Safety stock analysis of ship fuel in shipping company (Case study: white oil ship PT. Pertamina (Persero))

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Abstract. Currently, fuel supply of PT. PERTAMINA (PERSERO) SHIPPING for each trip with a predictive safety stock to supply as much as 40% of the total fuel provided. The fuel that is stored for too long will also affect the sediment, thereby reducing the performance of the ship's engine in the long run. Optimization was conducted by using the safety stock formula which influenced by the uncertainty of demand and the uncertainty lead time (sailing time) of the ship. Calculations are based on demand from three distance routes that have the highest frequency assignment. Calculations are performed by comparing the safety stock in the four conditions, namely: (a) the condition of safety stock with combination of three routes (heterogeneous); (b) the condition of the safety stock by successively using the distance 286 NM; (c) 320 NM; and (d) 536 NM. The results obtained by calculating safety stock with the heterogeneous condition was 81.44%; homogeneous conditions within the 286 NM; 320 NM; 536 NM were 15.2%; 7.3%; and 29.2% of the total fuel supplied. Thus, the safety stock application is done by plotting trend charts to get an increase of 0.056% for each NM.

Keywords: Fuel Supplies, Safety Stock, Voyage, and Storage.

1. Introduction

The new policy applied by the PT. PERTAMINA (PERSERO) SHIPPING is to use a supply system that performed each voyage. Ship activities when loading until the ship unload all cargo (discharge), means that the ship has undertaken a voyage. Fuel consumption used for the one-way trip despite the same service will not spend the same fuel as well. PT. PERTAMINA (PERSERO) SHIPPING had a calculation to control vessel fuel consumption with the Slow Speed and Over Bunker (SSOB) method.

The positive effects of this policy will minimize the occurrence of theft, as well as the use of more fuel-efficient because it prevents sediment caused by nature. On the other hand, the negative effects of this policy are the amount of fuel that is too little allows the vessel run out of fuel amid the trip. Ship refueling is done at loading port for efficiencies voyage activities. The problems that occur are (1) not all of the port where cargo loading has the willingness of time or (2) lack of fuel stock to supply ships. With a small fuel stock, determining the location when a deviation occurs will be quite difficult. Another issue that will occur is when the ship experiences slow speed which will affect the use of excess fuel. Nowadays, the company implements a safety stock policy for 40% of the supply of fuel used for a single voyage. The determination of the number is the result of a rough prediction of operators in the field. The new problem that will arise is in the determination of safety stock. If the safety stock was too little, it would not fulfill the demand (fuel consumption). By contrast, if the safety stock was too large, it would cause wastage due to sedimentation that would damage the ship's engine performance in the long term.
This issue is the basis for the need to analyze the fuel supply safety policy, whether the amount is sufficiently optimal. This paper will investigate how the computation and application of optimal safety stock to apply to this policy and evaluate the SSOB calculation that is going to be one of the processes to calculate the safety stock.

2. Methods

Inventory is a current asset owned by the company as a tool to meet customer demand and is further processed in meeting a particular goal [1]. Meanwhile, inventory is an investment in the form of sales in the future, expecting a return on these sales and minimizing costs [2]. Based on the inventory theory, it can be concluded that inventory is goods or resources that are used for the company's needs to do further processing or immediate resale in the future. Inventory in this paper refers to the amount of fuel that will be consumed during the course of the ship.

In the case of this inventory requires inventory management which can optimize the number and the right time in the store inventory. Inventory management is all the planning, implementation, and supervision to meet the operating needs optimally [3]. The purposes of inventory management are to keep inventory so that the costs can be kept low and to ensure uninterrupted supply during operation (production) [4]. Things to note, inventory control is not able to eliminate all risks due to the amount of inventory [5]. But it also does not mean inventory control or inventory management is done to achieve the lowest inventory. The inventory control processes are centered on the process when investments and stocks are adjusted according to a limit set by company policy [6].

The crucial part of the inventory is the calculation of safety stock. Definition of additional inventory safety stock is used to prevent the situation out of stock [7]. Even so, the safety stock must still be taken into account because of the high safety stock will result in additional costs [8]. Safety stock will act as a buffer if there is a surge in demand or normal orders that are not able to close the request [9]. No different from some of the opinions that have been quoted, the authors assume the demand is the amount of fuel consumption during the ship trip.

Calculating safety stock are divided based on the uncertainty of each variable as the uncertainty of demand, the uncertainty of lead time, and a mixture of both uncertainties [10]. Other research also has the same opinion, the size of the safety stock is affected by the variance that is in the required variable [11]. This study takes into account the fuel consumption as demand uncertainty and long lead time of the ship is uncertain. Safety stock calculations taking into account the uncertainty of demand and the lead time is [12];

\[ Safety\ Stock = \sqrt{l \times S_d^2 + d^2 \times S_l^2} \]  

... (2.1)

**Information:**
- \( d \) = Demand per voyage (MT/voyage)
- \( S_d \) = Standard deviation of demand
- \( l \) = Lead time per voyage (day/voyage)
- \( S_l \) = Standard deviation of lead time

Calculating safety stock requires preliminary stages of determinations and sample calculations. Sampling is a method used when research is not possible to collect data or process one by one the data of all existing data [13], the population consists of all the data that will be observed, while the sample is a set of existing in a population that is able to represent the entire population to be studied [14], calculation of the sample using the following equation:

\[ n = \frac{Z^2 \times p \times (1 - p)}{d^2} \]  

... (2. 2)

**Information:**
- \( n \) = Minimum number of samples required
- \( Z \) = Degree of confidence
- \( p \) = the sample proportions in the population
- \( d \) = Limit of error or absolute precision
Multi-Stage sampling method is used to decide the sample. The principle of this method is to select a sample that meets the adjustment of a stage in the sampling design [15]. Then, from this highly specific group, several samples are taken that will represent the population. This method aims to select a sample that is concentrated in a population.

PT. PERTAMINA (PERSERO) SHIPPING is currently implementing these policies consisting of:

1. The vessel will be given the supply of fuel for each voyage.
2. Safety stock for ships that will carry out the voyage is 40% of the supply to be provided.

These policies are applied to ships carrying white oil only. This is because these ships generally only have single loading and discharge for a single voyage. The route followed is fairly close and has a certain pattern. In the illustration in Figure 1, it appears that the possibility of water entering the fuel tank so that the performance of the fuel to be reduced. Moreover, the appearance of the sediment if the fuel is in the tank are too high can also reduce the amount of fuel that is still fit for use.

![Figure 1. Illustration of the fuel tank with the excess sediment](image)

Another possibility is that the engine will consume the sediment of fuel. Figure 1 shows that the ship's engine will consume sediment of fuel, due to the amount of sediment (line A) already exceed the end of the tank pipeline (line B). The sediment, which has a viscosity that is denser, will reduce boat engine performance in the long term.

A voyage is the condition of a journey for single loading and single discharge, and it spends about 50% of the fuel supply. 40% of safety stock policy is applied, the ship ought to be able to do almost three times the activity (twice loading and discharge one or vice versa). Furthermore, if the ship deviated for refueling purposes, it will be heading to the nearest port that probably only spend a little bit of safety stock. Here are some of the potential losses that would be borne by the company if the safety stock is high or low:

1. Large safety stock would cause deposits that affect the quantity of fuel (which is still fit for use) and engine performance.
2. Small safety stock will affect the ship stopped amid the trip due to run out of fuel.
3. Increase the risk of theft if the safety stock is still left after the ship has deviated.

Therefore, it is necessary to evaluate the stock safety policy currently applied and determine the optimal safety stock level transform and reduce the residue.

### 3. Results and Discussion

Calculations start by taking the sample. SSOB then performed calculations to determine the ideal conditions of a data received. The last step is to calculate the safety stock with four different conditions.

#### 3.1. Sample calculation

Before taking the sample, the authors conducted a proper sampling to determine in advance the target population to be tested samples. Charter ship that still has a contract with PT. PERTAMINA
(PERSERO). Operational of ship should having voyage by only doing single loading and single discharge. Calculating the number of samples needed as in equation (2.2) with known secondary data up to 0.005 p-values and 95% confident level, the sample that will be used are 2 ships included in the sampling frame. The sample calculation process has not stopped at this stage, still has to do the sorting to choose which is the best ship which, with additional as the two samples. At this stage, sorting will be done based on the Multi Stage Sampling method:

1. Stage 1: Sister ship shorting
   The more similar the ship used as a sample the more accurate. The results showed that further sorting is done by 18 ships or 9 pairs of samples to be processed.

2. Stage 2: Checking the performance speed input data in January 2016 - July 2019
   This inspection function is to see if data on a ship is still available because the ship and sister ship also have a different contract. Thus, there is a possibility that the contract only exists in certain years. The results showed that there were two pairs of ships removed.

3. Stage 3: Checking attribute of the performance speed input data in January 2016 - July 2019
   There are 7 pairs of vessels from the previous sorting. This stage requires the completeness of the attributes of the data input speed performance of each vessel. The results obtained are a pair of ships.

4. Stage 4: Voyage most
   A pair of these ships have the same voyage numbers (the same task time) with a different route. To shorten calculation time, the writer decides to use the data with the highest number of the voyage to avoid duplicate data. This will not affect the results for the two ships are vessels that have the same specifications.

3.2. SSOB calculation
   The SSOB calculation is applied to determine the ideal condition of a ship by calculating whether the ship consumes fuel with the quantity that should be and runs at speeds under the agreement. The SSOB calculation will result in: (a) the time it should have while sailing and (b) the amount of excess fuel used. Generally, when a ship experiences a slowdown (the delivery time is longer than it should), it will automatically consume more fuel.

3.2.1. Slow Speed Calculation. The purpose of this calculation is to look for differences in actual sailing time and standard sailing time. The process of determining the actual sailing time can be determined by looking at the length of the ship's journey from the ship departing from the port before arriving at the destination port. While checking the sailing time in ideal conditions (Standard sailing time) aims to ensure the speed of the ship following the agreement. The speed of the ship uses the Knot unit(s). 1 Knot is equivalent to 1,852 Km/hour\[^{16}\]. The speed that is generally used at sea is Knot, except for special cases (powerboat racing and waterskiing), Knot also means Nautical Mile (NM) per hour or Sea Mile per hour\[^{16}\]. If the actual sailing time is bigger than standard sailing time, it can be concluded that the speed of the ship is slowing down.

3.2.2. Fuel consumption calculation. This calculation is done by finding the difference between actual fuel consumption and standard fuel consumption. Actual fuel consumption is the amount of fuel consumed or consumed by the ship to run the engine and crew needs (electricity, heating/cooling, etc.) since the ship departs from the port before arriving at the port of destination. Whereas standard fuel consumption is the maximum fuel consumption that can be consumed by ship. In general, if a ship experiences a slowdown it will consume more fuel than it should.

3.2.3. Safety stock calculation. The safety stock calculation requires sailing time variable or the amount of fuel consumption. This calculation has several stages that must be passed before the data can be calculated. The stages among which:

1. Adjust the data of ships experiencing
the slowdown or excess fuel consumption, calculation of fuel consumption, distance, and sailing
time per voyage. This adjustment was made to reach the assumption that the ship will get the amount
of safety stock in ideal conditions (conditions when the ship does not experience a slowdown or
excessaive fuel consumption).

2. Determine the distance for the calculation of safety stock

Based on the graph in Figure 2, it appears that the three most frequently traveled distances are: 286
NM (39 times) 320 NM (11 times), and 536 NM (19 times). It can be concluded that the three
distances can be used as a reference in determining safety stock.

3. Making the dummy data as a real activity representation

The making of the dummy data is intended to get an idea of the ship is in real activity. This is caused
by the presence of data to be tested to have an unbalanced amount of data. These conditions are still
not able to represent the activities in real activity.

Figure 2. Distance Voyage Frequency Distribution Graph

4. Safety stock calculation with 4 conditions

After making a dummy data will be calculated safety stock with four conditions. The first condition
is where the calculation condition of safety stock when the distance heterogeneous (containing 3
types of distance) and when the distance is homogeneous (there is only one kind of distance).
Determination of dummy data for heterogeneous conditions requires a calculation by comparing if
the three types of distance voyage distributed at 136 voyages. Here is a comparison of the distance
distribution for the heterogeneous condition. With a total of 3 distance voyages with the highest
frequency was 69. The percentage for each distance is:

Figure 3. Percentage of Each Distance

If there will be 136 voyage numbers for heterogeneous dummy data, then it is necessary:
- distance 286 NM = 57% (77 of 136 voyages);
- distance 320 NM = 16% (22 of 136 voyages); and
- distance 536 NM (37 of 136 voyages)
This study will be limited to these 4 conditions. The distance that has been mentioned has represented at least a short distance, a medium distance, and a long distance. Conditions taking into account one type of distance is said to be a homogeneous condition. Whereas, mixing of 3 types of distances is said to be a heterogeneous condition.

a) Heterogeneous condition
Heterogeneous conditions are data compilation conditions with the three types of routes. When the data is inputted by not changing the standard deviation as well as the average of demand and lead times of each route, the new safety stock is 81.44% of the demand.

b) Homogeneous conditions
Homogeneous conditions, means that all demand and lead time is spent adjusting for consumption and time spent on the voyage with that distance only. Based on the dummy data homogeneous safety stock amount of 286 NM, it obtained 15.2% of the demand, 320 NM was 7.3% of the demand, and 536 NM was 29.2% of the demand.

3.3. Analysis of safety stock calculation
The safety stock calculation is carried out by four different conditions. The purpose of grouping is to determine whether the optimal safety stock if carried out with varying distances or distances that do not vary. Other considerations that the authors assume is:

a) The safety stock is determined by applying three distances in one calculation. It is assumed that in real practice activities, the ship will have different routes or travel distances.

b) The safety stock is determined by applying each distance. If the results indicate a more optimal safety stock in the homogeneous conditions, the fuel supply can then be determined by calculating the safety stock at each distance.

Both these assumptions have advantages and disadvantages to each. On the first assumption, the calculation of safety stock will not be repeated. But the high variance causes the result of too much safety stock calculations, even reaching 80% of the supply must be provided. Supply when using heterogeneous dummy data is also relatively small for medium to long-distance routes, but also relatively large for short-distance routes.

In the second assumption, the safety stock calculation must be done repeatedly. Depending on the distance to be traveled. This will not make time-efficient if the ship has a varied route scheduling. The positive side of this calculation is the existence of a fairly rational value because the calculation is certainly more accurate and focused on travel times and fuel consumption are relatively the same.

The calculation is performed by the safety stock formula which is influenced by demand uncertainty and lead time. Based on historical demand data, each ship has a different amount of consumption for each trip. Although the data processed has been normalized by adjusting the data to the ideal conditions, this certainly cannot be used as a reference because the ship may slow down the speed and/or excessive fuel consumption due to travel conditions.

Based on calculations, heterogeneous conditions of safety stock produce more than 80% because of the many variations of the route that must be taken. Each route certainly has a different standard deviation of demand and lead times. So if the calculation combines all these deviations will result in the emergence of a new standard that will be good. Seeing the results of calculations that allocate quite a lot of fuel, this calculation is less than optimal in terms of the amount and risk that occurs if this calculation is applied in real activities. The amount of safety stock that is too much will cause a bad effect (sediment) if the fuel is stored for too long in the tank.

From the above calculation, the safety stock with this homogeneous condition will be more profitable because the amount of additional fuel is also relatively small. This allows the right quantity of fuel to refill the tank. Based on the calculation of the lowest consecutive safety stock when the 320 mileage is 7.3%; mileage 286 by 15.2%; and 536 mileage as much as 29.2% of supply requests. Based on the results of homogeneous calculations, it can be seen that there is no trend line (Figure 4) in easy application to the company.
This difference is also influenced by variations in lead time and demand for each route. This variance is also influenced by field conditions such as waves when sailing ships, changes in direction of travel (to avoid pirates or other disturbances), or other conditions that may occur.

Figure 4 shows the trend line in a linear, exponential, and standard error line to determine the best path as a reference to the percent increase in safety stock per distance voyage. The trend line is used in determining the safety stock approach for various distance voyages without having to do calculations for each distance voyage.

Table 1. Linear and Exponential Plotting Result.

| Distance Voyage (NM) | Linear | Exponential |
|----------------------|--------|-------------|
| 286                  | 10%    | 11.5%       |
| 320                  | 16.5%  | 15%         |
| 536                  | 24%    | 20.5%       |

The results of plotting the two trend lines can be determined the percent increase in safety stock based on the exponential line is equal to 0.035% per Nautical Mile (NM), while for the linear line has an increase of 0.056% per Nautical Mile (NM). Reviews based on standard errors show linear trend lines better than exponential trend lines. Based on this calculation, companies should use safer percentages because there might be unexpected events that will consume more fuel. also, calculations with linear tendencies give results that are not too far from the error limit illustrated in the graph. the author further recommends using additional fuel by following linear calculations.

4. Conclusions

After doing the calculations and discussion of case studies, the conclusions of the previous calculation are:

1. The volume of fuel for each trip has a different volume. But for the three types of distances with the highest frequency, it can be seen based on average fuel consumption.
   
   \[
   \text{Distance 286} = 1.786802423 \text{ MT} \\
   \text{Distance 320} = 1.705224317 \text{ MT} \\
   \text{Distance 536} = 3.204817322 \text{ MT}
   \]

2. Variables used for calculating safety stock are a demand or fuel consumption \( \backslash \) and lead time or sailing time under ideal circumstances. Furthermore, the calculated average and standard deviation for the calculation of the variable safety stock as well.

3. The amount of safety stock is calculated with 4 conditions. But for accuracy reasons, the safety stock is divided into 3 distance categories (the result of homogeneous condition calculations).

\[
\text{Distance 286} = 15.2\% \text{ of demand}
\]
Distance 320 = 7.3% of demand  
Distance 536 = 29.2% of demand 

Safety stock can only be applied at a specified distance, with an increase of 0.056% for each Nautical Mile (NM) on long-distance shipping. It aims to accurately supply quantities and also avoid the risk of losses arising from the fuel storage period.

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