparison is shown in Table 4. 40 until Table 4. 42.

4.6.7.1 Comparison for Class A Product

The policies give different output in the simulation. The outputs are unit cost, holding cost, setup cost, stockout cost, fill rate, and cost reduction. Each policy can give different values from the output. The recapitulation for the output from a different policy for class A product is shown in Table 4. 39.

Table 4. 39 Recapitulation of Class A Product Output

Item	Policy	Unit Cost	Holding Cost	Setup Cost	Stockout Cost	Fill Rate	Total Cost	Cost Reduction
20SDR 17	Existing	Rp6,409,498,720	Rp26,787,008	Rp41,486,558	Rp56,416,144	96.24%	Rp6,534,188,430	0.00%
	R, S	Rp6,379,843,200	Rp49,406,713	Rp37,337,903	Rp12,043,920	99.34%	Rp6,478,631,736	0.85%
	R, s, S	Rp6,418,291,497	Rp93,122,442	Rp35,263,575	Rp12,043,920	99.34%	Rp6,558,721,433	-0.38%
	s, Q	Rp6,191,102,539	Rp31,620,794	Rp33,189,247	Rp32,148,759	97.79%	Rp6,288,061,338	3.77%
	s, S	Rp6,287,667,398	Rp28,547,168	Rp33,189,247	Rp87,044,035	94.26%	Rp6,436,447,848	1.50%
110SD R17	Existing	Rp4,951,718,450	Rp42,273,669	Rp18,668,951	Rp76,751,906	91.989%	Rp5,089,412,976	0.00%
	R, S	Rp4,869,581,944	Rp49,076,356	Rp37,337,903	Rp56,326,195	96.72%	Rp5,012,322,397	1.51%
	R, s, S	Rp4,899,765,302	Rp89,097,626	Rp33,189,247	Rp40,978,994	97.56%	Rp5,063,031,170	0.52%
	s, Q	Rp4,829,853,032	Rp39,875,450	Rp29,040,591	Rp63,261,133	95.63%	Rp4,962,030,206	2.50%
	s, S	Rp4,843,553,012	Rp34,754,915	Rp26,966,263	Rp41,010,082	97.55%	Rp4,946,284,271	2.81%
63SDR 17	Existing	Rp4,396,794,600	Rp24,322,139	Rp41,486,558	Rp23,301,828	98.364%	Rp4,485,905,126	0.00%
	R, S	Rp4,381,760,987	Rp41,781,824	Rp37,337,903	Rp0	100.00%	Rp4,460,880,713	0.56%
	R, s, S	Rp4,604,414,018	Rp79,230,649	Rp31,114,919	Rp0	100.00%	Rp4,714,759,586	-5.10%
	s, Q	Rp4,471,551,174	Rp34,210,949	Rp31,114,919	Rp27,323,124	98.07%	Rp4,564,200,167	-1.75%
	s, S	Rp4,205,039,265	Rp28,183,135	Rp26,966,263	Rp48,616,559	95.41%	Rp4,308,805,222	3.95%
25SDR 17	Existing	Rp4,585,831,660	Rp28,697,326	Rp24,891,935	Rp62,029,110	93.967%	Rp4,701,450,031	0.00%
	R,S	Rp4,627,313,300	Rp38,933,108	Rp26,966,263	Rp24,781,298	97.60%	Rp4,717,993,969	-0.35%
	R,s,S	Rp4,840,776,359	Rp88,668,559	Rp37,337,903	Rp22,734,114	97.82%	Rp4,989,516,935	-6.13%
	s,Q	Rp4,397,845,659	Rp24,341,091	Rp31,114,919	Rp50,980,466	95.09%	Rp4,504,282,135	4.19%
	s,S	Rp4,631,327,635	Rp21,667,913	Rp29,040,591	Rp72,600,899	92.46%	Rp4,754,637,038	-1.13%
20SDR 11	Existing	Rp4,113,771,300	Rp67,065,861	Rp41,486,558	Rp13,742,424	97.995%	Rp4,236,066,144	0.00%
	R,S	Rp4,145,652,988	Rp41,781,531	Rp26,966,263	Rp13,742,424	97.99%	Rp4,228,143,206	0.19%
	R,s,S	Rp4,359,284,518	Rp90,704,898	Rp37,337,903	Rp13,742,424	97.99%	Rp4,501,069,742	-6.26%
	s,Q	Rp4,046,353,545	Rp28,732,599	Rp29,040,591	Rp16,956,513	97.68%	Rp4,121,083,248	2.71%

Table 4. 39 Recapitulation of Class A Product Output (Con't)

Item	Policy	Unit Cost	Holding Cost	Setup Cost	Stockout Cost	Fill Rate	Total Cost	Cost Reduction
20SDR 11	s,S	Rp3,947,163,244	Rp23,864,885	Rp26,966,263	Rp38,475,882	95.0%	Rp4,036,470,274	4.71%
32SDR 17	Existing	Rp3,321,435,600	Rp51,404,055	Rp43,560,886	Rp10,190,992	98.497%	Rp3,426,591,533	0.00%
	R,S	Rp3,311,306,903	Rp38,622,433	Rp26,966,263	Rp22,656,583	97.33%	Rp3,399,552,181	0.79%
	R,s,S	Rp3,381,952,165	Rp80,306,987	Rp26,966,263	Rp10,190,992	98.50%	Rp3,499,416,407	-2.13%
	s,Q	Rp3,317,368,556	Rp36,448,476	Rp22,817,607	Rp16,385,873	97.97%	Rp3,393,020,512	0.98%
	s,S	Rp3,134,271,032	Rp27,766,356	Rp22,817,607	Rp38,752,933	95.57%	Rp3,223,607,928	5.92%
32SDR 11	Existing	Rp3,336,413,600	Rp51,370,742	Rp53,932,526	Rp10,346,024	98.650%	Rp3,452,062,892	0.00%
	R,S	Rp3,261,413,945	Rp31,789,958	Rp26,966,263	Rp11,469,495	98.52%	Rp3,331,639,661	3.49%
	R,s,S	Rp3,294,895,935	Rp68,472,734	Rp29,040,591	Rp10,346,024	98.65%	Rp3,402,755,284	1.43%
	s,Q	Rp3,283,942,614	Rp29,163,555	Rp24,891,935	Rp10,346,024	98.65%	Rp3,348,344,128	3.00%
	s,S	Rp3,072,638,056	Rp22,559,049	Rp24,891,935	Rp27,087,508	96.43%	Rp3,147,176,548	8.83%

Description:

(green box) : Chosen Method

4.6.7.2 Comparison for Class B Product

The policy gives different output in the simulation. The outputs are unit cost, holding cost, setup cost, stockout cost, fill rate, and cost reduction. Each policy can give different values from the output. The recapitulation for the output from a different policy for class B product is shown in Table 4. 40.

Table 4. 40 Recapitulation of Class B Product Output

Item	Policy	Unit Cost	Holding Cost	Setup Cost	Stockout Cost	Fill Rate	Total Cost	Cost Reduction
90SDR 17	Existing	Rp3,538,660,500	Rp79,349,038	Rp26,966,263	Rp-	100%	Rp3,644,975,801	0.00%
	R,S	Rp3,318,245,067	Rp35,193,129	Rp26,966,263	Rp0	100%	Rp3,380,404,459	7.26%
	R,s,S	Rp3,384,387,107	Rp77,939,964	Rp33,189,247	Rp0	100%	Rp3,495,516,318	4.10%
	s,Q	Rp3,208,220,388	Rp26,675,110	Rp26,966,263	Rp9,619,623	99.01%	Rp3,271,481,384	10.25%
	s,S	Rp3,273,233,925	Rp22,978,953	Rp22,817,607	Rp37,492,275	94.71%	Rp3,356,522,760	7.91%
50SDR 11	Existing	Rp2,496,748,800	Rp58,735,804	Rp16,594,623	Rp2,620,800	99.560%	Rp2,574,700,027	0.00%
	R, S	Rp2,286,820,967	Rp32,538,714	Rp22,817,607	Rp2,620,800	99.56%	Rp2,344,798,088	8.93%
	R, s, S	Rp2,433,879,211	Rp71,131,807	Rp24,891,935	Rp2,620,800	99.56%	Rp2,532,523,753	1.64%
	s, Q	Rp2,372,243,800	Rp24,302,303	Rp20,743,279	Rp12,030,492	98.41%	Rp2,429,319,874	5.65%
	s, S	Rp2,282,128,648	Rp21,296,360	Rp18,668,951	Rp25,180,023	94.83%	Rp2,347,273,982	8.83%
200SD R17	Existing	Rp1,569,340,200	Rp12,215,429	Rp20,743,279	Rp39,902,058	92.570%	Rp1,642,200,966	0.00%
	R,S	Rp1,614,615,501	Rp21,681,916	Rp18,668,951	Rp11,235,838	97.23%	Rp1,666,202,205	-1.46%
	R,s,S	Rp1,620,835,139	Rp53,665,985	Rp16,594,623	Rp0	100.00%	Rp1,691,095,748	-2.98%
	s,Q	Rp1,511,956,113	Rp24,647,427	Rp18,668,951	Rp2,398,571	99.46%	Rp1,557,671,063	5.15%
	s,S	Rp1,521,817,158	Rp20,474,464	Rp18,668,951	Rp426,362	99.90%	Rp1,561,386,935	4.92%
63SDR 11	Existing	Rp1,836,902,880	Rp21,131,494	Rp18,668,951	Rp3,704,256	99.372%	Rp1,880,407,581	0.00%
	R,S	Rp1,838,698,578	Rp26,623,604	Rp18,668,951	Rp0	100.00%	Rp1,883,991,133	-0.19%
	R,s,S	Rp1,900,253,906	Rp59,501,555	Rp20,743,279	Rp0	100.00%	Rp1,980,498,740	-5.32%
	s,Q	Rp1,767,222,795	Rp24,758,636	Rp18,668,951	Rp0	100.00%	Rp1,810,650,382	3.71%
	s,S	Rp1,647,369,886	Rp19,497,091	Rp18,668,951	Rp8,985,620	98.33%	Rp1,694,521,549	9.89%
160SD R17	Existing	Rp1,982,785,730	Rp21,767,236	Rp29,040,591	Rp7,232,320	98.734%	Rp2,040,825,877	0.00%
	R,S	Rp1,838,435,736	Rp20,972,079	Rp22,817,607	Rp9,554,666	98.24%	Rp1,891,780,087	7.30%
	R,s,S	Rp2,141,334,045	Rp57,010,899	Rp22,817,607	Rp7,232,320	98.73%	Rp2,228,394,871	-9.19%
	s,Q	Rp1,964,559,134	Rp23,596,448	Rp20,743,279	Rp7,530,068	98.69%	Rp2,016,428,929	1.20%

Table 4. 40 Recapitulation of Class B Product Output (Con't)

Item	Policy	Unit Cost	Holding Cost	Setup Cost	Stockout Cost	Fill Rate	Total Cost	Cost Reduction
160SD R17	s,S	Rp1,887,713,599	Rp20,777,647	Rp18,668,951	Rp14,433,409	97.72%	Rp1,941,593,606	4.86%
90SDR 11	Existing	Rp1,771,502,780	Rp21,783,632	Rp26,966,263	Rp3,539,424	99.495%	Rp1,823,792,099	0.00%
	R,S	Rp1,784,764,091	Rp28,521,987	Rp18,668,951	Rp31,110,203	92.91%	Rp1,863,065,232	-2.15%
	R,s,S	Rp1,818,913,743	Rp60,295,440	Rp18,668,951	Rp0	100.00%	Rp1,897,878,134	-4.06%
	s,Q	Rp1,761,150,489	Rp29,844,643	Rp18,668,951	Rp492,230	99.94%	Rp1,810,156,313	0.75%
	s,S	Rp1,689,826,558	Rp23,273,399	Rp18,668,951	Rp21,856,626	96.79%	Rp1,753,625,534	3.85%
20SDR 13.6	Existing	Rp1,404,470,690	Rp8,315,912	Rp22,817,607	Rp39,708,718	87.686%	Rp1,475,312,927	0.00%
	R,S	Rp1,446,548,664	Rp19,277,528	Rp18,668,951	Rp2,082,557	99.28%	Rp1,486,577,701	-0.76%
	R,s,S	Rp1,519,100,592	Rp48,922,006	Rp22,817,607	Rp225,624	99.89%	Rp1,591,065,829	-7.85%
	s,Q	Rp1,367,514,528	Rp16,626,963	Rp18,668,951	Rp4,237,812	98.63%	Rp1,407,048,255	4.63%
	s,S	Rp1,419,240,115	Rp15,340,030	Rp16,594,623	Rp11,537,409	96.45%	Rp1,462,712,178	0.85%
63SDR 21	Existing	Rp1,198,036,730	Rp20,789,282	Rp33,189,247	Rp2,791,608	98.644%	Rp1,254,806,867	0.00%
	R,S	Rp1,228,711,827	Rp19,046,809	Rp16,594,623	Rp2,791,608	98.64%	Rp1,267,144,867	-0.98%
	R,s,S	Rp1,343,746,153	Rp47,754,744	Rp18,668,951	Rp2,791,608	98.64%	Rp1,412,961,456	-12.60%
	s,Q	Rp1,069,863,889	Rp14,936,604	Rp16,594,623	Rp3,403,836	98.32%	Rp1,104,798,952	11.95%
	s,S	Rp1,166,757,447	Rp13,960,449	Rp14,520,295	Rp11,451,762	94.81%	Rp1,206,689,953	3.83%
200SD R11	Existing	Rp1,200,537,250	Rp39,109,288	Rp8,297,312	Rp0	100%	Rp1,247,943,849	0.00%
	R,S	Rp956,032,122	Rp12,939,829	Rp14,520,295	Rp11,960,505	94.77%	Rp995,452,751	20.23%
	R,s,S	Rp1,134,207,706	Rp39,990,492	Rp14,520,295	Rp0	100.00%	Rp1,188,718,494	4.75%
	s,Q	Rp944,158,204	Rp19,030,445	Rp16,594,623	Rp1,235,955	99.69%	Rp981,019,227	21.39%
	s,S	Rp1,000,780,609	Rp13,198,256	Rp14,520,295	Rp13,437,882	95.44%	Rp1,041,937,043	16.51%
25SDR 11	Existing	Rp774,715,500	Rp30,542,087	Rp8,297,312	Rp2,435,040	98.271%	Rp815,989,938	0.00%
	R,S	Rp738,970,081	Rp13,145,321	Rp12,445,968	Rp4,266,024	97.14%	Rp768,827,393	5.78%
	R,s,S	Rp878,782,133	Rp34,173,177	Rp14,520,295	Rp2,435,040	98.27%	Rp929,910,645	-13.96%

Table 4. 40 Recapitulation of Class B Product Output (Con't)

Item	Policy	Unit Cost	Holding Cost	Setup Cost	Stockout Cost	Fill Rate	Total Cost	Cost Reduction
25SDR 11	s,Q	Rp701,952,171	Rp11,300,058	Rp12,445,968	Rp4,597,522	97.09%	Rp730,295,718	10.50%
	s,S	Rp728,718,601	Rp11,181,934	Rp12,445,968	Rp4,641,389	96.80%	Rp756,987,892	7.23%
90SDR 21	Existing	Rp782,068,000	Rp33,587,886	Rp6,222,984	Rp7,401,800	96.939%	Rp829,280,670	0.00%
	R,S	Rp546,509,651	Rp14,187,201	Rp12,445,968	Rp46,309,207	83.72%	Rp619,452,027	25.30%
	R,s,S	Rp650,824,840	Rp37,518,332	Rp8,297,312	Rp7,401,800	96.94%	Rp704,042,283	15.10%
	s,Q	Rp564,965,285	Rp16,023,513	Rp10,371,640	Rp7,401,800	96.94%	Rp598,762,237	27.80%
	s,S	Rp614,534,660	Rp10,581,856	Rp10,371,640	Rp12,642,236	95.29%	Rp648,130,391	21.84%

Description:

(green) : Chosen Method

4.6.7.3 Comparison for Class C Product

The policy gives different output in the simulation. The outputs are unit cost, holding cost, setup cost, stockout cost, fill rate, and cost reduction. Each policy can give different values from the output. The recapitulation for the output from a different policy for class C product is shown in Table 4. 41.

Table 4. 41 Recapitulation of Class C Product Output

Item	Policy	Unit Cost	Holding Cost	Setup Cost	Stockout Cost	Fill Rate	Total Cost	Cost Reduction
50SDR 17	Existing	Rp710,520,160	Rp32,279,526	Rp10,371,640	Rp0	100.000%	Rp753,171,326	0.00%
	R,S	Rp493,173,638	Rp10,869,031	Rp12,445,968	Rp7,014,554	92.73%	Rp523,503,191	30.49%

Table 4. 41 Recapitulation of Class C Product Output (Con't)

Item	Policy	Unit Cost	Holding Cost	Setup Cost	Stockout Cost	Fill Rate	Total Cost	Cost Reduction
50SDR 17	R,s,S	Rp677,024,207	Rp31,389,472	Rp12,445,968	Rp0	100.00%	Rp720,859,646	4.29%
	s,Q	Rp631,716,742	Rp13,163,109	Rp12,445,968	Rp0	100.00%	Rp657,325,818	12.73%
	s,S	Rp547,238,660	Rp10,409,229	Rp10,371,640	Rp11,388,744	94.46%	Rp579,408,273	23.07%
110SD R11	Existing	Rp381,609,800	Rp630,252	Rp43,560,886	Rp109,889,780	54.575%	Rp535,690,718	0.00%
	R,S	Rp461,689,617	Rp6,897,936	Rp10,371,640	Rp41,207,760	83.25%	Rp520,166,952	2.90%
	R,s,S	Rp515,024,964	Rp27,155,272	Rp8,297,312	Rp0	100.00%	Rp550,477,548	-2.76%
	s,Q	Rp444,320,753	Rp11,263,304	Rp10,371,640	Rp1,547,750	98.98%	Rp467,503,446	12.73%
	s,S	Rp461,193,482	Rp8,466,192	Rp10,371,640	Rp3,470,718	96.67%	Rp483,502,031	9.74%
25SDR 13.6	Existing	Rp256,283,836	Rp7,936,373	Rp31,114,919	Rp1,568,104	97.347%	Rp296,903,232	0.00%
	R,S	Rp262,037,705	Rp7,923,575	Rp8,297,312	Rp1,568,104	97.35%	Rp279,826,696	5.75%
	R,s,S	Rp311,182,892	Rp21,421,885	Rp8,297,312	Rp1,568,104	97.35%	Rp342,470,192	-15.35%
	s,Q	Rp258,392,130	Rp6,936,886	Rp8,297,312	Rp1,568,104	97.35%	Rp275,194,432	7.31%
	s,S	Rp268,888,307	Rp6,404,277	Rp8,297,312	Rp2,687,447	95.30%	Rp286,277,342	3.58%
40SDR 17	Existing	Rp285,298,260	Rp11,296,758	Rp26,966,263	Rp1,108,296	98.757%	Rp324,669,577	0.00%
	R,S	Rp288,076,358	Rp7,893,842	Rp8,297,312	Rp1,968,832	96.75%	Rp306,236,344	5.68%
	R,s,S	Rp344,566,592	Rp21,743,493	Rp8,297,312	Rp1,108,296	98.76%	Rp375,715,693	-15.72%
	s,Q	Rp279,686,202	Rp8,331,294	Rp8,297,312	Rp1,108,296	98.76%	Rp297,423,104	8.39%
	s,S	Rp283,724,770	Rp6,890,676	Rp8,297,312	Rp1,910,680	97.70%	Rp300,823,437	7.34%
75SDR 11	Existing	Rp265,970,750	Rp7,834,997	Rp8,297,312	Rp1,611,500	97.087%	Rp283,714,559	0.00%
	R,S	Rp261,968,998	Rp9,341,709	Rp8,297,312	Rp1,630,001	95.15%	Rp281,238,019	0.87%
	R,s,S	Rp317,348,309	Rp22,273,050	Rp8,297,312	Rp1,611,500	97.09%	Rp349,530,171	-23.20%
	s,Q	Rp267,610,982	Rp7,699,875	Rp8,297,312	Rp1,806,402	96.84%	Rp285,414,570	-0.60%
	s,S	Rp206,340,423	Rp7,682,363	Rp8,297,312	Rp2,946,581	95.49%	Rp225,266,679	20.60%
32SDR 13.6	Existing	Rp219,153,200	Rp6,616,358	Rp29,040,591	Rp861,350	97.97%	Rp255,671,499	0.00%
	R,S	Rp232,552,903	Rp8,910,264	Rp8,297,312	Rp861,350	97.97%	Rp250,621,828	1.98%

Table 4. 41 Recapitulation of Class C Product Output (Con't)

Item	Policy	Unit Cost	Holding Cost	Setup Cost	Stockout Cost	Fill Rate	Total Cost	Cost Reduction
32SDR 13.6	R,s,S	Rp275,222,214	Rp22,657,205	Rp8,297,312	Rp861,350	97.97%	Rp307,038,081	-20.09%
	s,Q	Rp236,412,173	Rp7,399,348	Rp8,297,312	Rp861,350	97.97%	Rp252,970,183	1.06%
	s,S	Rp242,320,044	Rp6,890,638	Rp8,297,312	Rp1,096,621	97.46%	Rp258,604,614	-1.15%
160SD R11	Existing	Rp271,489,100	Rp15,420,592	Rp12,445,968	Rp0	100.000%	Rp299,355,660	0.00%
	R,S	Rp179,818,343	Rp4,837,273	Rp6,222,984	Rp19,202,931	80.10%	Rp210,081,531	29.82%
	R,s,S	Rp249,128,956	Rp18,895,433	Rp8,297,312	Rp0	100.00%	Rp276,321,700	7.69%
	s,Q	Rp247,553,025	Rp8,184,001	Rp8,297,312	Rp731,060	99.62%	Rp264,765,397	11.55%
	s,S	Rp197,291,842	Rp5,025,742	Rp8,297,312	Rp13,728,503	91.87%	Rp224,343,399	25.06%
110SD R13.6	Existing	Rp212,882,880	Rp6,778,225	Rp6,222,984	Rp8,520,624	94.354%	Rp234,404,713	0.00%
	R,S	Rp160,795,385	Rp3,091,097	Rp6,222,984	Rp27,228,018	80.42%	Rp197,337,484	15.81%
	R,s,S	Rp226,232,505	Rp15,154,194	Rp6,222,984	Rp6,290,928	97.00%	Rp253,900,611	-8.32%
	s,Q	Rp203,035,429	Rp6,702,189	Rp8,297,312	Rp6,290,928	97.00%	Rp224,325,858	4.30%
	s,S	Rp210,367,303	Rp3,755,589	Rp8,297,312	Rp15,099,874	88.83%	Rp237,520,078	-1.33%
50SDR 13.6	Existing	Rp241,279,200	Rp11,574,504	Rp6,222,984	Rp0	100.000%	Rp259,076,688	0.00%
	R,S	Rp187,160,048	Rp6,800,262	Rp8,297,312	Rp0	100.00%	Rp202,257,622	21.93%
	R,s,S	Rp303,997,989	Rp18,994,593	Rp8,297,312	Rp0	100.00%	Rp331,289,894	-27.87%
	s,Q	Rp188,243,914	Rp6,038,018	Rp8,297,312	Rp0	100.00%	Rp202,579,244	21.81%
	s,S	Rp196,362,836	Rp6,076,959	Rp6,222,984	Rp824,786	97.16%	Rp209,487,565	19.14%
250SD R17	Existing	Rp92,395,680	Rp6,713,602	Rp4,148,656	Rp0	100.000%	Rp103,257,938	0.00%
	R,S	Rp73,337,897	Rp4,901,792	Rp4,148,656	Rp0	100.00%	Rp82,388,344	20.21%
	R,s,S	Rp111,182,646	Rp12,787,629	Rp4,148,656	Rp0	100.00%	Rp128,118,931	-24.08%
	s,Q	Rp78,665,607	Rp5,315,350	Rp4,148,656	Rp0	100.00%	Rp88,129,613	14.65%
	s,S	Rp80,067,608	Rp3,329,164	Rp4,148,656	Rp1,481,518	94.36%	Rp89,026,947	13.78%
40SDR 11	Existing	Rp94,192,290	Rp7,570,964	Rp8,297,312	Rp0	100.000%	Rp110,060,565	0.00%
	R,S	Rp68,121,296	Rp4,302,407	Rp4,148,656	Rp0	100.00%	Rp76,572,359	30.43%
	R,s,S	Rp103,466,543	Rp11,452,831	Rp4,148,656	Rp0	100.00%	Rp119,068,029	-8.18%

Table 4. 41 Recapitulation of Class C Product Output (Con't)

Item	Policy	Unit Cost	Holding Cost	Setup Cost	Stockout Cost	Fill Rate	Total Cost	Cost Reduction
40SDR 11	s,Q	Rp73,372,045	Rp4,073,087	Rp4,148,656	Rp0	100.00%	Rp81,593,788	25.86%
	s,S	Rp73,309,020	Rp3,780,107	Rp4,148,656	Rp288,234	98.92%	Rp81,526,016	25.93%
40SDR 13.6	Existing	Rp70,561,050	Rp2,877,829	Rp6,222,984	Rp0	100.000%	Rp79,661,863	0.00%
	R,S	Rp67,063,131	Rp4,180,022	Rp4,148,656	Rp0	100.00%	Rp75,391,809	5.36%
	R,s,S	Rp99,759,335	Rp10,890,753	Rp4,148,656	Rp0	100.00%	Rp114,798,744	-44.11%
	s,Q	Rp68,893,654	Rp3,717,768	Rp4,148,656	Rp0	100.00%	Rp76,760,078	3.64%
	s,S	Rp70,709,747	Rp3,528,840	Rp4,148,656	Rp680,691	96.00%	Rp79,067,934	0.75%
160SD R13.6	Existing	Rp49,687,440	Rp3,521,373	Rp4,148,656	Rp280,720	97.976%	Rp57,638,189	0.00%
	R,S	Rp48,294,258	Rp4,653,801	Rp4,148,656	Rp615,500	97.31%	Rp57,712,216	-0.13%
	R,s,S	Rp85,527,769	Rp12,254,337	Rp4,148,656	Rp0	100.00%	Rp101,930,762	-76.85%
	s,Q	Rp35,040,671	Rp3,889,365	Rp4,148,656	Rp346,730	97.91%	Rp43,425,422	24.66%
	s,S	Rp34,832,001	Rp3,866,575	Rp4,148,656	Rp388,464	97.88%	Rp43,235,696	24.99%
60SDR 17	Existing	Rp46,539,920	Rp2,951,108	Rp4,148,656	Rp101,024	97.235%	Rp53,740,708	0.00%
	R,S	Rp45,820,507	Rp3,579,110	Rp4,148,656	Rp0	100.00%	Rp53,548,272	0.36%
	R,s,S	Rp67,940,316	Rp9,331,515	Rp4,148,656	Rp0	100.00%	Rp81,420,487	-51.51%
	s,Q	Rp46,827,732	Rp3,290,471	Rp4,148,656	Rp0	100.00%	Rp54,266,859	-0.98%
	s,S	Rp47,835,570	Rp2,969,947	Rp4,148,656	Rp85,270	96.30%	Rp55,039,443	-2.42%
63SDR 13.6	Existing	Rp21,677,520	Rp2,556,686	Rp2,074,328	Rp0	100.000%	Rp26,308,534	0.00%
	R,S	Rp12,662,731	Rp2,063,296	Rp2,074,328	Rp0	100.00%	Rp16,800,355	36.14%
	R,s,S	Rp28,793,286	Rp5,232,142	Rp2,074,328	Rp0	100.00%	Rp36,099,756	-37.22%
	s,Q	Rp16,138,832	Rp1,795,034	Rp2,074,328	Rp0	100.00%	Rp20,008,193	23.95%
	s,S	Rp16,247,194	Rp1,747,139	Rp2,074,328	Rp52,872	98.35%	Rp20,121,533	23.52%
125SD R21	Existing	Rp13,642,000	Rp418,778	Rp12,445,968	Rp753,900	96.181%	Rp27,260,645	0.00%
	R,S	Rp12,565,000	Rp1,856,172	Rp2,074,328	Rp0	100.00%	Rp16,495,500	39.49%
	R,s,S	Rp29,890,277	Rp4,674,880	Rp2,074,328	Rp0	100.00%	Rp36,639,485	-34.40%

Table 4. 41 Recapitulation of Class C Product Output (Con't)

Item	Policy	Unit Cost	Holding Cost	Setup Cost	Stockout Cost	Fill Rate	Total Cost	Cost Reduction
125SD R21	s,Q	Rp17,116,072	Rp1,315,652	Rp2,074,328	Rp0	100.00%	Rp20,506,052	24.78%
	s,S	Rp16,914,163	Rp967,695	Rp2,074,328	Rp0	100.00%	Rp19,956,186	26.79%
125SD R11	Existing	Rp24,373,200	Rp356,075	Rp12,445,968	Rp1,949,856	85.922%	Rp39,125,099	0.00%
	R,S	Rp16,574,297	Rp1,064,450	Rp2,074,328	Rp15,158,256	62.69%	Rp34,871,331	10.87%
	R,s,S	Rp33,352,130	Rp4,079,550	Rp2,074,328	Rp446,842	96.15%	Rp39,952,851	-2.12%
	s,Q	Rp33,128,156	Rp1,831,862	Rp4,148,656	Rp1,214,415	93.46%	Rp40,323,089	-3.06%
	s,S	Rp32,775,137	Rp1,787,358	Rp4,148,656	Rp1,285,019	93.38%	Rp39,996,170	-2.23%
125SD R17	Existing	Rp6,349,500	Rp489,660	Rp6,222,984	Rp0	100.000%	Rp13,062,144	0.00%
	R,S	Rp4,645,406	Rp815,724	Rp2,074,328	Rp0	100.00%	Rp7,535,458	42.31%
	R,s,S	Rp13,920,508	Rp2,413,581	Rp2,074,328	Rp0	100.00%	Rp18,408,417	-40.93%
	s,Q	Rp9,328,349	Rp727,040	Rp2,074,328	Rp261,450	96.92%	Rp12,391,167	5.14%
	s,S	Rp9,252,830	Rp721,315	Rp2,074,328	Rp261,450	96.92%	Rp12,309,923	5.76%

Description:

: Chosen Method

4.6.8 Scenario Design

After obtaining the simulation result, the next step is to make scenario based on the parameter that has been formulated. The scenario design is conducted by altering the value of the parameter from the recommended system in an incremental manner. The scenarios are formulated in order to discover a more optimal solution from the inventory control policy. The plan in performing the scenario are shown in table 4. 42. The table shows the magnitude of alteration from the recommended system.

Table 4. 42 Scenario Planning

Scenario	Policy								
	R, S		R,s,S			s,Q		s,S	
	R	S	R	s	S	s	Q	s	S
1	+0	-10%	+0	-10%	+0%	-10%	+0%	-10%	+0%
2	+0	-9%	+0	-9%	+0%	-9%	+0%	-9%	+0%
3	+0	-8%	+0	-8%	+0%	-8%	+0%	-8%	+0%
4	+0	-7%	+0	-7%	+0%	-7%	+0%	-7%	+0%
5	+0	-6%	+0	-6%	+0%	-6%	+0%	-6%	+0%
6	+0	-5%	+0	-5%	+0%	-5%	+0%	-5%	+0%
7	+0	-4%	+0	-4%	+0%	-4%	+0%	-4%	+0%
8	+0	-3%	+0	-3%	+0%	-3%	+0%	-3%	+0%
9	+0	-2%	+0	-2%	+0%	-2%	+0%	-2%	+0%
10	+0	-1%	+0	-1%	+0%	-1%	+0%	-1%	+0%
11	+0	+1%	+0	+1%	+0%	+1%	+0%	+1%	+0%
12	+0	+2%	+0	+2%	+0%	+2%	+0%	+2%	+0%
13	+0	+3%	+0	+3%	+0%	+3%	+0%	+3%	+0%
14	+0	+4%	+0	+4%	+0%	+4%	+0%	+4%	+0%
15	+0	+5%	+0	+5%	+0%	+5%	+0%	+5%	+0%
16	+0	+6%	+0	+6%	+0%	+6%	+0%	+6%	+0%
17	+0	+7%	+0	+7%	+0%	+7%	+0%	+7%	+0%
18	+0	+8%	+0	+8%	+0%	+8%	+0%	+8%	+0%
19	+0	+9%	+0	+9%	+0%	+9%	+0%	+9%	+0%
20	+0	+10%	+0	+10%	+0%	+10%	+0%	+10%	+0%
21	+1	-10%	+0	+0%	-10%	+0%	-10%	+0%	-10%

Table 4.42 Scenario Planning (Con't)

Scenario	Policy								
	R, S		R,s,S			s,Q		s,S	
	R	S	R	s	S	s	Q	s	S
22	+1	-9%	+0	+0%	-9%	+0%	-9%	+0%	-9%
23	+1	-8%	+0	+0%	-8%	+0%	-8%	+0%	-8%
24	+1	-7%	+0	+0%	-7%	+0%	-7%	+0%	-7%
25	+1	-6%	+0	+0%	-6%	+0%	-6%	+0%	-6%
26	+1	-5%	+0	+0%	-5%	+0%	-5%	+0%	-5%
27	+1	-4%	+0	+0%	-4%	+0%	-4%	+0%	-4%
28	+1	-3%	+0	+0%	-3%	+0%	-3%	+0%	-3%
29	+1	-2%	+0	+0%	-2%	+0%	-2%	+0%	-2%
30	+1	-1%	+0	+0%	-1%	+0%	-1%	+0%	-1%
31	+1	+1%	+0	+0%	+1%	+0%	+1%	+0%	+1%
32	+1	+2%	+0	+0%	+2%	+0%	+2%	+0%	+2%
33	+1	+3%	+0	+0%	+3%	+0%	+3%	+0%	+3%
34	+1	+4%	+0	+0%	+4%	+0%	+4%	+0%	+4%
35	+1	+5%	+0	+0%	+5%	+0%	+5%	+0%	+5%
36	+1	+6%	+0	+0%	+6%	+0%	+6%	+0%	+6%
37	+1	+7%	+0	+0%	+7%	+0%	+7%	+0%	+7%
38	+1	+8%	+0	+0%	+8%	+0%	+8%	+0%	+8%
39	+1	+9%	+0	+0%	+9%	+0%	+9%	+0%	+9%
40	+1	+10%	+0	+0%	+10%	+0%	+10%	+0%	+10%

The result of the scenarios is quite similar. To be able to choose the most optimal scenarios, the weight of the related variables is measured. The variables that are used for decision making are the fill rate and cost reduction. To obtain the weight of each variable, an interview to the stakeholders is conducted. A pairwise comparison is used to calculate the weight of the variables. The result of the calculation is shown in Table 4. 43.

Table 4. 43 Variables Weight

No	Variable	Score	Weight
1	Fill Rate	1	0.33
2	Cost Reduction	2	0.66

The scenario is conducted by changing the parameter as shown in Table 4.41. The result of applying the scenario in the simulation for 50SDR11 using (R, S) system is shown in Table 4. 44.

Table 4. 44 Scenario Formulation for 50SDR11 Using (R, S) System

Scenario	R	S	Fill Rate	Total Cost	Cost Reduction	Weight
Existing	-	-	99.560%	Rp2,574,700,027	0.00%	0.332
0	+0	+0%	99.56%	Rp2,344,798,088	8.93%	0.3911
1	+0	-10%	98.49%	Rp2,308,704,526	10.33%	0.3969
2	+0	-9%	98.84%	Rp2,311,358,523	10.23%	0.3973
3	+0	-8%	99.18%	Rp2,314,012,519	10.12%	0.3978
4	+0	-7%	99.48%	Rp2,316,898,642	10.01%	0.3980
5	+0	-6%	99.56%	Rp2,320,636,889	9.87%	0.3974
6	+0	-5%	99.56%	Rp2,324,663,755	9.71%	0.3963
7	+0	-4%	99.56%	Rp2,328,690,622	9.55%	0.3953
8	+0	-3%	99.56%	Rp2,332,717,488	9.40%	0.3942
9	+0	-2%	99.56%	Rp2,336,744,355	9.24%	0.3932
10	+0	-1%	99.56%	Rp2,340,771,222	9.09%	0.3921
11	+0	+1%	99.56%	Rp2,348,824,955	8.77%	0.3900
12	+0	+2%	99.56%	Rp2,352,851,821	8.62%	0.3890
13	+0	+3%	99.56%	Rp2,356,878,688	8.46%	0.3880
14	+0	+4%	99.56%	Rp2,360,905,554	8.30%	0.3869

Table 4. 44 Scenario Formulation for 50SDR11 Using (R, S) System (Con't)

Scenario	R	S	Fill Rate	Total Cost	Cost Reduction	Weight
15	+0	+5%	99.56%	Rp2,364,932,421	8.15%	0.3859
16	+0	+6%	99.56%	Rp2,368,959,288	7.99%	0.3848
17	+0	+7%	99.56%	Rp2,372,986,154	7.83%	0.3838
18	+0	+8%	99.56%	Rp2,377,013,021	7.68%	0.3827
19	+0	+9%	99.56%	Rp2,381,039,887	7.52%	0.3817
20	+0	+10%	99.56%	Rp2,385,066,754	7.37%	0.3807
21	+1	-10%	94.23%	Rp2,394,982,869	6.98%	0.3603
22	+1	-9%	94.78%	Rp2,395,656,853	6.95%	0.3620
23	+1	-8%	95.34%	Rp2,396,330,837	6.93%	0.3637
24	+1	-7%	95.89%	Rp2,397,004,822	6.90%	0.3653
25	+1	-6%	96.40%	Rp2,398,428,483	6.85%	0.3667
26	+1	-5%	96.87%	Rp2,400,396,045	6.77%	0.3677
27	+1	-4%	97.34%	Rp2,402,363,607	6.69%	0.3688
28	+1	-3%	97.71%	Rp2,404,938,272	6.59%	0.3694
29	+1	-2%	98.07%	Rp2,407,592,268	6.49%	0.3699
30	+1	-1%	98.43%	Rp2,410,246,265	6.39%	0.3704
31	+1	+1%	99.15%	Rp2,415,554,259	6.18%	0.3714
32	+1	+2%	99.51%	Rp2,418,218,607	6.08%	0.3719
33	+1	+3%	100%	Rp2,421,995,453	5.93%	0.3711
34	+1	+4%	100%	Rp2,426,022,320	5.77%	0.3701
35	+1	+5%	100%	Rp2,430,049,186	5.62%	0.3690
36	+1	+6%	100%	Rp2,434,076,053	5.46%	0.3680
37	+1	+7%	100%	Rp2,438,102,919	5.31%	0.3669
38	+1	+8%	100%	Rp2,442,129,786	5.15%	0.3659
39	+1	+9%	100%	Rp2,446,156,652	4.99%	0.3648
40	+1	+10%	100%	Rp2,450,183,519	4.84%	0.3638

Description:

(green)	:	1st Best Scenario
(blue)	:	2nd Best Scenario
(grey)	:	3rd Best Scenario

The result of applying the scenario in the simulation for 125SDR11 using (R, s, S) system is shown in the table 4. 45.

Table 4. 45 Scenario Formulation for 20SDR17 Using (R, s, S) System

Scenario	R	s	S	Fill Rate	Total Cost	Cost Reduction	Weight
Existing	-	-	-	96%	Rp39,952,851	-2.12%	0.306
0	+0	+0%	+0%	96%	Rp39,952,851	-2.12%	0.306
1	+0	-10%	+0%	96%	Rp39,952,851	-2.12%	0.306
2	+0	-9%	+0%	96%	Rp39,952,851	-2.12%	0.306
3	+0	-8%	+0%	96%	Rp39,952,851	-2.12%	0.306
4	+0	-7%	+0%	96%	Rp39,952,851	-2.12%	0.306
5	+0	-6%	+0%	96%	Rp39,952,851	-2.12%	0.306
6	+0	-5%	+0%	96%	Rp39,952,851	-2.12%	0.306
7	+0	-4%	+0%	96%	Rp39,952,851	-2.12%	0.306
8	+0	-3%	+0%	96%	Rp39,952,851	-2.12%	0.306
9	+0	-2%	+0%	96%	Rp39,952,851	-2.12%	0.306
10	+0	-1%	+0%	96%	Rp39,952,851	-2.12%	0.306
11	+0	+1%	+0%	96%	Rp39,952,851	-2.12%	0.306
12	+0	+2%	+0%	96%	Rp39,952,851	-2.12%	0.306
13	+0	+3%	+0%	96%	Rp39,952,851	-2.12%	0.306
14	+0	+4%	+0%	96%	Rp39,952,851	-2.12%	0.306
15	+0	+5%	+0%	96%	Rp39,952,851	-2.12%	0.306
16	+0	+6%	+0%	96%	Rp39,952,851	-2.12%	0.306
17	+0	+7%	+0%	96%	Rp39,952,851	-2.12%	0.306
18	+0	+8%	+0%	96%	Rp39,952,851	-2.12%	0.306
19	+0	+9%	+0%	96%	Rp39,952,851	-2.12%	0.306
20	+0	+10%	+0%	96%	Rp35,960,670	8.09%	0.374
21	+0	+0%	-10%	96%	Rp36,359,888	7.07%	0.367
22	+0	+0%	-9%	96%	Rp36,759,106	6.05%	0.361
23	+0	+0%	-8%	96%	Rp37,158,324	5.03%	0.354
24	+0	+0%	-7%	96%	Rp37,557,542	4.01%	0.347
25	+0	+0%	-6%	96%	Rp37,956,760	2.99%	0.340
26	+0	+0%	-5%	96%	Rp38,355,979	1.97%	0.333
27	+0	+0%	-4%	96%	Rp38,755,197	0.95%	0.326
28	+0	+0%	-3%	96%	Rp39,154,415	-0.07%	0.320
29	+0	+0%	-2%	96%	Rp39,553,633	-1.10%	0.313
30	+0	+0%	-1%	96%	Rp40,352,069	-3.14%	0.299
31	+0	+0%	+1%	96%	Rp40,751,287	-4.16%	0.292
32	+0	+0%	+2%	96%	Rp41,150,505	-5.18%	0.286
33	+0	+0%	+3%	96%	Rp39,952,851	-2.12%	0.306

Table 4. 45 Scenario Formulation for 20SDR17 Using (R, s, S) System (Con't)

Scenario	R	s	S	Fill Rate	Total Cost	Cost Reduction	Weight
34	+0	+0%	+4%	96%	Rp41,549,723	-6.20%	0.279
35	+0	+0%	+5%	96%	Rp41,948,941	-7.22%	0.272
36	+0	+0%	+6%	96%	Rp42,348,159	-8.24%	0.265
37	+0	+0%	+7%	96%	Rp42,747,377	-9.26%	0.258
38	+0	+0%	+8%	96%	Rp43,146,595	-10.28%	0.252
39	+0	+0%	+9%	96%	Rp43,545,813	-11.30%	0.245
40	+0	+0%	+10%	96%	Rp43,945,031	-12.32%	0.238

Description:

(green)	:	1st Best Scenario
(blue)	:	2nd Best Scenario
(grey)	:	3rd Best Scenario

The result of applying the scenario in the simulation for 110SDR17 using (s, S) system is shown in the table 4. 46.

Table 4. 46 Scenario Formulation for 110SDR17 Using (s, S) System

Scenario	s	S	Fill Rate	Total Cost	Cost Reduction	Weight
Existing	-	-	91.9%	Rp5,089,412,976	0.00%	0.306
0	+0%	+0%	97.6%	Rp4,946,284,271	2.81%	0.344
1	-10%	+0%	92%	Rp4,999,401,988	1.77%	0.320
2	-9%	+0%	92%	Rp4,999,401,988	1.77%	0.320
3	-8%	+0%	93%	Rp4,796,911,408	5.75%	0.348
4	-7%	+0%	93%	Rp4,796,911,408	5.75%	0.348
5	-6%	+0%	93%	Rp4,796,911,408	5.75%	0.348
6	-5%	+0%	93%	Rp4,796,911,408	5.75%	0.348
7	-4%	+0%	93%	Rp4,796,911,408	5.75%	0.348
8	-3%	+0%	93%	Rp4,796,911,408	5.75%	0.348
9	-2%	+0%	93%	Rp4,796,911,408	5.75%	0.348
10	-1%	+0%	96%	Rp4,971,782,867	2.31%	0.336
11	+1%	+0%	98%	Rp4,946,284,271	2.81%	0.344
12	+2%	+0%	98%	Rp4,946,284,271	2.81%	0.344

Table 4. 46 Scenario Formulation for 110SDR17 Using (s, S) System (Con't)

Scenario	s	S	Fill Rate	Total Cost	Cost Reduction	Weight
13	+3%	+0%	98%	Rp4,946,284,271	2.81%	0.344
14	+4%	+0%	98%	Rp4,946,284,271	2.81%	0.344
15	+5%	+0%	98%	Rp4,831,987,598	5.06%	0.359
16	+6%	+0%	98%	Rp4,831,987,598	5.06%	0.359
17	+7%	+0%	98%	Rp4,831,987,598	5.06%	0.359
18	+8%	+0%	98%	Rp4,831,987,598	5.06%	0.359
19	+9%	+0%	98%	Rp4,831,987,598	5.06%	0.359
20	+10 %	+0%	98%	Rp4,831,987,598	5.06%	0.359
21	+0%	-10%	97.40%	Rp4,697,519,284	7.70%	0.376
22	+0%	-9%	96.88%	Rp4,710,439,443	7.45%	0.372
23	+0%	-8%	97.02%	Rp4,714,354,638	7.37%	0.372
24	+0%	-7%	97%	Rp4,719,179,782	7.27%	0.372
25	+0%	-6%	96%	Rp4,810,338,810	5.48%	0.357
26	+0%	-5%	97%	Rp4,812,191,186	5.45%	0.358
27	+0%	-4%	97%	Rp4,814,740,039	5.40%	0.359
28	+0%	-3%	97%	Rp4,817,684,754	5.34%	0.360
29	+0%	-2%	97%	Rp4,821,518,975	5.26%	0.360
30	+0%	-1%	97%	Rp4,941,459,127	2.91%	0.344
31	+0%	+1%	93%	Rp4,796,781,939	5.75%	0.350
32	+0%	+2%	94%	Rp4,796,652,470	5.75%	0.352
33	+0%	+3%	94%	Rp4,996,009,114	1.84%	0.326
34	+0%	+4%	95%	Rp4,998,045,881	1.80%	0.327
35	+0%	+5%	91%	Rp4,923,301,141	3.26%	0.326
36	+0%	+6%	92%	Rp4,921,724,714	3.29%	0.328
37	+0%	+7%	92%	Rp4,921,595,245	3.30%	0.329
38	+0%	+8%	93%	Rp4,921,465,776	3.30%	0.331
39	+0%	+9%	94%	Rp4,909,296,988	3.54%	0.338
40	+0%	+10%	95%	Rp4,910,158,442	3.52%	0.339

Description:

(green)	:	1st Best Scenario
(blue)	:	2nd Best Scenario
(grey)	:	3rd Best Scenario

The result of applying the scenario in the simulation for 20SDR17 using (s, Q) system is shown in the table 4. 47.

Table 4. 47 Scenario Formulation for 20SDR17 Using (s, Q) System

Scenario	s	Q	Fill Rate	Total Cost	Cost Reduction	Weight
Existing	-	-	96.2%	Rp6,534,188,430	0.00%	0.320
0	+0%	+0%	98%	Rp6,288,061,338	3.77%	0.351
1	-10%	+0%	96%	Rp6,309,798,480	3.43%	0.343
2	-9%	+0%	96%	Rp6,309,798,480	3.43%	0.343
3	-8%	+0%	96%	Rp6,309,798,480	3.43%	0.343
4	-7%	+0%	96%	Rp6,309,798,480	3.43%	0.343
5	-6%	+0%	96%	Rp6,309,798,480	3.43%	0.343
6	-5%	+0%	96%	Rp6,309,798,480	3.43%	0.343
7	-4%	+0%	96%	Rp6,311,370,081	3.41%	0.343
8	-3%	+0%	98%	Rp6,288,061,338	3.77%	0.351
9	-2%	+0%	98%	Rp6,288,061,338	3.77%	0.351
10	-1%	+0%	98%	Rp6,288,061,338	3.77%	0.351
11	+1%	+0%	98%	Rp6,288,061,338	3.77%	0.351
12	+2%	+0%	98%	Rp6,288,061,338	3.77%	0.351
13	+3%	+0%	98%	Rp6,283,639,111	3.83%	0.353
14	+4%	+0%	99%	Rp6,279,181,499	3.90%	0.355
15	+5%	+0%	99%	Rp6,279,181,499	3.90%	0.355
16	+6%	+0%	99%	Rp6,720,106,667	-2.85%	0.312
17	+7%	+0%	99%	Rp6,720,106,667	-2.85%	0.312
18	+8%	+0%	99%	Rp6,720,106,667	-2.85%	0.312
19	+9%	+0%	99%	Rp6,282,515,555	3.85%	0.356
20	+10%	+0%	99%	Rp6,282,515,555	3.85%	0.356
21	+0%	-10%	96%	Rp6,442,225,319	1.41%	0.329
22	+0%	-9%	96%	Rp6,512,163,880	0.34%	0.322
23	+0%	-8%	96%	Rp6,579,421,393	-0.69%	0.317
24	+0%	-7%	96%	Rp6,262,299,592	4.16%	0.349
25	+0%	-6%	97%	Rp6,322,210,343	3.24%	0.344
26	+0%	-5%	96%	Rp6,407,894,714	1.93%	0.332
27	+0%	-4%	96%	Rp6,461,545,686	1.11%	0.328
28	+0%	-3%	95%	Rp6,544,505,738	-0.16%	0.317
29	+0%	-2%	98%	Rp6,573,585,559	-0.60%	0.322
30	+0%	-1%	99%	Rp6,655,074,065	-1.85%	0.318
31	+0%	+1%	98%	Rp6,352,197,906	2.79%	0.345

Table 4. 47 Scenario Formulation for 20SDR17 Using (s, Q) System (Con't)

Scenario	s	Q	Fill Rate	Total Cost	Cost Reduction	Weight
32	+0%	+2%	97%	Rp6,436,531,471	1.49%	0.332
33	+0%	+3%	97%	Rp6,485,928,113	0.74%	0.330
34	+0%	+4%	98%	Rp6,547,543,645	-0.20%	0.323
35	+0%	+5%	99%	Rp6,592,547,219	-0.89%	0.322
36	+0%	+6%	99%	Rp6,654,736,553	-1.84%	0.316
37	+0%	+7%	98%	Rp6,288,061,338	3.77%	0.351
38	+0%	+8%	96%	Rp6,309,798,480	3.43%	0.343
39	+0%	+9%	96%	Rp6,309,798,480	3.43%	0.343
40	+0%	+10%	96%	Rp6,309,798,480	3.43%	0.343

Description:

(green)	:	1st Best Scenario
(blue)	:	2nd Best Scenario
(grey)	:	3rd Best Scenario

Table 4. 44 until Table 4. 47 shows about the result of fill rate and total costs change from different scenario. The graph about the change of fill rate and total cost caused by scenario is shown in Figure 4. 3 until Figure 4. 10.

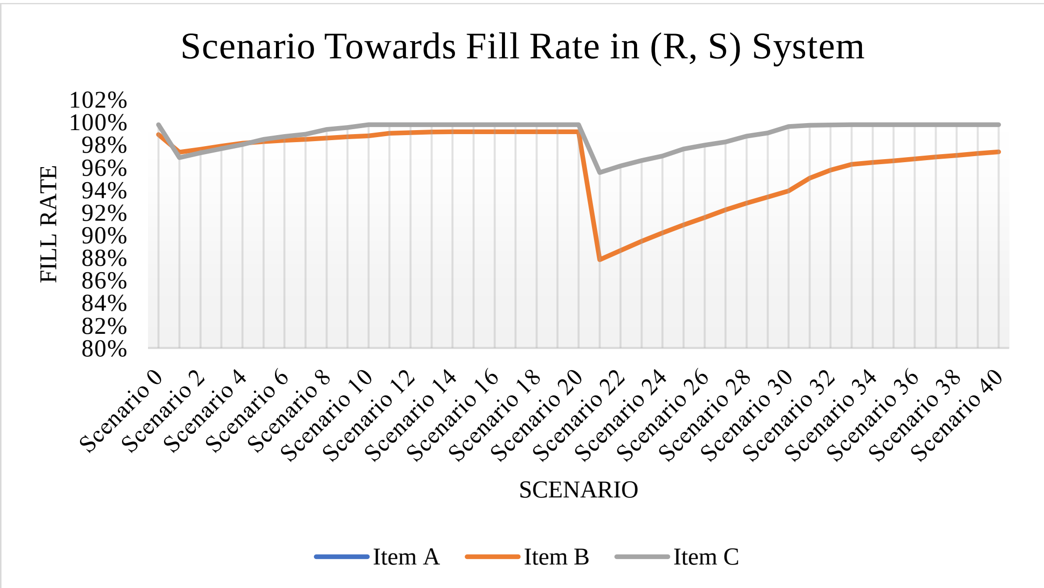

Figure 4. 3 Results of Scenario Change Towards Fill Rate in (R, S) System

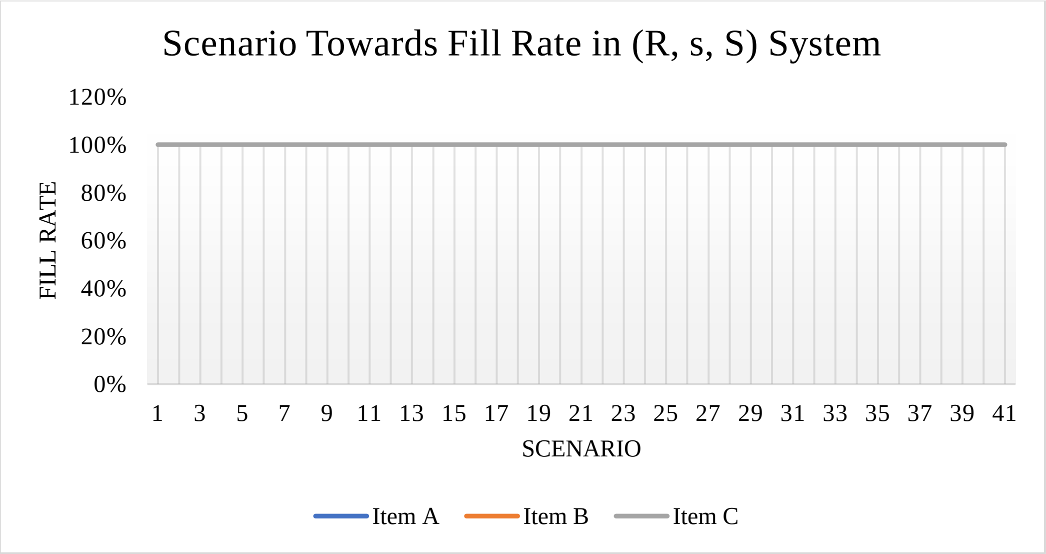

Figure 4. 4 Results of Scenario Change Towards Fill Rate in (R, s, S) System

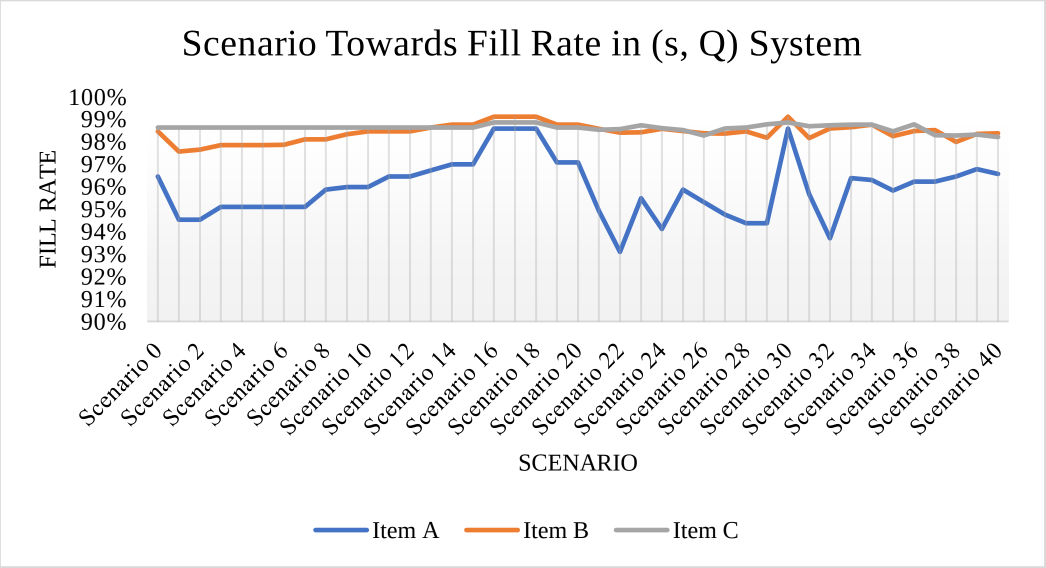

Figure 4. 5 Results of Scenario Change Towards Fill Rate in (s, Q) System

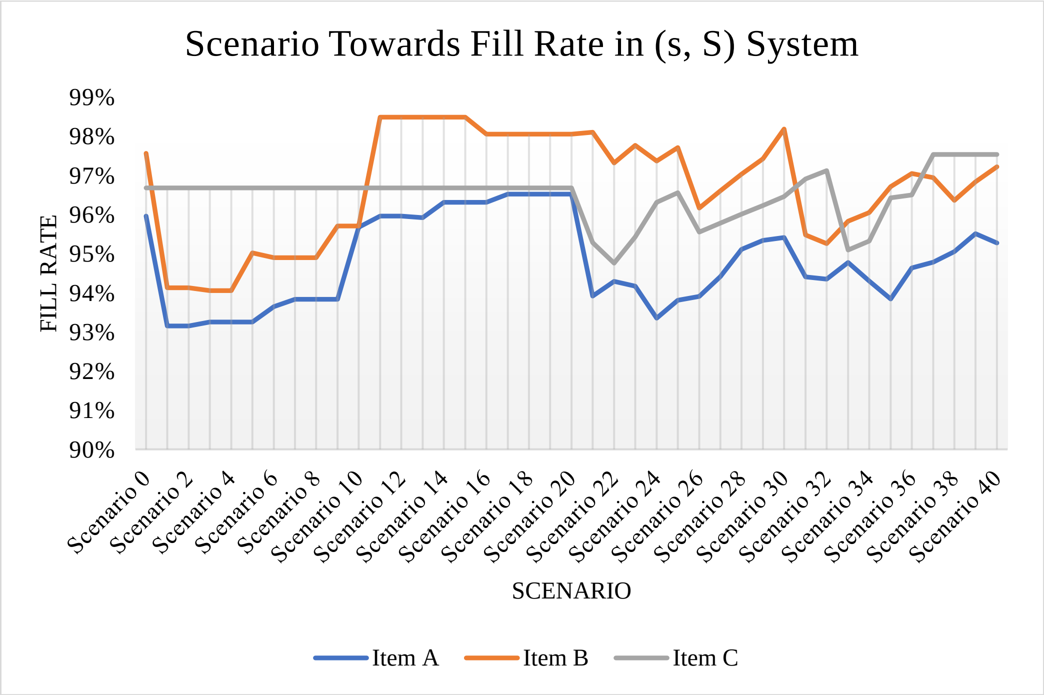

Figure 4. 6 Results of Scenario Change Towards Fill Rate in (s, S) System

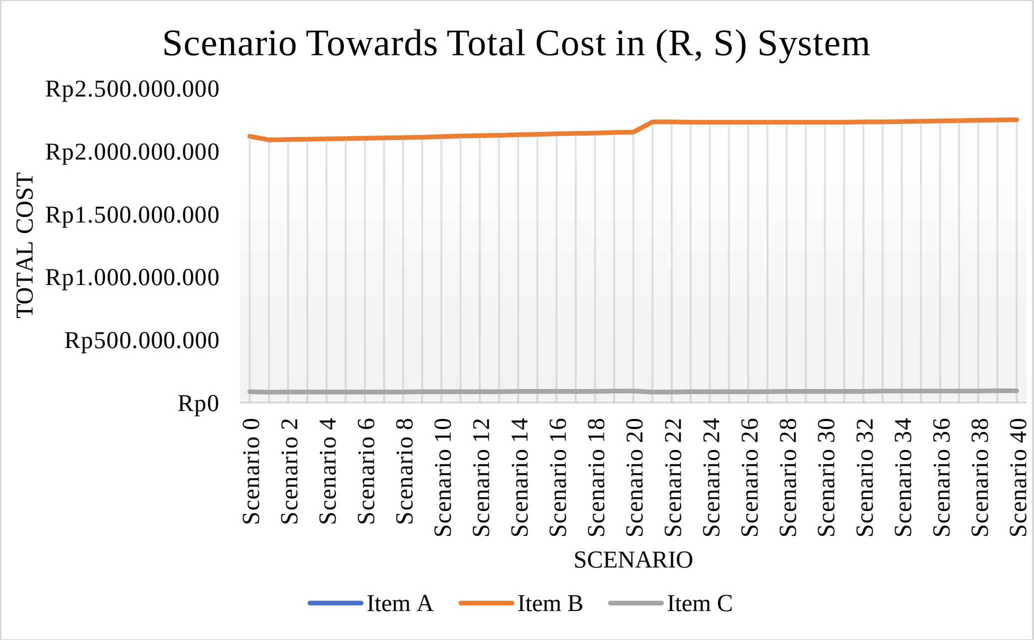

Figure 4. 7 Results of Scenario Change Towards Total Cost in (R, S) System

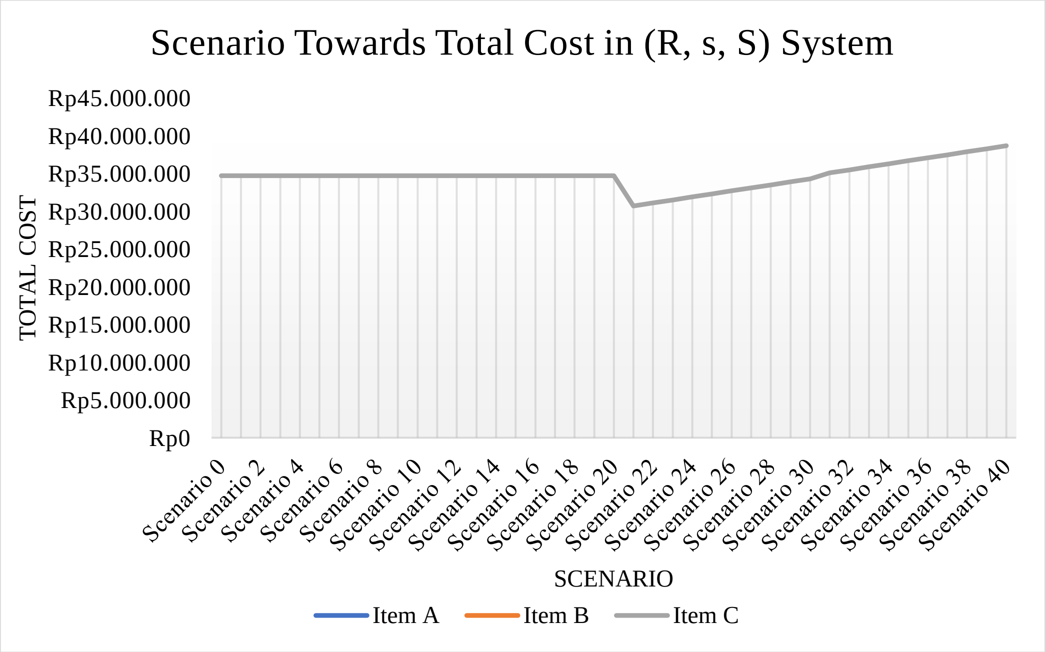

Figure 4. 8 Results of Scenario Change Towards Total Cost in (R, s, S) System

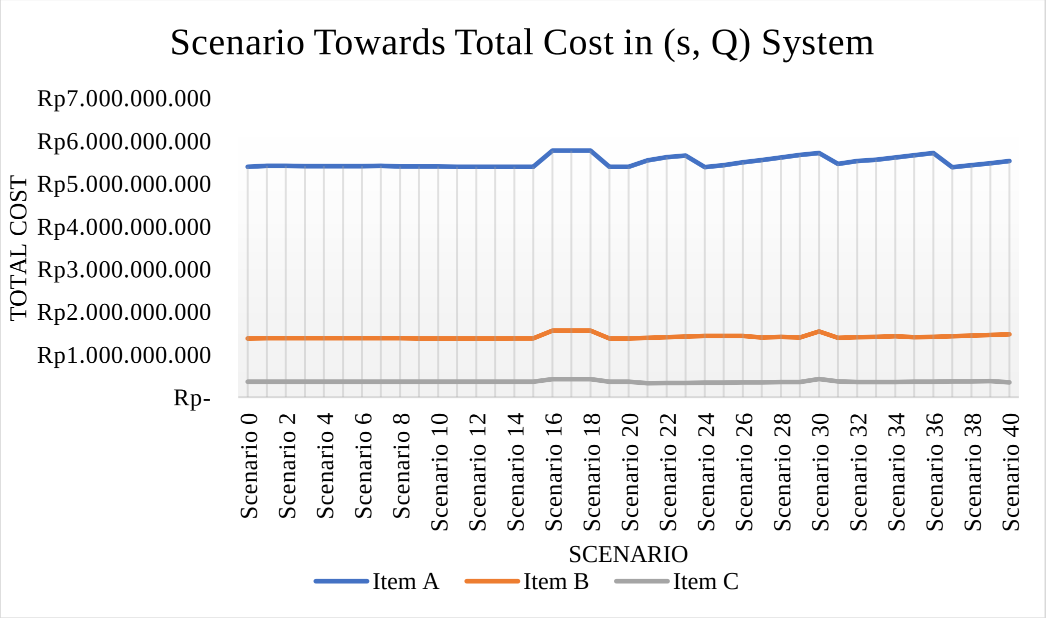

Figure 4. 9 Results of Scenario Change Towards Total Cost in (s, Q) System

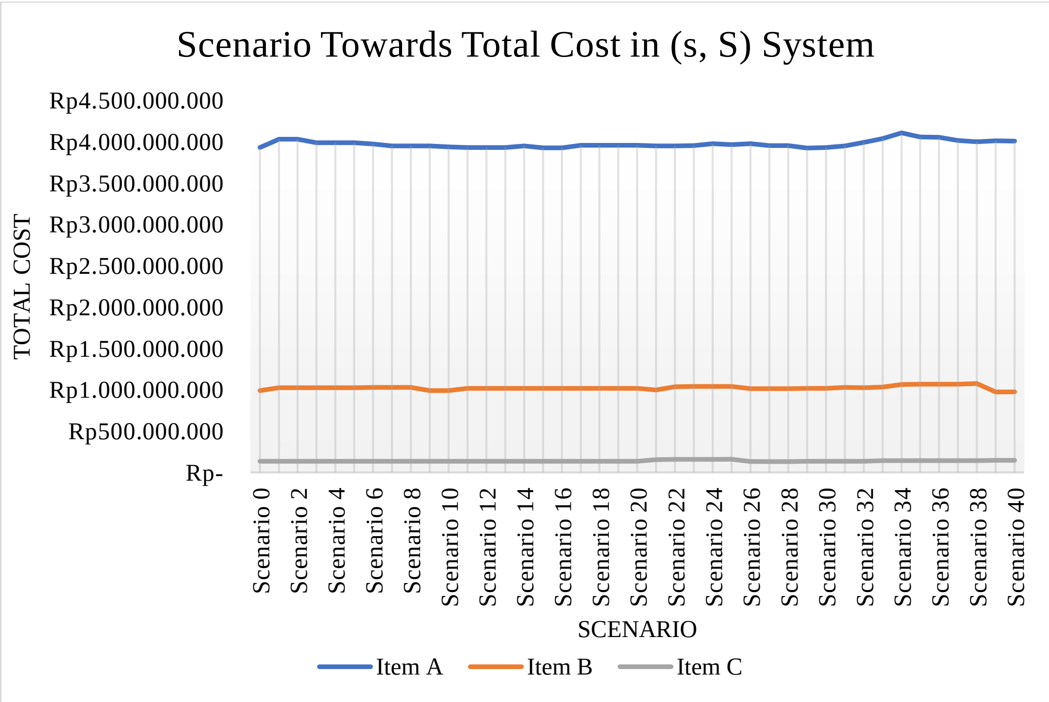

Figure 4. 10 Results of Scenario Change Towards Total Cost in (s, S) System

The scenarios that are observed are the top three best scenarios that can provide the optimal fill rate and total cost. The recapitulation of the chosen scenario is shown in the Table 4. 48. To see the magnitude of parameter change in the scenarios, refer to Table 4. 42.

Table 4. 48 Recapitulation of Chosen Scenario

No	Item	Policy	1st Best Scenario	2nd Best Scenario	3rd Best Scenario
1	20SDR17	(s, Q)	Scenario 19	Scenario 20	Scenario 14
2	110SDR17	(s, S)	Scenario 21	Scenario 22	Scenario 23
3	63SDR17	(s, S)	Scenario 33	Scenario 32	Scenario 31
4	25SDR17	(s, Q)	Scenario 37	Existing	Scenario 11
5	20SDR11	(s, S)	Scenario 36	Scenario 31	Existing
6	32SDR17	(s, S)	Scenario 31	Existing	Scenario 6
7	32SDR11	(s, S)	Scenario 39	Scenario 38	Existing
8	90SDR17	(s, Q)	Scenario 27	Scenario 35	Scenario 36

Table 4. 48 Recapitulation of Chosen Scenario (Con't)

No	Item	Policy	1st Best Scenario	2nd Best Scenario	3rd Best Scenario
9	50SDR11	(R, S)	Scenario 4	Scenario 3	Scenario 5
10	200SDR17	(s, Q)	Scenario 1	Scenario 2	Scenario 3
11	63SDR11	(s, S)	Existing	Scenario 11	Scenario 12
12	160SDR17	(R, S)	Scenario 11	Existing	Scenario 10
13	90SDR11	(s, S)	Scenario 40	Scenario 39	Scenario 21
14	20SDR13.6	(s, Q)	Scenario 29	Scenario 13	Scenario 14
15	63SDR21	(s, Q)	Existing	Scenario 7	Scenario 8
16	200SDR11	(s, Q)	Scenario 26	Scenario 27	Scenario 28
17	25SDR11	(s, Q)	Scenario 27	Scenario 28	Scenario 29
18	90SDR21	(s, Q)	Scenario 25	Scenario 26	Scenario 27
19	50SDR17	(s, Q)	Scenario 32	Scenario 33	Scenario 34
20	110SDR11	(s, Q)	Scenario 40	Scenario 21	Scenario 22
21	25SDR13.6	(s, Q)	Scenario 40	Scenario 21	Scenario 22
22	40SDR17	(s, Q)	Scenario 21	Scenario 22	Scenario 23
23	75SDR11	(s, S)	Scenario 26	Scenario 27	Scenario 28
24	32SDR13.6	(R, S)	Scenario 1	Scenario 2	Scenario 3
25	160SDR11	(s, Q)	Scenario 21	Scenario 22	Scenario 23
26	110SDR13.6	(s, Q)	Scenario 21	Scenario 22	Scenario 23
27	50SDR13.6	(R, S)	Scenario 8	Scenario 7	Scenario 6
28	250SDR17	(R, S)	Scenario 1	Scenario 2	Scenario 3
29	40SDR11	(R, S)	Scenario 1	Scenario 2	Scenario 3
30	40SDR13.6	(R, S)	Scenario 1	Scenario 2	Scenario 3
31	160SDR13.6	(s, S)	Scenario 21	Scenario 22	Scenario 23
32	60SDR17	(R, S)	Scenario 1	Scenario 2	Scenario 3
33	63SDR13.6	(R, S)	Scenario 1	Scenario 21	Scenario 2
34	125SDR21	(R, S)	Scenario 1	Scenario 21	Scenario 2
35	125SDR11	(R, s, S)	Scenario 21	Scenario 22	Scenario 23
36	125SDR17	(R, S)	Scenario 10	Scenario 30	Scenario 8

4.6.9 Sensitivity Analysis

This sub-chapter explains about the sensitivity analysis conducted in this research. Sensitivity analysis is analysis of set of independent variables affect the dependent variable under specific conditions (Corporate Finance Institute, 2015). In this research the independent variables are the demand. The demand will be changed in 8 conditions, which are -40%, -30%, -20%, -10%, +10%, +20%, +30%, and +40%. The example of the output from sensitivity analysis in 110SDR17 is shown in table 4.49.

Table 4. 49 Sensitivity Analysis in 110SDR17

Policy	Change	Fill Rate	Total Cost	Cost Change
(s,S)	-60%	99.96%	Rp 2,183,764,528	-55.85%
	-40%	98.52%	Rp 3,012,586,839	-39.09%
	-20%	97.91%	Rp 3,879,131,381	-21.57%
	0%	97.55%	Rp 4,946,284,271	0.00%
	+20%	92.95%	Rp 5,661,550,545	+14.46%
	+40%	91.16%	Rp 6,924,715,150	+40.00%
	+60%	76.76%	Rp 7,843,018,014	+58.56%
	+80%	77.68%	Rp 9,050,848,799	+82.98%
	+100%	70.42%	Rp 10,220,044,389	+106.62%

Table 4. 49 shows about the result of sensitivity analysis towards the total cost and the fill rate in 110SDR17. The graph about the change of fill rate caused by demand change in class A item is shown in Figure 4. 11.

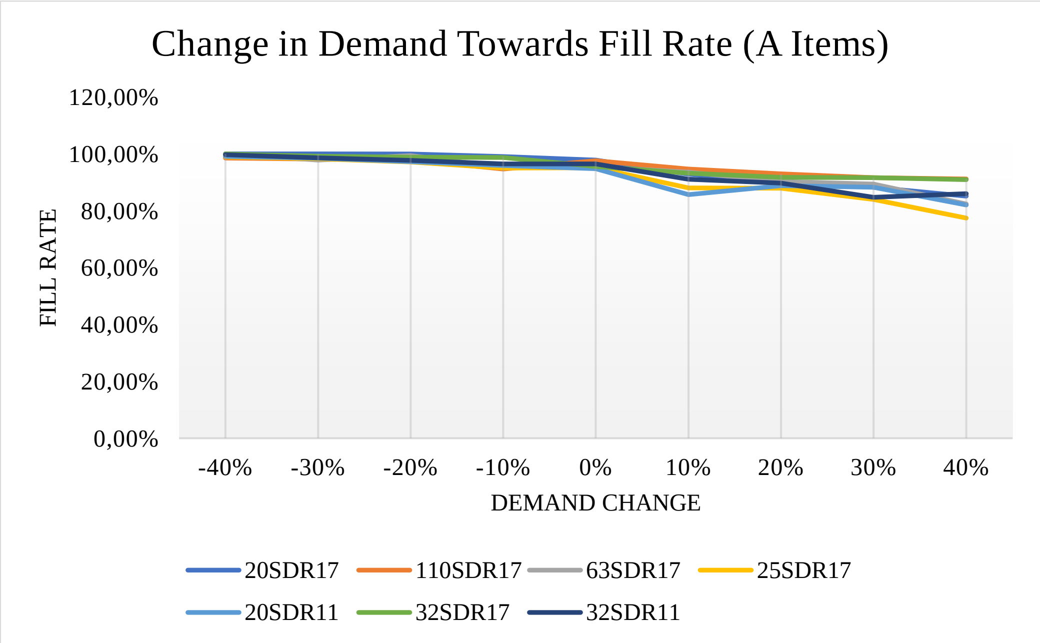

Figure 4.11 Change in Demand Towards Fill Rate (Class A Item)

The graph about the change of fill rate caused by demand change in class B item is shown in Figure 4. 12.

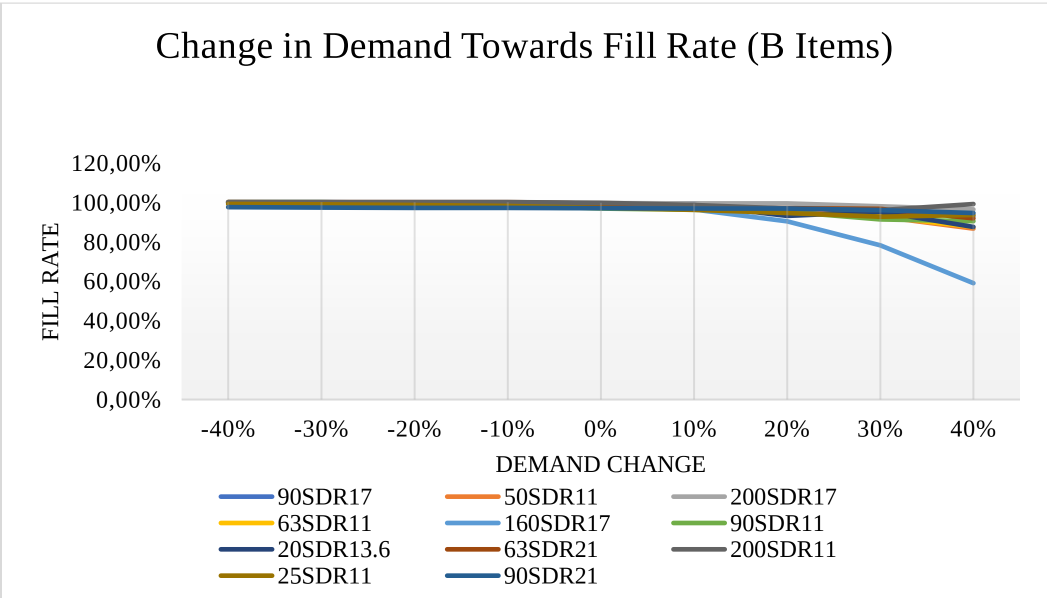

Figure 4. 12 Change in Demand Towards Fill Rate (Class B Item)

The graph about the change of fill rate caused by demand change in class C item is shown in Figure 4. 13.

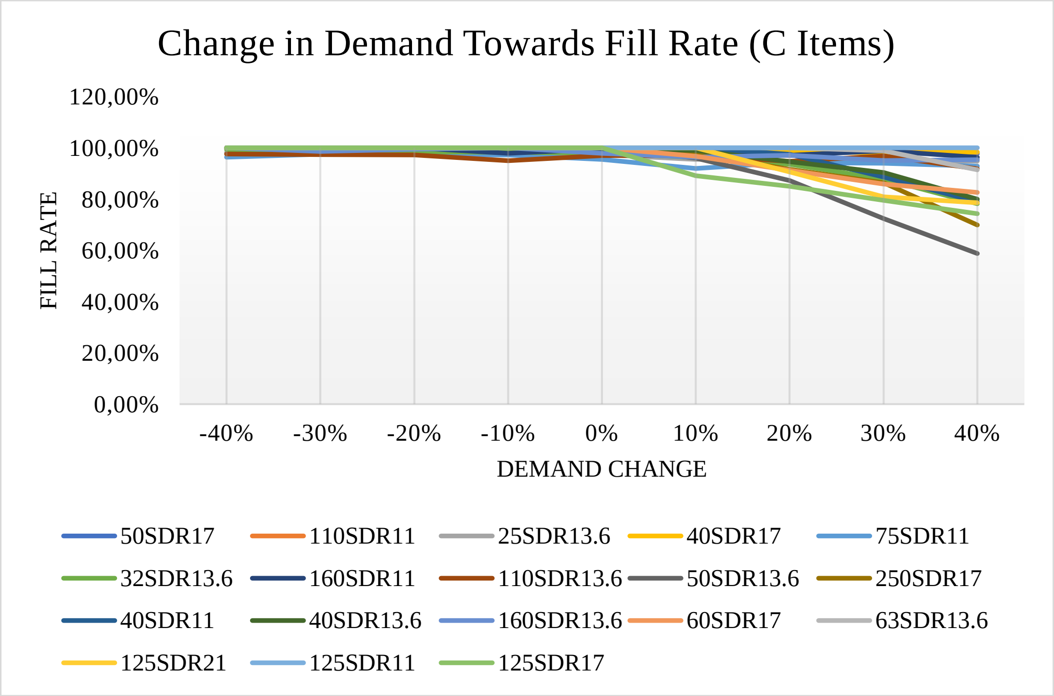

Figure 4. 13 Change in Demand Towards Fill Rate (Class C Item)

Figure 4. 11 until Figure 4. 13 shows about the impact of demand change towards the fill rate. It can be seen from the graph that by increasing the demand, the fill rate in every class of item is decreasing. The graph about the change of total cost caused by change in demand in class A item is shown in Figure 4. 14 until Figure 4. 16.

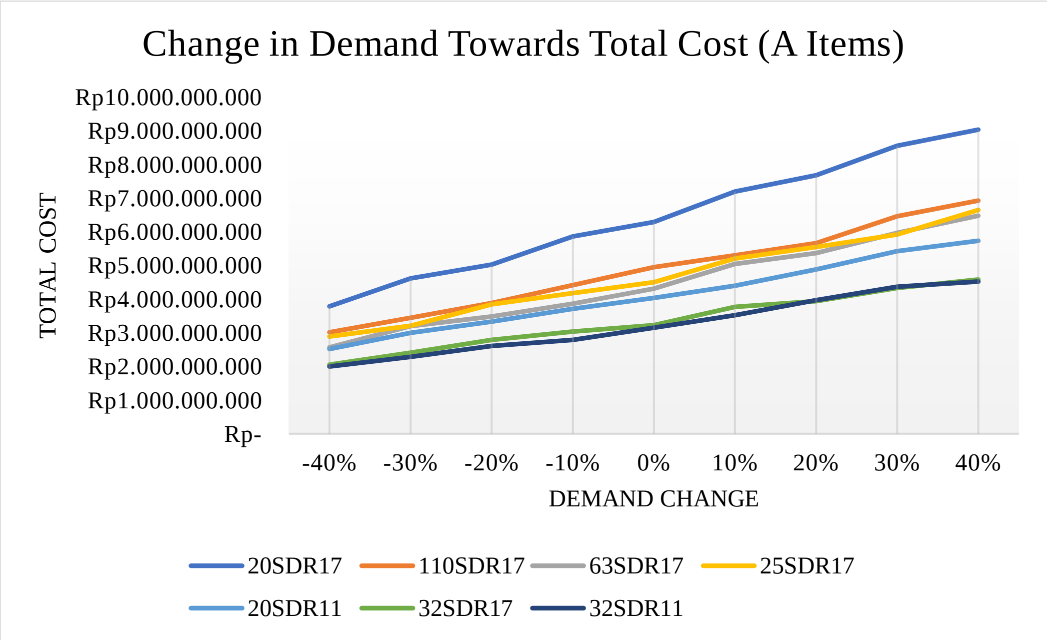

Figure 4.14 Change in Demand Towards Total Cost (Class A Item)

The graph about the change of total cost caused by change in demand in class B item is shown in Figure 4. 15.

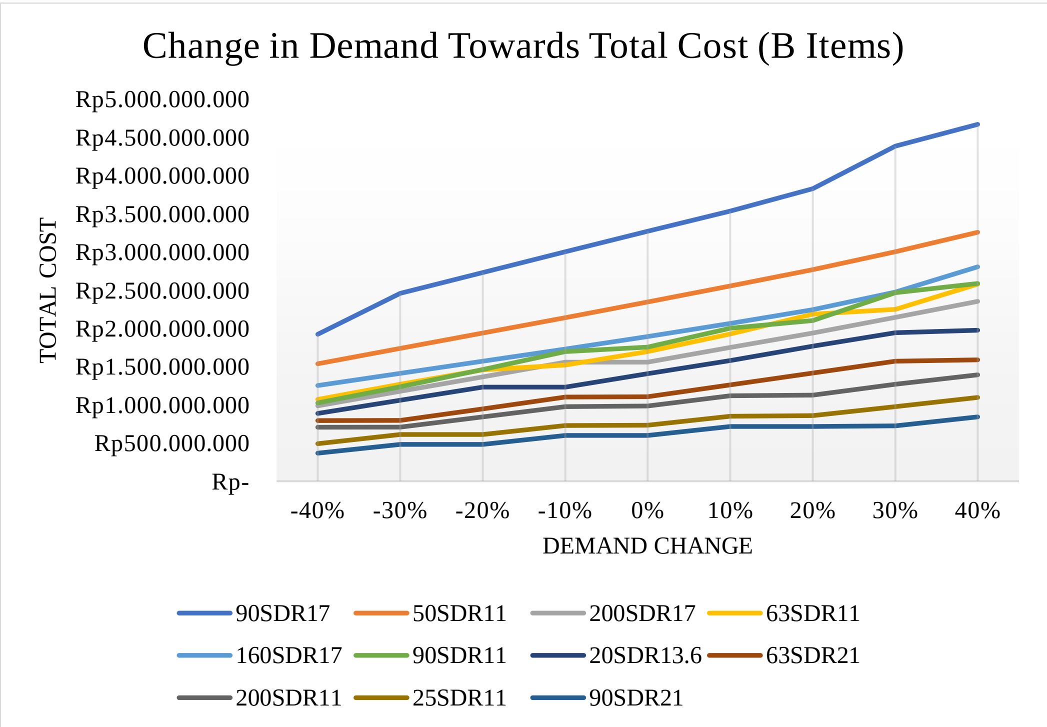

Figure 4. 15 Change in Demand Towards Total Cost (Class B Item)

The graph about the change of total cost caused by change in demand in class C item is shown in Figure 4. 16.

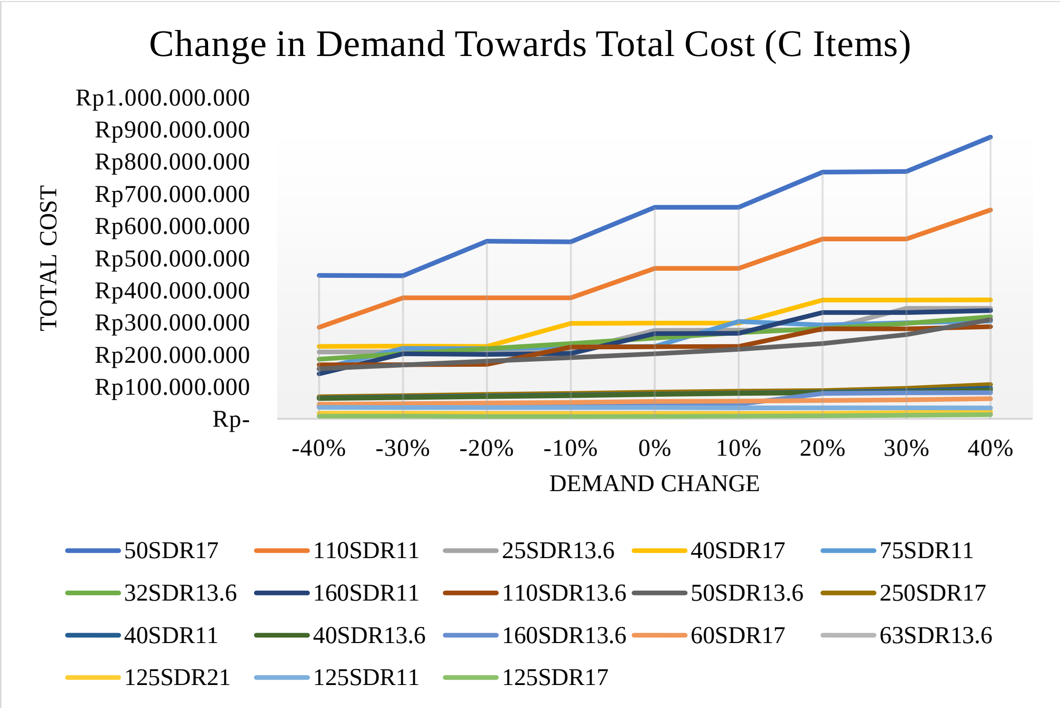

Figure 4. 16 Change in Demand Towards Total Cost (Class C Item)

Figure 4. 14 until Figure 4. 16 shows about the impact of demand change towards the total cost. It can be seen from the graph that by increasing the demand, the total cost in every policy is increasing.

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CHAPTER 5
ANALYSIS AND INTERPRETATION

This chapter explains about the analysis and interpretation of the data based on the collected and processed data.

5.1 Analysis of Product Classification

Product classification is used to classify the product according to its characteristics. It can give insight to the company on how to handle the product according to its characteristics. In this research, there are two methods of classification that are used which are ABC analysis and ADI-CV analysis. Both of the classification is essential to be used in order to give proper analysis towards the inventory item due to different aspect of characteristics that are reviewed. ABC analysis is the classification of product according to the value of the item, while ADI-CV is the classification of product according to the pattern of demand.

In ABC analysis, items are classified into three categories which are class A, class B, and class C. In theory, class A is 20% of items that contribute around 80% of the value, class B is 30% of items that contribute around 15% of value, and class C is 50% of items that contribute around 5% of value. It shows that the most important items are classified as class A item and the unimportant items are classified as class C item. This implies that the company should give more attention to class A items rather than class C items. From conducting the calculation, it is shown that seven items are categorized as class A items such as 20SDR17, 110SDR17, 63SDR17, and four other items. It is shown that 20% of the items contribute to around 60% of the total money value, showing a significant contribution to the company. For class B items, eleven items are categorized as class B items such as 90SDR17, 50SDR11, 200SDR17, and eight other items. It is shown that 30% of the items contribute to around 35% of the total money value. For class C items, eighteen items are categorized as class C items such as 50SDR17, 110SDR11, 25SDR13.6, and fifteen other items. It is shown that 50% of the items contributes to around 5% of the total money value. Information about the importance of the item can give insight to the company in formulating strategy on handling the inventory more accurately.

In ADI-CV analysis, items are classified into two categories which are smooth pattern and intermittent pattern. ADI-CV analysis is performed because there are data with intermittent pattern that exists in the item. Smooth pattern is a pattern with little or no variation in the interval between demand while intermittent pattern is pattern with high variation in the interval between demand. The item is classified as smooth when the value of ADI is less than 1.32 and the value of CV^2 is less than 0.49 while for the item to be classified as intermittent the value of ADI is equal or more than 1.32 and the value of CV is less than 0.49. From conducting the calculation, it is shown that there are nineteen items that are categorized as smooth such as 20SDR17, 110SDR17, 63SDR17, and sixteen other items. Meanwhile, there are seventeen items that are categorized as intermittent such as 200SDR17, 160SDR17, 50SDR17, and fourteen other items. Information about the pattern type of the data can be useful in determining the proper forecasting method to be implemented because different pattern has a different method of solution.

Table 5. 1 Recapitulation of Product Classification

Class	Class A	Class B	Class C
Smooth	- 20SDR17 - 25SDR17 - 110SDR17 - 20SDR11 - 63SDR17 - 32SDR11 - 32SDR17	- 90SDR17 - 63SDR21 - 50SDR11 - 25SDR11 - 63SDR11 - 20SDR13.6	- 25SDR13.6 - 40SDR11 - 32SDR13.6 - 60SDR17 - 50SDR13.6 - 40SDR13.6
Intermittent		- 200SDR17 - 160SDR17 - 90SDR21 - 200SDR11 - 90SDR21	- 110SDR11 - 50SDR17 - 250SDR17 - 40SDR17 - 160SDR13.6 - 75SDR11 - 63SDR13.6 - 160SDR11 - 125SDR21 - 125SDR11 - 125SDR17 - 110SDR13.6

5.2 Analysis of Demand Forecasting and Error Measurement

Forecast is the estimation of uncertain future events that can offer insight to the organization about planning an appropriate strategy. In this research, the objects that are forecasted are the demand of HDPE pipes. A good forecast can give accurate estimation of future demand, increasing the effectiveness and efficiency of the replenishment, production, and inventory system. However, forecast inevitably comprises of error. This research use MAD and MSE to measure the error from forecast. To minimize the error, a proper forecasting method is utilized.

Currently, the company still uses the naïve forecasting method by using previous year data to estimate future demand. Several methods can be utilized to reduce the error of the forecast. In this research, there are two kinds of demand pattern that requires a different method of forecast. For a smooth pattern, the method used to forecast is moving average, exponential smoothing, Holt's, and Winter's method. For an intermittent pattern, the method used to forecast is Croston's method and Syntetos Boylan Approximation.

In smooth pattern, there are 19 items that classified to have smooth pattern such as 20SDR17, 110SDR17, and 63SDR17. The forecast method that are used and compared are the existing method, moving average, exponential smoothing, Holt's, and Winter's method. The forecast uses historical data for 36 months ranging from January 2017 until December 2019. MAD and MSE are used to measure and compare the error from each forecasting method. From the calculation, Winter's method generates the lowest error in 14 items for both MAD and MSE such as in item 110SDR17, 20SDR11, and 20SDR13.6 while Holt's method generates the lowest error in 1 item for both MAD and MSE which is in item 60SDR17. This can happen because Winter's method can consider most of the demand behavior such as trend and seasonality while Holt's method only considers trend, therefore Winter's is the most used forecasting method in smooth pattern. Moving average and exponential smoothing failed to generate the lowest value of error because it can't consider the trend and seasonality of the data while in reality the trend and seasonality exist in most of the historical data. However, there are 4 items that have value of MAD that are not aligned with the value of MSE. Such as item 25SDR11 shows that the smallest value of MAD is achieved by using Holt's method but the smallest value of MSE is achieved by using Winter's method. According to Chopra (2016), MSE penalizes large errors more significantly. In this condition, the result of MSE is more preferable because MSE is more sensitive to error if compared with the MAD.

In intermittent pattern, there are seventeen items that classified to have intermittent pattern such as 200SDR17, 160SDR17, and 50SDR17. The forecast method that are used and compared are Croston's method and Syntetos Boylan Approximation. The forecast uses historical data for 36 months ranging from January 2017 until December. MAD and MSE are used to measure and compare the error from each forecasting method. From the calculation, Syntetos Boylan Approximation generates the lowest error in ten items for both MAD and MSE such as in item 200SDR17, 110SDR11, and 125SDR21 while Croston's method generates the lowest error in four items for both MAD and MSE such as in item 160SDR17, 40SDR17, and 90SDR11. SBA can outperform Croston's method in most of the item because it is shown that Croston's method is often associated with positive bias resulting in over-forecast demand. SBA is also proven to outperform Croston's method in numerous independent empirical studies in terms of forecasting and inventory performance (Babai, et al., 2017). However, some negative bias still remains in SBA which can cause some cases to loss of performance compared to Croston's method making the Croston's method to lead in several items. Besides SBA and Croston's method, there are 2 items with the existing method as the chosen method which are item 75SDR11 and item 125SDR11. This shows that for this particular item the proposed methods are unable to provide a better solution. Therefore, it is more appropriate to use the existing method to forecast the future event. It is also shown in several items that the value of MAD and MSE is not aligned such as in item 50SDR17 where the smallest value of MAD is achieved by using SBA but the smallest value of MSE is achieved by using Croston's method. In this condition the decision that is taken is from the method that generates the lowest MSE.

Table 5. 2 Recapitulation of Chosen Method in Smooth Pattern

	Winter's Method		**Holt Method**	**Existing Method**
Class A	- 110SDR17 - 20SDR11 - 20SDR17 - 32SDR11	- 25SDR17 - 32SDR17 - 63SDR17	-	-

Table 5. 2 Recapitulation of Chosen Method in Smooth Pattern (Con't)

	- Winter's Method		- Holt Method	- Existing Method
Class B	- 20SDR13.6 - 25SDR11 - 50SDR11	- 63SDR21 - 90SDR17	- 63SDR11	-
Class C	- 25SDR13.6	- 32SDR13.6	- 60SDR17	-

Table 5. 3 Recapitulation of Chosen Method in Intermittent Pattern

	Syntetos Boylan Approximation	Croston's Method	Existing Method
Class A	-	-	-
Class B	- 200SDR17 - 200SDR11	- 160SDR17 - 40SDR17 - 50SDR17 - 90SDR11 - 90SDR21	-
Class C	- 110SDR11 - 250SDR17 - 63SDR13.6 - 110SDR13.6 - 125SDR17 - 125SDR21 - 160SDR13.6	-	- 75SDR11 - 125SDR11

5.3 Analysis of Existing Condition and Recommended Inventory Control Policy

The current existing condition use a min-max system, where the minimum value and maximum value of the inventory are determined. In the current system, production is triggered when the item reached its minimum level of inventory and produced until reaching the maximum inventory level. However, the value of the parameter in the existing condition is mostly based on intuition and has not been updated, making it still far from the optimal state. From the simulation result, it is shown that the fill rate from the existing condition is quite high with most of the items reach more than 95% of fill rate. However, the total cost generated is still high. This is caused by overstock that often occurs making the ability to fulfill the demand is high and also the inventory cost to be high. Although in several cases the company experience stockout making the fill rate not reaching 100%. Currently, the company focuses more on cost reduction. In order to reach the optimal fill rate and cost reduction, a new inventory control policy is proposed.

The inventory control policy that are proposed are *(R, S)*, *(R, s, S)*, *(s, Q)*, and *(s, S)* system. Each of the control policy has its own characteristics and parameter. *(R, S)* system has reviewing period and maximum inventory level as its parameter. *(R, s, S)* system has reviewing period, minimum inventory level, and maximum inventory level as its parameter. *(s, Q)* system has minimum inventory level and order quantity as its parameter. *(s, S)* system has minimum inventory level and maximum inventory level as its parameter. These policies are expected to generate a more optimal solution compared with the existing condition. The optimality of the policy has to be compared to understand which policy best implemented to the items. The comparation of the policies are using the aid of Monte Carlo simulation in order to capture the randomness of the data. The variables that are observed as performance measure are fill rate and total cost. The weight of the variables is different since the company focus more on cost reduction. Therefore, to obtain the weight value, a pairwise comparison is conducted and used to calculate the score of the recommended inventory control policy.

5.3.1 Analysis of (R, S) System

(R, S) system uses two parameters as control variables which are reviewing period and maximum inventory level. This system offer advantage such as it can give a more predictable period in making the order resulting in a more level workload. However, there are also disadvantages that can appear by implementing the system which are it can generate a higher holding cost than continuous review.

In this research, several items use *(R, S)* system as the most optimal policy to be used, such as item 50SDR11, 160SDR17, and 32SDR13.6. In total, there are 11 items use *(R, S)* system out of 36 items. From the 11 items, it consists of 0 item out of 7 items in the class A product, 2 items out of 11 items in the class B product, and 9 items out of 18 items in the class C item. It is shown that in this research *(R, S)* system is dominant to be used in class C item. According to Silver (2016), *(R, S)* system is particularly effective to control C items as well as B items, as it is shown in this research. The nature of class C items is low money value making it doesn't require a sophisticated inventory record to be implemented to the product and appropriate to use periodic review with a relatively long interval, therefore *(R, S)* system is suitable for C class items.

For example, in item 32SDR13.6, the chosen policy is the *(R, S)* system. The interval of reviewing period (R) is 15 period with the value of maximum inventory level (S) reaching 8465 meters. It is shown that the recommended system can provide a similar level of fill rate with the existing condition and also reducing the cost generated by having cost reduction reaching 2% from the existing condition. Even though the holding cost of *(R, S)* system is higher than the existing condition, due to the long reviewing interval *(R, S)* system requires less production quantity therefore less unit cost, resulting in a lower total cost than the existing condition. If compared with the other continuous review system, *(R, S)* system can offer the highest cost reduction in item 32SDR13.6.

5.3.2 Analysis of (R, s, S) System

(R, s, S) system uses three parameters as control variables which are reviewing period (R), reorder point (s), and maximum inventory level (S). In this system, replenishment is made when in reviewing period and the inventory position drops to order point s or lower. The replenishment quantity is vary depending on the inventory position and the maximum inventory level. This system offer advantage such as it can give a more predictable period in making the order resulting a more level workload. However, there are also disadvantages that can appear by implementing the system which are it can generate a higher holding cost than continuous review and the computational effort required to implement the system.

In this research, there is one item that use (R, s, S) system as the most optimal policy to be used which is item 125SDR11. According to Silver (2016), *(R,* *s, S)* system is appropriate to implement in class A item. Since it is a periodic review it has to cover more period without replenishment if compared with continuous review, making the inventory stored to be larger. It causes the unit cost and holding cost to be generally higher than continuous review, resulting a higher total cost. Since it holds more inventory than the other system, it can provide a higher fill rate. However, the cost reduction is not as significant as the other system, making the system barely chosen as the optimal policy to be implemented.

For example, in item 125SDR11 the chosen policy is the *(R, s, S)* system. The reviewing period is 65 period, reorder point is 124 meters, and the maximum inventory level is 164 meters. It is shown that the recommended system can provide a higher level of fill rate with the existing condition and also reducing the cost generated by having cost reduction reaching 3.9% from the existing condition. Even though the holding cost of (R, s, S) system is higher than the existing condition, due to the long reviewing interval it requires less production quantity therefore less setup cost, resulting a lower total cost than the existing condition. If compared with the other continuous review system, *(R, s, S)* system can offer the highest cost reduction in item 125SDR11 because of the long reviewing interval resulting a lower setup, therefore the setup cost is significantly lower.

5.3.3 Analysis of (s, Q) System

(s, Q) system uses two parameters as control variables which are reorder point *(s)* and order quantity *(Q).* in this system, replenishment is made when the inventory position drops to order point s or lower and replenish the inventory in the size of Q. *(s, Q)* system is a fixed replenishment quantity therefore the amount replenished is always the same. This system offer advantage such as it is quite simple resulting error to be less likely to occur. However, there are also disadvantages that can appear by implementing the system which is in its unmodified form it may not be able to cope the situation effectively if the demand is very high.

In this research, several items use *(s, Q)* system as the most optimal policy to be used such as item 20SDR17, 90SDR17, and 200SDR17. In total, there are 15 items use (*s, Q*) system out of 36 items. From the 15 items, it consists of 2 items out of 7 items in the class A product, 7 items out of 11 items in the class B product, and 6 items out of 18 items in the class C products. It is shown that from this research *(s, Q)* system is more dominant to be used in class B and also quite dominant to be used in class C. According to Silver (2016) *(s, Q)* is appropriate to use in class B item and also class C item. Class B and C item is less important than class A item making it doesn't require computational effort as advance as for class A item, therefore *(s, Q)* system is suitable for class B and class C items.

For example, in item 20SDR17, the chosen policy is the *(s, Q)* system. The reorder point (s) is 39,770 meters and the order quantity (Q) is 77,004 meters. It is shown that the recommended system can provide a higher fill rate and reduce the cost generated by having cost reduction reaching 3.77% from the existing condition. Even though the holding cost of *(s, Q)* system is higher than the existing condition, the setup cost, shortage cost, and unit cost are lower and able to minimize the total cost. If compared with the other system, *(s, Q)* system can offer the highest cost reduction in item 20SDR17.

5.3.4 Analysis of (s, S) System

(s, S) system uses two parameters as control variables which are reorder point (s) and maximum inventory level (S). In this system, replenishment is made when the inventory position drops to order point s or lower and replenish the inventory position to the level S. The difference between (s, S) and (s, Q) system is that (s, S) system has a variable replenishment quantity where (s, Q) system has a fixed replenishment quantity. This system offer advantage such as it can give a lower holding cost if compared with periodic review. However, there are also disadvantages that can appear by implementing the system which is error can occur more frequently due to the variable replenishment quantity.

In this research, several items use (s, S) system as the most optimal policy to be used such as item 110SDR17, 63SDR17, and 20SDR11. In total, there are 9 items use (s, S) system out of 36 items. From the 9 items, it consists of 5 items out of 7 items in the class A product, 2 items out of 11 items in the class B product, and 2 items out of 18 items in the class C products. It is shown that (s, S) system is more dominant to be used in class A. According to Silver (2016), (s, S) system is appropriate to use in class A item. The nature of class A item is high money value that requires frequent control and records should be maintained on a perpetual basis. In most cases, the best (s, S) system has shown to generate a lower total cost of replenishment, carrying inventory, and shortage than (s, Q) system, therefore (s, S) system is suitable for class A items.

For example, in item 110SDR17, the chosen policy is the (s, S) system. The reorder point (s) is 1545 meters and the maximum inventory level (S) is 4499 meters. It is shown that the recommended system can provide a higher fill rate and reduce the cost generated by having cost reduction reaching 2.5% from the existing condition. Even though the setup cost of (s, S) system is higher than the existing condition, the unit cost, holding cost, and shortage cost are lower and able to minimize the total cost. If compared with the other system, (s, S) system can offer the highest cost reduction in item 110SDR17.

Table 5. 4 Recapitulation of Inventory Control Policy Selection

	Class A	**Class B**	**Class C**
(R, S)	-	- 50SDR11 - 160SDR17	- 32SDR13.6 - 50SDR13.6 - 250SDR17 - 40SDR11 - 40SDR13.6 - 60SDR17 - 63SDR13.6 - 125SDR21 - 125SDR17
(R, s, S)	-	-	- 125SDR11
(s, Q)	- 20SDR17 - 25SDR17	- 90SDR17 - 200SDR17 - 20SDR13.6 - 63SDR21 - 200SDR1 - 25SDR11 - 90SDR21	- 50SDR17 - 110SDR11 - 25SDR13.6 - 40SDR17 - 160SDR11 - 110SDR13.6

Table 5. 5 Recapitulation of Inventory Control Policy Selection (Con't)

	Class A	Class B	Class C
(s, S)	- 110SDR17 - 63SDR17 - 20SDR11 - 32SDR17 - 32SDR11	- 63SDR11 - 90SDR11	- 75SDR11 - 160SDR13.6

5.4 Analysis of Scenario Planning

Scenario planning is conducted because there could be a more optimal solution with a better fill rate and lower total cost. Scenario formulation is conducted in all of the observed objects with each of the items is processed using 40 scenarios. The scenarios are performed by increasing and decreasing the input parameters of the policies in an incremental manner. The input parameters that are changed in (R, S) system are the review period and the maximum inventory level, in *(R, s, S)* system are minimum inventory level and maximum inventory level, in *(s, Q)* system are minimum inventory level and order quantity, and in *(s, S)* system are minimum inventory level and maximum inventory level. The best scenario is chosen based on the optimal value of fill rate and total cost. Since the company focus more on cost reduction, the scenario with better cost reduction is more preferable but still considering the fill rate. The weight of each aspect is compared using a pairwise comparison. In this research, the observed scenarios are the first best scenario until the third-best scenario.

The result of the scenario formulation is various. Some item still keeps the initial value of parameters as the preferred solutions such as in item 63SDR21 and 63SDR11. In total seven items use the initial parameter as its top three scenario. It is shown that the initial optimal parameters are already optimal to be implemented. Nevertheless, there are still other scenarios that can generate more optimal results in other items.

For *(R, S)* system, the best scenario that are most used are scenario 1 and scenario 2 with both are best used in 7 items. Scenario 1 is changing the parameter by decreasing the initial maximum inventory level until 10% while for scenario 2 is changing the parameter by decreasing the initial maximum inventory level until 9%. The scenario that can provide the minimum total cost in general for class B and C item is also scenario 1 and the scenario that can provide the maximum fill rate in general for class B and C item is scenario 14 which increases the value of maximum inventory level by 4%. It is shown that for both item B and C, the fill rate drops significantly at scenario 21 which reduce the maximum inventory level by 10% and increase the reviewing period by 1 period. This is caused by the scenario have to cover more period but the level of inventory is reduced, making stockout to appears more than other scenarios.

For *(R, s, S)* system, since it only used in one item so the best scenario used is scenario 21 which is changing the parameter by decreasing the initial maximum inventory level until 10%. The scenario that can provide the minimum total cost is scenario 21 which reduces the value of maximum inventory level by 10% and the scenario that can provide the maximum fill rate is also scenario 21.

For *(s, S)* system, the best scenario that are most used are the initial parameter that are best used in four items. The scenario that can provide the minimum total cost in general for class A is scenario 29, class B is scenario 39, and for class C is scenario 26 which reduces the value of the maximum inventory level by 2%, increase the maximum inventory level by 9%, and reduce the maximum inventory level by 5% respectively. The scenario that can provide the maximum fill rate in general for class A is scenario 17, class B is scenario 15, and class C is scenario 37 which increases the value of minimum inventory level by 5%, 7%, and increase the maximum inventory level by 7% respectively. In class A and B items, it shows that scenario 1 until scenario 10 generates a lower fill rate. This condition appears because scenario 1 until scenario 10 reduces the level of minimum inventory level, causing stockout to appear more than the initial parameter. However, scenario 11 until scenario 20 generates a higher fill rate. This condition appears because scenario 11 until scenario 20 increases the level of minimum inventory level, making it to be able to minimize the probability of stockout.

For *(s, Q)* system, the best scenario that are most used are scenario 21 and scenario 22 with both are best used in five items. Scenario 21 is changing the parameter by decreasing the order quantity until 10% while for scenario 22 is changing the parameter by decreasing the order quantity until 9%. The scenario that can provide the minimum total cost in general for class A is scenario 37, class B is scenario 14, and for class C is scenario 21 which increase the order quantity by 2%, increase the minimum inventory level by 4%, and reduce the order quantity by 10% respectively. The scenario that can provide the maximum fill rate in general for class A, B, and C is scenario 18 which increases the value of minimum inventory level by 8%. The total cost is generally high in scenario 16, 17, and 18 which increase the minimum inventory level. The total cost is particularly high because it carries a higher level of inventory causing a higher holding cost and unit cost resulting a higher total cost. However, since it carries a higher level of inventory, the scenarios can provide a higher fill rate in general. In general, it is shown that the scenarios that can optimize the fill rate and cost reduction are scenarios that reduce the value of order quantity, whether it is an *(R, S)*, *(s, Q)* or other system.

As an example, item 110SDR17 use *(s, S)* system and choose scenario 21, scenario 22, and scenario 23 as the first until third best scenario. In the existing condition, the fill rate reached 92% and the total cost is Rp5,089,412,976. In the recommended policy, the policy can provide 97.6% of fill rate and a total cost of Rp4,946,284,271 which the fill rate and total cost are better than the existing condition. However, in scenario 21 where the parameter of maximum inventory level from the recommended policy is reduced by 10%, the fill rate is 97.4% and the total cost is Rp4,697,519,284. Even though the fill rate is decreased if compared with the recommended policy, the cost reduction appears to be more significant resulting scenario 21 to be the best scenario to be implemented. Followed by scenario 22 with the reduction of 9% from the maximum inventory level resulting the fill rate to reach 96.8% and total cost of Rp4,710,439,443 and scenario 23 with reduction of 8% from the maximum inventory level resulting the fill rate to reach 97.02% and total cost of Rp4,714,354,638 as the second and third best scenario to be implemented in 110SDR17

5.5 Analysis of Sensitivity Analysis

Sensitivity analysis is conducted to understand the impact of changing the independent variables towards the outcome of the inventory control policies. The independent variable in this research is the demand while the outcome of the inventory control policies is the total cost and fill rate. In this research, the demand is changed in 8 conditions which are changing the value by -60%, -40%, -20%, +20%, +40%, +60%, +80%, and +100%. However, the input parameters for the inventory control policies remain unchanged. It is shown that by changing the value of demand, it also changed the value of total cost and fill rate.

The correlation between the change of demand and change of total cost is directly proportional. It is shown that in all of the items, by decreasing the demand the total cost is decreased and vice versa. By decreasing the demand, the number of production and produced item is decreased, causing the unit cost, holding cost, and setup cost to decrease, therefore reducing the total cost and by increasing the demand the number of production and produced item is increased, causing the unit cost, holding cost, and setup cost to increase, therefore increasing the total cost. For example, in item 20SDR17 which is classified as class A item, when the demand is decreased for 40% the total cost is decreased 39.8% while when the demand is increased for 40%, the total cost is increased for 43.6%. In average, when class A item demand is decreased to 40% the total cost is decreased by 37.9% while when the demand is increased for 40% the total cost is increased by 44.1%. Another example, in class C item such as item 50SDR17, when the demand is decreased by 40% the total cost is decreased by 33%, while when the demand is increased by 40%, the total cost is increased by 33%. In average, when class C item demand is decreased by 40%, the total cost is decreased by 18.54% while when the demand is increased by 40%, the total cost is increased by 32.12%. This shows that class A item is more sensitive towards demand changes rather than class C item in terms of total cost. If the recommended policy compared with the existing policy, by decreasing and increasing the demand by 40% it shows only a slight difference. However, after the demand is increased from 60% to 100%, it shows a significant difference where the recommended policy is more sensitive. This is caused by in general the recommended policy carries a lower level of inventory, resulting a more significant increase of stockout cost if the demand is increased tremendously.

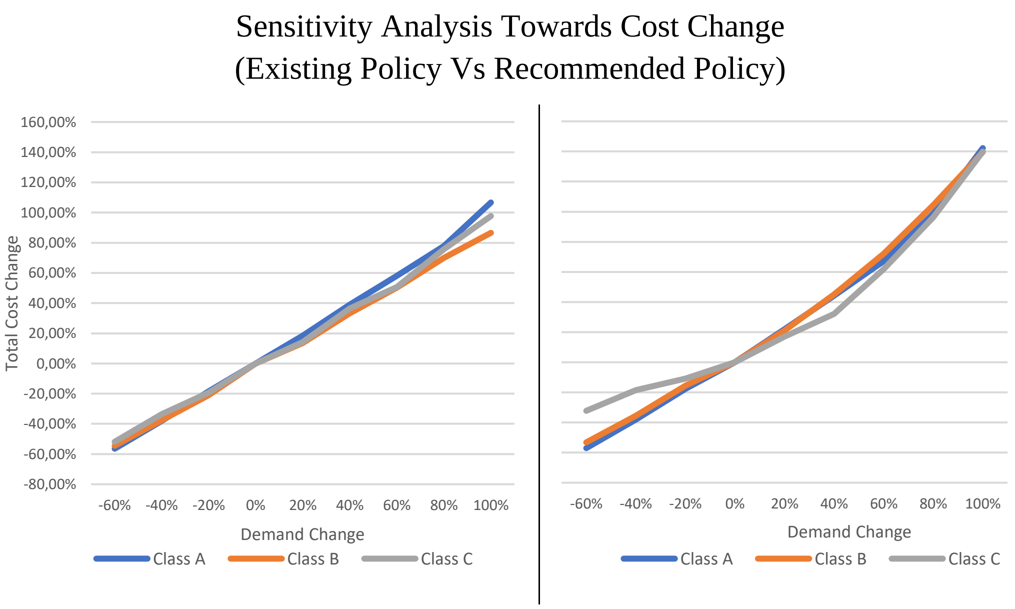

Figure 5. 1 Sensitivity Analysis Towards Cost Change

The correlation between the change of demand and change of fill rate is inversely proportional. It is shown that in all of the item, by decreasing the demand the fill rate is increased and by increasing the demand the total cost is decreased. By decreasing the demand, the number of orders that need to be fulfilled is decreased, resulting an increase of the fill rate and vice versa. For example, in item 20SDR17 which is classified as class A item, when the demand is decreased by 40% the fill rate is increased by 2.26% while when the demand is increased by 40% the fill rate is decreased by 12.95%. In average, when class A item demand is decreased by 40% the fill rate is increased by 3.5% while when the demand is increased by 40% the fill rate is decreased by 11.5%. another example, in class C item such as item 32SDR13.6, when the demand is decreased by 40% the fill rate is increased by 1.36% while when the demand is increased by 40%, the fill rate is decreased for 20.2%. In average, when class C item demand is decreased by 40%, the fill rate is increased by 0.4% while when the demand is increased by 40%, fill rate is decreased by 12.5%. If the recommended policy compared with the existing policy, it shows a difference where the recommended policy is more sensitive. This is caused by in general the recommended policy carries a lower level of inventory, resulting a more significant increase of stockout when demand is increased, therefore reducing the fill rate more significantly than the existing policy.

Sensitivity Analysis Towards Fill Rate Change
(Existing Policy Vs Recommended Policy)

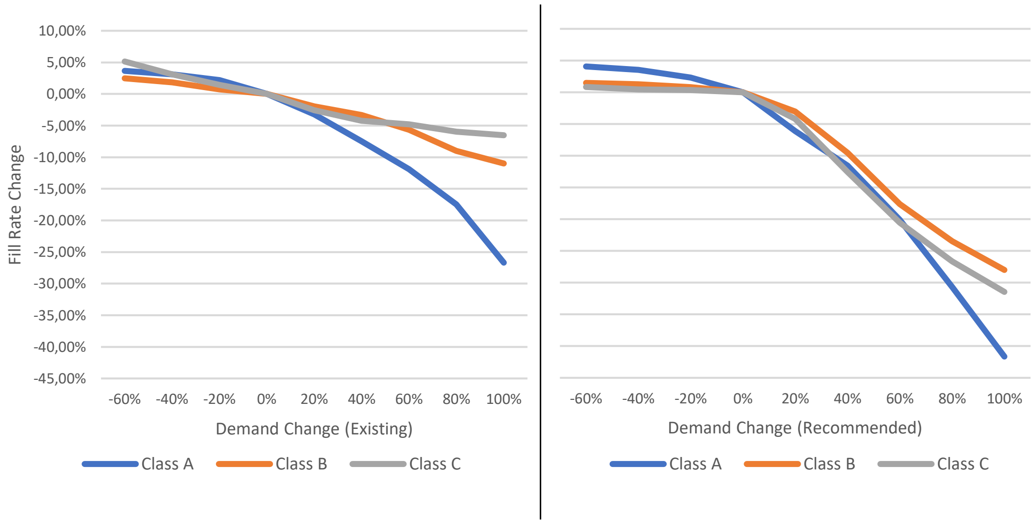

Figure 5. 2 Sensitivity Analysis Towards Fill Rate

CHAPTER 6
CONCLUSION AND RECOMMENDATION

This chapter explains about the conclusion and recommendation from conducting this research.

6.1 Conclusion

This sub-chapter explains about the conclusion from conducting this research. The conclusions of this research are shown below.

1. The forecasting methods that are proposed in this research is shown to be able to generate a lower error. It is shown that for items with continuous pattern, the most used method is Winter's method followed by Holt's method, while for intermittent pattern, the most used method is Syntetos Boylan Approximation followed by Croston's method. However, there are two items that still use the existing method as the best way to forecast the demand.
2. Product classification is conducted using ABC analysis which classifies the product according to the value of the product towards the company and ADI-CV analysis which classify the product according to the demand pattern. Based on the calculation from 36 items, there are 7 items that are classified as class A item, 11 items that are classified as class B item, and 18 items that are classified as class C item. From ADI-CV analysis, there are 19 items that have continuous pattern and 17 items that have intermittent pattern. From the classification, the company can provide an accurate strategy according to the characteristics of the product.
3. The systems that are designed as recommendation to the company are periodic review and continuous review. Periodic review consists of *(R, S)* system and *(R, s, S)* system. Continuous review consists of *(s, Q)* and *(s, S)* system. From the calculation, it is shown that for class A items which are categorized as high-value items the appropriate policy to be implemented is *(s, S)* system due to its ability to hold a lower level of inventory resulting in

a lower total cost while maintaining a considerable fill rate. For class B items the appropriate policy to be implemented is *(s, Q)* system due to its simplicity and its ability to generate a lower total cost while maintaining a considerable fill rate. For class C items the appropriate policy to be implemented is *(R, S)* due to its simplicity and longer reviewing interval resulting in a lower total cost while maintaining a considerable fill rate. It is also shown that continuous data is dominated by *(s, Q)* and *(s, S)* system while for intermittent data is dominated by *(s, Q)* and *(R, S)* system.

4. By implementing the recommended inventory control policy, the company are able to reduce the total cost by Rp3,841,592,754 which is 7% from the initial total cost. It is also shown that the company are able to maintain a considerable fill rate reaching an average of 97.7%. The most optimal policy is also measured using scenarios which conducted by changing the value of the inventory control parameters. It is shown that the most optimal policy to be implemented are able to reach 97.8% of fill rate and reduce the total cost by Rp4,859,084,608 which reduces the initial total cost by 8.8%.

6.2 Recommendation

This sub-chapter explains about the recommendation for future research and the company. The recommendation of this research are shown below.

1. To be able to consider other factor in a more detailed manner such as considering cost changes in order to make the model more precise.
2. To make the system for reviewing the inventory control policy performance in order to aid the company to adapt with the changes.

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ATTACHMENT

Attachment A: Demand of HDPE Sales

No	Item	Month						Total (m)
		1	2	3	4	…	36	
1	110SDR17	1,250	2,000	525	2,750	…	5,800	139,641
2	160SDR17	556	0	1,090	0	…	0	23,238
3	200SDR17	750	315	249	650	…	640	13,419
4	20SDR11	44,525	51,250	78,512	64,315	…	32,576	2,134,130
5	20SDR13.6	14,250	18,025	11,240	15,510	…	30,025	718,179
6	20SDR17	74,225	76,126	75,111	78,101	…	126,540	3,506,053
7	25SDR11	4,225	5,005	6,225	4,910	…	7,250	229,191
8	25SDR13.6	1,995	2,105	2,450	2,300	…	4,250	105,000
9	32SDR11	25,110	21,450	21,100	28,550	…	21,756	653,733
10	25SDR17	58,535	60,025	57,125	55,775	…	32,700	1,661,105
11	32SDR13.6	1,000	1,250	1,450	1,800	…	2,000	76,150
12	32SDR17	12,950	21,245	14,335	16,450	…	21,250	945,241
13	40SDR17	1,100	1,350	1,210	0	…	3,850	47,200
14	50SDR11	2,000	2,750	3,250	3,000	…	8,000	213,500
15	50SDR17	1,755	2,025	1,916	2,465	…	4,996	65,572
16	63SDR11	1,320	1,005	1,450	1,990	…	1,260	101,717
17	63SDR17	6,005	11,201	9,505	8,540	…	10,104	375,941
18	63SDR21	2,450	2,750	2,500	3,100	…	4,450	120,550
19	75SDR11	375	380	0	0	…	0	8,710
20	90SDR11	2,850	2,450	3,005	0	…	2,200	47,965
21	90SDR17	3,700	3,755	3,335	3,105	…	5,750	137,148
22	90SDR21	0	900	0	0	…	0	28,904

No	Item	Month						Total (m)
		1	2	3	4	…	36	
23	200SDR11	250	0	240	0	…	350	4,690
24	110SDR11	350	0	0	425	…	374	6,943
25	250SDR17	22	0	23	0	…	25	404
26	40SDR11	200	225	500	350	…	85	9,150
27	40SDR13.6	250	275	250	225	…	350	9,805
28	50SDR13.6	1,000	775	850	750	…	160	20,481
29	60SDR17	25	50	30	75	…	210	4,420
30	63SDR13.6	50	25	10	75	…	25	864
31	110SDR13.6	125	0	0	0	…	0	2,625
32	125SDR11	0	0	0	0	…	24	190
33	125SDR17	0	0	17	0	…	24	59
34	125SDR21	0	0	0	85	…	60	190
35	160SDR11	150	0	0	0	…	0	1,558
36	160SDR13.6	0	0	0	155	…	0	596

Attachment B: Data of Unit Cost and Lead Time

No	Item	Unit Cost	Lead Time (Week)
1	110SDR17	Rp108,010.00	2
2	160SDR17	Rp226,010.00	2
3	200SDR17	Rp351,870.00	2
4	20SDR11	Rp5,580.00	2
5	20SDR13.6	Rp5,530.00	2
6	20SDR17	Rp5,360.00	2
7	25SDR11	Rp8,550.00	2
8	25SDR13.6	Rp6,323.00	2
9	32SDR11	Rp13,780.00	2
10	25SDR17	Rp7,610.00	2
11	32SDR13.6	Rp8,050.00	2
12	32SDR17	Rp10,640.00	2
13	40SDR17	Rp14,660.00	2
14	50SDR11	Rp33,600.00	2

No	Item	Unit Cost	Lead Time (Week)
15	50SDR17	Rp22,960.00	2
16	63SDR11	Rp52,320.00	2
17	63SDR17	Rp35,860.00	2
18	63SDR21	Rp28,370.00	2
19	75SDR11	Rp73,250.00	2
20	90SDR11	Rp105,340.00	2
21	90SDR17	Rp72,250.00	2
22	90SDR21	Rp59,500.00	2
23	200SDR11	Rp517,250.00	2
24	110SDR11	Rp157,300.00	2
25	250SDR17	Rp546,720.00	2
26	40SDR11	Rp21,510.00	2
27	40SDR13.6	Rp17,850.00	2
28	50SDR13.6	Rp27,900.00	2
29	60SDR17	Rp22,960.00	2
30	63SDR13.6	Rp44,060.00	2
31	110SDR13.6	Rp132,720.00	2
32	125SDR11	Rp203,110.00	2
33	125SDR17	Rp186,750.00	2
34	125SDR21	Rp179,500.00	2
35	160SDR11	Rp332,300.00	2
36	160SDR13.6	Rp280,720.00	2

Attachment C: Safety Factor Table

K	F(K)	F'(K)	E(K)	K
0	0.5	0.5	0.3989	0
0.1	0.5398	0.4602	0.3509	0.1
0.2	0.5793	0.4207	0.3069	0.2
0.3	0.6179	0.3821	0.2668	0.3
0.4	0.6554	0.3446	0.2304	0.4
0.5	0.6915	0.3085	0.1978	0.5
0.6	0.7257	0.2743	0.1687	0.6
0.7	0.758	0.242	0.1429	0.7
0.8	0.7881	0.2119	0.1202	0.8
0.9	0.8159	0.1841	0.1004	0.9
1	0.8413	0.1587	0.0833	1
1.1	0.8643	0.1357	0.0686	1.1
1.2	0.8849	0.1151	0.0561	1.2
1.3	0.9032	0.0968	0.0455	1.3
1.4	0.9192	0.0808	0.0367	1.4
1.5	0.9332	0.0668	0.0293	1.5
1.6	0.9452	0.0548	0.0232	1.6
1.7	0.9554	0.0446	0.0183	1.7

K	F(K)	F'(K)	E(K)	K
1.8	0.9641	0.0359	0.0143	1.8
1.9	0.9713	0.0287	0.0111	1.9
2	0.9772	0.0228	0.0085	2
2.1	0.9821	0.0179	0.0065	2.1
2.2	0.9861	0.0139	0.0049	2.2
2.3	0.9893	0.0107	0.0037	2.3
2.4	0.9918	0.0082	0.0027	2.4
2.5	0.9938	0.0062	0.002	2.5
2.6	0.9953	0.0047	0.0015	2.6
2.7	0.9965	0.0035	0.0011	2.7
2.8	0.9974	0.0026	0.0008	2.8
2.9	0.9981	0.0019	0.0005	2.9
3	0.9984	0.0016	0.0004	3

Attachment D: Recapitulation of Sensitivity Analysis

Sensitivity Analysis Towards Cost Change

Item	-60%	-40%	-20%	0%	20%	40%	60%	80%	100%
20SDR17	-59.5%	-39.8%	-20.1%	0%	22.1%	43.6%	71%	155%	264%
110SDR17	-55.9%	-39.1%	-21.6%	0%	14.5%	40.0%	59%	83%	107%
63SDR17	-55.5%	-40.5%	-19.3%	0%	24.5%	50.3%	71%	93%	115%
25SDR17	-56.9%	-35.9%	-14.6%	0%	23.1%	47.5%	70%	95%	182%
20SDR11	-59.5%	-37.7%	-17.5%	0%	21.0%	42.0%	65%	83%	109%
32SDR17	-55.0%	-36.3%	-13.4%	0%	22.3%	42.1%	67%	90%	108%
32SDR11	-56.8%	-36.5%	-17.3%	0%	25.9%	43.6%	67%	91%	110%
90SDR17	-57.6%	-41.3%	-16.6%	0%	17.0%	42.7%	62%	85%	114%
50SDR11	-51.7%	-34.5%	-17.3%	0%	18.1%	38.9%	67%	147%	246%
200SDR17	-61.1%	-36.7%	-12.3%	0%	24.4%	51.0%	65%	92%	114%
63SDR11	-50.3%	-36.9%	-14.2%	0%	29.0%	52.1%	74%	93%	110%
160SDR17	-50.8%	-33.9%	-17.0%	0%	18.6%	48.2%	130%	230%	331%
90SDR11	-64.1%	-41.7%	-16.8%	0%	19.8%	47.5%	69%	96%	113%
20SDR13.6	-49.2%	-37.0%	-12.5%	0%	25.6%	40.3%	65%	79%	105%
63SDR21	-56.2%	-28.3%	-14.3%	0%	28.1%	43.6%	73%	88%	105%
200SDR11	-55.7%	-28.1%	-14.3%	0%	14.8%	41.8%	59%	74%	91%

Item	-60%	-40%	-20%	0%	20%	40%	60%	80%	100%
25SDR11	-49.2%	-32.9%	-16.7%	0%	17.1%	50.0%	69%	85%	105%
90SDR21	-39.2%	-38.9%	-19.5%	0%	19.4%	40.4%	60%	79%	100%
50SDR17	-48.6%	-32.2%	-16.0%	0%	16.7%	33.3%	49%	52%	69%
110SDR11	-58.2%	-39.1%	-19.6%	0%	19.6%	38.9%	41%	61%	83%
25SDR13.6	-48.4%	-24.5%	-24.3%	0%	0.8%	24.9%	50%	51%	75%
40SDR17	-48.3%	-24.2%	-24.3%	0%	24.1%	24.4%	49%	50%	75%
75SDR11	-33.2%	-31.4%	-3.2%	0%	29.4%	34.9%	66%	100%	105%
32SDR13.6	-38.9%	-26.0%	-13.0%	0%	12.2%	26.6%	64%	125%	193%
160SDR11	-48.2%	-47.1%	-24.4%	0%	24.8%	27.1%	55%	75%	82%
110SDR13.6	-49.4%	-25.2%	-24.7%	0%	24.9%	27.7%	51%	79%	75%
50SDR13.6	-34.5%	-23.0%	-11.5%	0%	15.8%	52.5%	122%	211%	307%
250SDR17	-25.1%	-16.7%	-8.4%	0%	6.8%	29.3%	76%	133%	194%
40SDR11	-23.8%	-15.9%	-7.9%	0%	8.5%	24.9%	63%	115%	178%
40SDR13.6	-24.6%	-16.4%	-8.2%	0%	6.8%	18.6%	52%	102%	164%
160SDR13.6	-92.2%	-7.5%	-6.8%	0%	82.3%	88.2%	94%	88%	167%
60SDR17	-23.3%	-15.5%	-7.8%	0%	5.7%	16.9%	33%	63%	108%
63SDR13.6	2.7%	1.8%	0.9%	0%	-0.9%	3.5%	23%	49%	90%
125SDR21	3.4%	2.3%	1.1%	0%	4.5%	36.9%	77%	118%	160%
125SDR11	3.1%	2.0%	1.0%	0%	-1.0%	-2.0%	6%	31%	68%
125SDR17	6.5%	4.4%	2.2%	0%	24.1%	72.1%	143%	229%	320%

Sensitivity Analysis Towards Fill Rate

Item	-60%	-40%	-20%	0%	20%	40%	60%	80%	100%
20SDR17	100%	100.0%	99.9%	97.8%	89.9%	85.1%	67%	26%	17%
110SDR17	100%	98.5%	97.9%	97.6%	92.9%	91.2%	77%	78%	70%
63SDR17	100%	100.0%	99.4%	95.4%	90.3%	82.4%	80%	74%	67%
25SDR17	100%	98.9%	97.1%	95.1%	87.9%	77.4%	74%	59%	24%
20SDR11	100%	99.1%	97.3%	94.8%	88.8%	82.0%	76%	72%	67%
32SDR17	100%	100.0%	98.8%	95.6%	91.8%	90.9%	86%	82%	77%
32SDR11	100%	99.7%	97.7%	96.4%	89.7%	85.9%	77%	74%	69%
90SDR17	100%	100.0%	99.3%	99.0%	96.6%	93.0%	87%	74%	67%

Item	-60%	-40%	-20%	0%	20%	40%	60%	80%	100%
50SDR11	100%	100.0%	100.0%	99.6%	95.6%	86.6%	59%	29%	20%
200SDR17	100%	100.0%	100.0%	99.5%	99.4%	96.3%	93%	90%	94%
63SDR11	100%	100.0%	99.0%	98.3%	94.3%	87.4%	90%	85%	80%
160SDR17	100%	99.3%	98.9%	98.2%	90.3%	59.0%	27%	20%	15%
90SDR11	100%	100.0%	99.1%	96.8%	95.1%	90.4%	84%	84%	75%
20SDR13.6	100%	100.0%	99.6%	98.6%	93.0%	87.4%	89%	84%	84%
63SDR21	100%	100.0%	99.3%	98.3%	96.9%	91.8%	88%	86%	81%
200SDR11	100%	100.0%	100.0%	99.7%	96.8%	99.1%	93%	93%	89%
25SDR11	100%	99.1%	98.5%	97.1%	94.6%	93.5%	85%	87%	80%
90SDR21	98%	97.5%	97.1%	96.9%	96.8%	94.5%	96%	95%	94%
50SDR17	100%	100.0%	100.0%	100.0%	99.6%	97.7%	99%	92%	93%
110SDR11	100%	100.0%	100.0%	99.0%	98.4%	98.2%	95%	89%	91%
25SDR13.6	99%	98.2%	97.6%	97.3%	97.1%	94.9%	94%	93%	92%
40SDR17	100%	99.9%	99.2%	98.8%	98.5%	98.3%	98%	98%	92%
75SDR11	100%	96.3%	97.3%	95.5%	94.3%	92.9%	91%	88%	86%
32SDR13.6	100%	99.3%	98.5%	98.0%	93.6%	78.2%	51%	37%	29%
160SDR11	100%	100.0%	100.0%	99.6%	97.1%	96.3%	93%	98%	91%
110SDR13.6	98%	97.6%	97.2%	97.0%	94.7%	91.8%	92%	90%	95%
50SDR13.6	100%	100.0%	100.0%	100.0%	87.2%	58.7%	35%	24%	19%
250SDR17	100%	100.0%	100.0%	100.0%	91.6%	69.9%	60%	54%	51%
40SDR11	100%	100.0%	100.0%	100.0%	97.5%	78.9%	65%	53%	43%
40SDR13.6	100%	100.0%	100.0%	100.0%	94.6%	79.9%	64%	50%	40%
160SDR13.6	100%	100.0%	99.5%	97.9%	97.1%	95.4%	95%	96%	93%
60SDR17	100%	100.0%	100.0%	100.0%	91.2%	82.6%	74%	57%	42%
63SDR13.6	100%	100.0%	100.0%	100.0%	100.0%	91.4%	85%	81%	65%
125SDR21	100%	100.0%	100.0%	100.0%	90.5%	78.6%	78%	77%	75%
125SDR11	96%	96.2%	96.2%	96.2%	96.2%	96.2%	79%	65%	63%
125SDR17	100%	100.0%	100.0%	100.0%	85.0%	74.3%	62%	56%	55%

AUTHOR'S BIOGRAPHY

The author, Daniel Bayu Kristanto was born in Serang on May 19th, 1998. The author is the second child of Hery Susanto and Evodia Trionerawati. The author took formal education in Mardi Yuana elementary school (2004-2010), Mardi Yuana Junior High School (2010-2013), SMAN 1 Kota Serang (2013-2016), and afterwards continue his study in industrial and systems engineering major in Institut Teknologi Sepuluh Nopember (ITS) Surabaya (2016-2020). During university, the author was actively participating in various organization and activities. The organization that the author joined during university was HMTI (Industrial Engineering Student Association) as staff of social community and AIESEC in Surabaya as manager of External Relations. The activities that the author participates was social community activities such as environment campaign towards the society and training of software such as ARENA and VBA. The author is also active in participating in competition such as becoming the finalist of Business Case Competition that was held by Darusallam University in 2020. The author was an intern in a cement manufacturing industry, PT. Indocement Tunggal Prakarsa, Department of Supply Chain in 2019. If there is a question, critic, or feedback towards this final project, the author is open and can be reached through email danielbayu19@gmail.com.