A Simulation Study of Bulk Cement Product Maritime Tranportation Considering Vessel's Maintenance

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ABSTRACT

This study considers an operational decision in the maritime inventory routing problem considering the maintenance schedules of the ships. The problem is to determine the exact number of ships serving to distribute bulk cement product. The problem is complex due to the uncertainties in demand, travel time, loading time, and unloading in each port so that exact optimization methods or mathematical formulations are difficult to do. Therefore, discrete-event simulation method is proposed to solve the problem. In determining the number of vessels to note the external factors that affect the performance of the ship in distributing. One of the activities undertaken to maintain the condition of the ship is maintenance. With the maintenance activities there is a possibility of increasing the number of boats to distribute bulk cement to avoid shortage. The results show that simulation module built can be used to determine the number of vessels and their capacity to determine the optimal number of ships to avoid shortage. From the research work also obtained the effect of maintenance activities in determining the optimal number of vessels. With the arrangement of maintenance schedules made at the time of cement demand is down then the number of ships with a capacity of 3,200-4,500 does not require any additional fleet. But for vessels with a capacity above 4,500 it is necessary to add one fleet of vessels to avoid shortage in unloading ports

Keywords:* *Bulk Cement Product, Maritime Transportation, Disruption of Maintenance, and Discrete Simulation.

1. Introduction

Cement as a material used to glue has an ever-increasing trend of demand. According to the head of the Indonesian Cement Association (ASI) cement sales increased by 1.7% year on year to May 2016 from early 2016 [1]. The increase was triggered by an increase in demand for cement in Central Java, an increase of 22%. The growth of infrastructure in eastern Indonesia has become one of the causes of the increasing demand for cement every year. In addition, other government projects such as the construction of a million homes, reservoirs, dams, power plants and others also increase the need for cement in Indonesia. This is indicated by the increase in the state budget for infrastructure budget.

This study is inspired form a real problem in one of the biggest cement producer in Indonesia whcih controlled 27.5% of the cement market in Indonesia. To meet the growing demand for cement, the company opened its 14th factory which is capable of producing 4.4 million tons of cement per year. In addition to increased production, the company also expanded its distribution in June 2016 by delivering bulk cement products to a new area by building a new terminal with a capacity of 8,000 M / T port silo. This is done so that the company can meet the demand of cement in Kalimantan area. With the addition of new factory and port discharging, it is necessary to calculate the ship's need and ship's capacity to adjust the increase of cement production and demand level.

To reach all existing customers, the company has several distributors. Distributors are spread across various islands in Indonesia. To distribute the cement products to distributors and end customers there are several transportation modes utilized by the company. Trucks and trains are the modes of transportation used to distribute cement products by land. While the mode of transportation of ships used to distribute through sea lanes. Sea transportation is the process of moving goods and people from the place of origin to the destination by sea. By using the ship the volume of delivery is so much that the shipping cost is low [2], [3] and [4].

There are three loading ports scattered namely Tarjun, Cirebon and Tanjung Priok ports. While there are four destinations for discharging ports of Surabaya, Lombok, Samarinda and Pontianak, which were opened in June 2016. In distributing the bulk cement, the company uses time charter leasing mechanism. Time charter is a chartering scheme of vessels within a certain period. The time charter chartering fee is determined for the duration of the lease.

As a company with functional products, the company needs to do an efficiency strategy that minimizes the total cost in order to produce a more competitive product. One of variable cost which has big influence to total cost is transportation cost and inventory cost [5], [6].

The amount of distribution costs cause the need for good management in order to generate profit to be more optimal. Optimization can be done on the distribution process by determining the number of transport used. One of the means of transportation used is the ship. To make shipments by ship cost is large enough, with the determination of the number of the right vessel will result in a more optimal distribution costs.

In determining the number of vessels to note the external factors that affect the performance of the ship in distributing. One of the activities undertaken to maintain the condition of the ship is maintenance. Treatment is all the activities undertaken to keep the system working properly. A treatment requires different periods of time. There are treatments that require only a few hours but there are also treatments that take up to days such as cross docking which takes 20 days. With the maintenance activities there is a possibility of increasing the number of boats to distribute bulk cement to avoid shortage. The addition of the vessel can be done using time charter leasing scheme as well as voyage charter.

Determination of the exact number of ships is a complex system. This is due to the uncertainty in demand, travel time, loading time, and unloading in each port so that exact optimization methods or mathematical formulations are difficult to do. Therefore the suitable method used to solve the problem is discrete-event simulation method. Using the experimental simulation method can be done with different scenarios without affecting daily operational performance [7], [8], [9].

2. Research Method

There are several steps in conducting this research. The first is identify the problems by defining the objective of the study and listing the asumptions and boundary of the study. The second step is to study the distribution system. At this stage the bulk cement distribution system is identified against the elements contained in the system. The elements identified include the elements, variables, and key performance indicators. The next step is to observe and collect the data. In doing the observation phase the first step is to identify and search the data needed in the research. In the simulation there are three types of data required are structural data, operational data, and numerical data.

After collecting the data, the next stage is to develop the scenarios which will be tested in the simulation model. The results of these scenarios are compared to find out the best scenarios. At present the company has six vessels used to distribute bulk cement products. The scenarios are either to increase or to decrease the number of vessels and also either to increase or to decrease the vessels' capacities.

The fifth step is to develop the conceptual model. To perform the simulation process firstly made a conceptual model that shows the problems in the real system. The conceptual model can be a flowchart, activity cycle diagram (ACD), and other forms. Following the conceptual model is to develop simulation model. Conceptual model that has been made then created a simulation model in accordance with the logic on the conceptual model and real system (real world). Then do the determination of the number of replication is also done because the results provided by the discrete simulation software is random output it is necessary to have more than one data so that the results of simulation software represent the actual population.

Verification and validation are the next steps. Internal validation (verification) and external validation is a process of testing the conceptual model and simulation model to find out whether it has represented the real system. Internal validation (verification) is a testing process to compare conceptual models with existing simulation models. Having verify and valid, the experiments for the scenarios are performed. At this stage experiments on the improvement scenarios exist in the simulation model. The experimental process is done by substituting the initial value of the decision variable in the bulk cement distribution system.

After experiments with simulation scenatrios then conducted analysis and interpretation of the results of running simulation model are conducted. Finally, the last step is a conclusion is drawn that answers the purpose of the study. In addition, a recommendation was given to the company regarding the bulk cement distribution system generated by this study.

Data Collection and Processing

In this section we will show the data used in making the simulation model of bulk cement transport of the company. These data consist of structural data, operational data, and numerical data.

Structural data is data that shows the object structure of the existing system. The structural data is divided into three data types based on the required data such as ship, port of loading, and port unloading. The structural data of the vessel is the data concerning the ship structure related to the type of vessel used and the type of leasing. The structural data of loading ports is the data on the structure of the ports used for loading bulk cement ie port location, port type, and port holding capacity. The port unloading structural data is the data on the structure of the bulk cement bulk port of destination or port. The unloading port structural data consists of location data, port types, and cement storage capacity.

Operational data is data that shows how the operation in a system. These operational data are also divided into ship data, loading ports, and unloading ports. Ship operating data is data on ship scheduling. The ship's destination selection system and return destination are determined based on the coverage days of each port. Coverage days at unloading ports are the duration of demand for cement at the port of cement destination can be met with existing cement inventory. While the coverage days on the loading port is the length of time the inventory contained in the loading port reaches the maximum storage capacity. The loading port operational data is data containing the time window contained in the loading port. On all ship loading ports can be served for 24 hours in 7 days if the jetty contained in the harbor is empty or the ship can lean. For port of loading it has two jetty that is A1 and A4. Therefore Tarjun port can still be able to serve the ship if one of the jetty can still accommodate the ship that match the characteristics of each jetty. The operational data from unloading ports has almost the same operational system as the loading port. Unloading harbors can serve for 24 hours in 7 days if there is an empty jetty. For unloading ports that have a common terminal type, the process of queuing is also done with other boats other than the company's vessels.

Numerical data is data that contains quantitative information contained in the system. This data is divided into three namely the numerical data of the ship, port of loading, and port unloading. The ship's numerical data required in designing a bulk cement transportation simulation system is the capacity to accommodate vessels, draft, vessel speed, rental rates, and duration of time. Observation data is historical data of long time sailing from unloading port to port of loading and vice versa. The data is processed to get the speed of each journey by dividing the distance and time of the voyage.

Numerical data on loading ports required are shelter capacity, production rate, pump loading speed, preload time, post-load time, and distance from loading port to unloading port. Observation data shows the length of time required to perform the loading process of historical data owned by the company. From the long time can be determined the speed of loading by dividing the capacity of the ship with the length of time required. Observation data also shows historical data of preload and post load process of ship scheduling. The data is used as input to determine the duration of preload and post-load activities in the fitting distribution process.

The required port unloading numerical data is port capacity, draft, demand rate, unloading speed, pre-unload and post-unload time. The observational data also shows the unloading time of each unloading port. By dividing the capacity with the required length of time, the unloading speed of each port is obtained.

Conceptual and Simulation Model

In this section it is explained about the conceptual model which shows the logic in the simulation model making. This conceptual model is divided into a conceptual model for bulk cement distribution system and selection of unloading port destination and determination of port loading destination.

A. Conceptual Model of Bulk Cement Distribution System

The first step is to set initial condition. At this stage an initial number of vessels is determined on the system, vessel capacity, and position of each vessel. Then, the arrival of ships at loading ports is a process that triggers the bulk cement distribution process. When the vessel is at a harbor dock it will be assigned to distribute bulk cement in order not to idle. The following is preload process that a series of activities undertaken to prepare ports and required administrative activities such as waiting for wizards, initial sounding, administrative document processing and connecting house. After this is an evaluation of cement availability at port of loading. This process is carried out to ensure the amount of cargo loaded to the vessel in accordance with the capacity of the vessel and the absence of load termination due to insufficient bulk cement. Process for that the following conditions must be met: Number of Cement in Silo ≥ Ship Capacity.

After that is loading process to a Ship. This process is a process to carry out the filling of cement to the ship. The time it takes to do the loading process is ship capacity divided by speed pPump at unloading port, followed by post unload process, that is the process is done similar to the postload process of loading tool loading activities, final sounding, and waiting for the waveguide. Determination of Port of Load is the next process. Determination of loading ports is based on the coverage days of each loading port so that inventory does not exceed the capacity of silos in each loading port. Unloading ports with the smallest cover value of the supply will be a priority as a destination port

Maintenance process is the following activity. The intended maintenance activities are periodic maintenance activities as well as maintenance overhaul needed to maintain the condition of the ship. At the time of docking long docking time is considered the same for all ships that is 30 days. Next is the process of sailing to port of load. This process is the process of shipping vessels from unloading ports to the port of loading that has been determined in the previous stage. Sailing time is determined by the speed of the ship. Where in this system there is a ship speed distribution pattern. Finally the last is the process to check the availability of loading port. In this process checks whether the dock in the loading port is empty so that it can be docked. If the dock is not available then the ship must wait until the dock is empty

B. Conceptual Model of Selecting unloading port destination

In the selection of port of unloading purpose is used rules of assignment to choose the level of coverage days of demand is the smallest. Unloading harbors with the smallest cover value of the day will be a priority as a destination port. The formula used to calculate the coverage days of demand is as follows Inventory at Unloading Port plus Intransit Inventory divided by demand rate times lead time.

There are several stages in the determination of port unloading purposes. The first, calculation of demand coverage days (CD). At this stage the process of calculating the coverage days for each port of loading and unloading. The second, sort a critical order. After doing the CD calculation then the port will be given the order of criticality. The most critical order is the one which will be given to the port that gives the smallest CD value. The third, check draft ability. Draft checks are performed to determine whether the ship can lean on the port of destination. If the draft of the ship exceeds the draft from the unloading port then the criticality of the port will be made greatest so that the unloading port is not chosen as the destination. Lastly, destination determination. At this stage the ship will depart to the port of unloading which has the smallest critical sequence

c. Conceptual Model of Determining Destination of Loading Port

The determination of the selected harbor is determined by the minimum coverage of the coverage days of supply. The smaller the level of coverage days indicates the inventory contained in the loading port is near the maximum capacity of cement storage. In calculating the coverage days of supply the length of time of delivery (lead time) is taken into account to select the lead time further because the time required to get to the port of loading will be longer. Here is the formula used to calculate the coverage days of supply, silo capacity minus inventory on silo minus intransit inventory divided by lead time.

There are several stages in determining the destination port of destination. The first, coverage days of supply (CDS) calculation. In determining the destination of the port, CDS calculation is made according to the above formula for each loading port. The second, sort a critical order. As with the critical sequence on the unloading port, the order of load criticality is also given to the loading port with the first order condition given to the port with the lowest CDS level. Lastly, destination determination. At this stage the ship will go to the port of loading with the most critical or small order.

D. Simulation Model

The conceptual model, then, is translated into simulation model. The model is divided into seven submodel simulations, namely initial condition submodel, stock update on loading and unloading port, submission submodel of unloading port, submission submission submodel, activity submodel at loading port and sailing process to destination port, submodel of activity at unloading port and process sailed back to the port of loading, as well as submodel to record data in spreadsheet.

3. Discussion

In this section will be undertaken alternative scenarios that have been determined. There are two scenarios that are done is the determination of the optimal number of vessels, the need for the number of ships when paying attention to maintenance, and the use of maintenance activity rules.

A. Determining the Optimal Ship's Number without Maintenance Scenario

In this scenario, the addition and reduction of the number of vessels to determine the optimal number of vessels in distributing bulk cement to avoid shortage. The addition and subtraction process is done by changing the max arrival value in the create module. To determine the determination of the addition or reduction of the number of ships in advance evaluation of the normal conditions. Under normal conditions there are six fleets of ships. If there is no shortage under normal conditions then the number of ships will be reduced but if there is a shortage then the number of ships will be added. Based on the results of running under normal conditions, a stock chart for each unloading port is shown in Fig. 1 and the stock at the loading port is shown in Fig. 2.

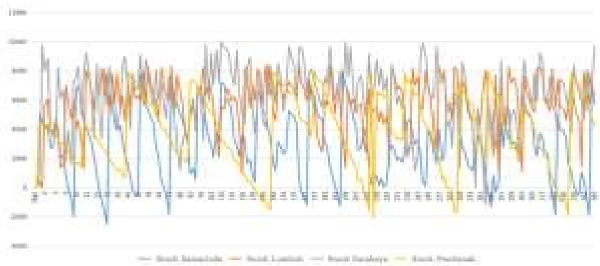

Figure. 1. Graph of Inventory at Unloading Port in the Normal Condition

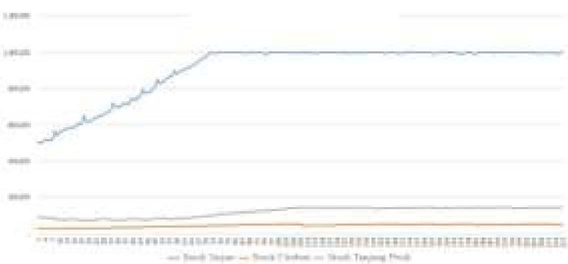

Figure. 2. Graph of Inventory at Loading Port in the Normal Condition

In Fig. 1, it can be seen that there is still a shortage under normal conditions. Therefore, an experiment was conducted by adding the number of vessels: one vessels with various capacity and two vessels with each has capacity 3200 DWT.

After experimenting the number of ships, it is known that six vessels used under normal conditions still produce shortages. In Fig. 1 the blue chart as stock of Samarinda Port and orange graph as stock of Lombok Port produces stock below value 0. The existence of stock value below 0 indicates a shortage in both ports. Therefore, the number of ships is still not sufficient to distribute bulk cement in order to avoid shortage. So, it is necessary to increase the number of fleets to transport bulk cement. The addition of vessels in the simulation model is done from the ship with the smallest capacity to the largest capacity. In Table 1 below, the experimental results of the number of vessels were added.

Table 1. Exsperiment Results to Determine the Number of Vessels

No	Additional Vessel	Capacity	Number of Shortage
1	1 Vessel	3.200	4
		4.500	3
		6.500	2
		7.500	3
		10.000	-
2	2 Vessels	3.200	0

From Table 1 above, it can be seen that the shortage views still occur with the addition of a fleet of vessels with a capacity of 3,200 DWT to 7,500 DWT. The calculation of additional vessels for 10,000 DWT capacity is not done because by adding two fleets of vessels with a capacity of 3,200 DWT the resulting cost is cheaper compared to adding 1 vessel capacity of 10,000 DWT. From the experiments conducted show that by adding 2 vessels of size 3200 DWT then the port stock unloading can meet the existing demand so that no shortage occurs. It shows that the optimal number of vessels is eight vessels by adding two vessels. So that, the the complete vessels are 3 ships with capacity 3.200 DWT, 1 ship with capacity 4.500 DWT, 1 ship with capacity 6.500 DWT, 1 ship with capacity 7.500 DWT, and 1 ship with 10,000 DWT.

B. Determining the Optimal Ship's Number with Maintenance Scenario

In this scenario the simulation model takes into account the overhaul maintenance activities that take one month. The optimal number of vessels that have been obtained in previous experiment scenario is then evaluated to see if any maintenance on the vessel will change the number of vessels optimally or not. This test is conducted for each ship according to the schedule of existing ship maintenance. By testing all types of vessels it can be seen when the needs of the ship will increase. Maintenance schedule is done in accordance with the maintenance schedule that has been determined by the company.

From the experiments, it can be concluded that there are still shortages in which five ships under maintenance. Therefore, it is necessary to recalculate the number of vessels needed to distribute bulk cement in order to avoid shortage at unloading ports. The addition of the ship with the smallest capacity, 3200 DWT, avoids the inventory stock out at any unloading ports when one ship under maintenance.

Then the scenario results of the optimal number of vessels in the scenario will be re-tested using maintenance rules when the demand for bulk cement is either off-peak or peak season. For that, it is necessary to undersatand the cycle of bulk cement demand of the company in one year as shown in Fig. 3 below.

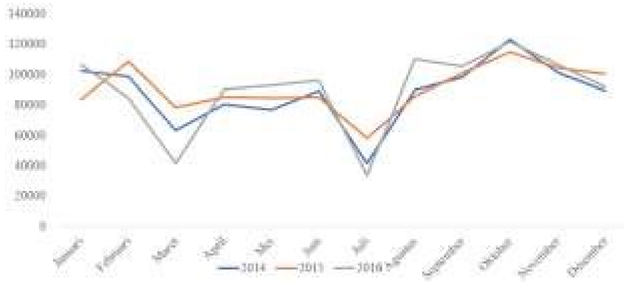

Figure 3. Graph of Bulk Cement Demand in Year 2014-2016

From Figure 3, it can be seen that the decrease in bulk cement demand occurred in March and July which the lowest demand. Therefore, July is the chosen month to perform maintenance for the off-peak while October is the chosen month to see the effect of the number of vessels in the peak demand. The experiments, then conducted by taking into account the overhaul maintenance activities that require docking for 30 days. In Table 2, it shows the results of the experiment with regard to maintenance activities

Tabel 2. Experimental Results Considering Maintenance Activities

No	Vessel Capacity (DWT)	Maintenance Schedule (Hour)	Number of Shortage
1	3.200	4.320	1
2	3.200	5.040	0
3	10.000	1.440	5
4	4.500	7200	3
5	6.500	720	3
6	7.500	2160	1

In accordance with Table 2, it is shown that the maintenance activities on five out of six vessels have shortage result on the port unloading. Therefore, it is necessary to calculate the additional number of vessels. The experiment started with the lowest capacity of vessel, 3200 DWT, which gives a result no shortage. This indicates that the smaller level of shortage on other ship maintenance activities will be covered by adding a fleet of 3,200 capacity vessels. The experiments then are repeated by changing maintenance activities during the low demand season. With this kind of experiments can be seen the need of the number of ships will decrease or remain. Table 3 shows the results of experiments when the demand is slowing down under maintenance activities.

In Table 3, it is shown that by changing the ship maintenance activity capacity of 3,200 DWT and 4,500 DWT when off peak demand is occured, there is no shortage at unloading ports. So, there is no need for additional fleet despite maintenance activities. However, by changing the maintenance activity on the vessel capacity of 6,500 DWT shortage remains. The calculation of the ship with a capacity of 7,500 DWT and 10,000 DWT is not done because at the capacity of 6,500 DWT has been found shortage so it can be known that larger capacity will result in a greater level of shortage.

Table 3. Maintenance Activity Experiment Results when

Of-peak Season

No	Vessel Capacity (DWT)	Number of Shortage
1	3.200	0
2	4.500	0
3	6.500	1
4	7.500	-
5	10.000	-

Experiments are also done by changing maintenance activities during peak season to see the comparisons. From the experiment at the capacity of 3,200 DWT can be seen happened shortage happened three times that is on day 280, 288, and 318. With the happening of shortage on ship with smallest capacity identify that bigger capacity will produce amount of shortage more. This indicates that maintenance activities as demand is increasing has the need to increase the number of fleets to distribute bulk cement to avoid shortage. Table 4 shows differences in experimental results regarding maintenance both during normal conditions, demand is down, and demand is rising

Table 4. Comparison of Experiments under Maintenance on off-peak and peak demand

Vessel's Capacity	*Offpeak Season*	*Peak Season*
3.200 DWT	No shortage	Shortage
3.200 DWT	No shortage	Shortage
4.500 DWT	No shortage	Shortage
6.500 DWT	Shortage	Shortage
7.500 DWT	Shortage	Shortage
10.000 DWT	Shortage	Shortage

Table 4 shows that shortage does not occur by altering maintenance activities on ships with capacity 3200 DWT and 4500 DWT when the demand is down. Therefore, the maintenance of these vessels in accelerate to the month of July so that no additional fleet is required. For the other vessels, the maintenance activities are still carried out in accordance with the schedule that has been determined due to move the maintenance activities at the time of demand is off-peak does not give effect of changes, still needs additional a ship to replace the maintenance vessel.

4. Conclusion

Based on the study above then the conclusions can be drawn is that with the addition of factory and port of loading, the optimal vessel distribution scenario in distributing bulk cement are 8 vessels, namely 3 vessels with capacity of 3.200 DWT, 1 vessel with capacity of 4.500 DWT, 1 vessel capacity of 6.500 DWT, 1 ship with capacity of 7.500 DWT, and 1 vessel with capacity of 10.000 DWT. With this number, the company can keep inventory under the level limit in the unloading port so that no shortages occur.

The existence of maintenance activities gives impact to the number of vessels needed to distribute bulk cement in order to avoid shortage. This can be seen with the maintenance of vessels under 4.500 DWT can be shifted to the off peak month in order to avoid shortage. However with the maintenance of other vessels which have greater than 4.500 DWT, the current number of optimal vessels is not enough, resulting stock out in unloading ports. Therefore, the addition of one fleet size of 3200 makes the number of optimal vessels become nine to avoid inventory shortage. These vessels maintenance activities are still done in accordance with the schedule that has been determined because by moving the maintenance activities when the demand is down still resulting inventory shortage without additional vessel.

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