Simulation Approach on the Performance Analysis of Rental Vessels Transportation and Shipment Management

Asmuliardi Muluk and Suhaiza Zailani

Abstract—The aim of this paper is to analyse the rental vessels transportation performance and explore solutions for its shipment management optimization. A simulation approach is adopted to evaluate the shipment strategy in this research. The simulation methodology is basically divided into two steps, first the development of simulation model of the actual system, second the development of a set of experimental design which is applied in evaluating its shipment optimisation. Two years secondary data are used to build a conceptual model for simulation. Afterward a number of scenarios are developed to seek an improved solution. The preferable result in this research is by having another alternate loading port for the rental vessel which more port scenario which minimise the average waiting time of each ship by 12% and maximise the average number of trips the vessel up to 22%. From the result can be concluded that when the capacity of a system cannot satisfy the demand, the flexibility of the transportation supply chain is a mandatory.

Index Terms—performance, simulation; supply chain, transportation.

I. INTRODUCTION

Cement Padang Company (CPC) is one of the oldest Indonesian cement producers which is located in the city of Padang, West Sumatra Indonesia. It lays on the west coast of the island Sumatera which is why its main bulk cements distribution is performed through sea line, with the ratio 70% through sea transportation and 30% through ground transportation. CPC rents vessels specifically to transport its bulk cement to three various destinations as can be seen in Fig. 1.

The types of the rental vessels are divided into two categories i.e.: vessels with time charter basis and vessels with freight charter basis. A vessel with time charter implies that CPC rents the vessel on real time charging, whether the vessel is in the queue waiting for loading or unloading the bulk cement, the meter keeps running, except when the vessel is in maintenance or having mechanical problem. While a vessel with freight charter implies that it will be compensated by the company on a single delivery, i.e. when the cements delivered to packing plants. CPC has 7 rental vessels with different types of leasing; capacities and tonnages as can be seen on Table I. The vessels operate based on the schedules determined by the management.

II. LITERATURE REVIEW

A. Supply Chain Performance Analysis

Supply chain performance analysis is related with the supply chain measurement. This is considering the question of what to measure and how to define measurement tools. However numerous authors have mentioned the supply chain measurement.
performance measurement. Such as Neely et al [2] categorize supply chain performance measurement including: quality, time, flexibility, and cost.


Beamon [3] advocates the use of a mix of measures, representing resources, output and flexibility, rather than relying on a single measure. Resource measures should indicate a high level of efficiency and may include cost and inventory. Output measures aim at a high level of customer service and may include customer responsiveness (e.g. lead-time, and on-time deliveries), quality, and quantity of final product produced. The goal of flexibility measures is to indicate the ability to respond to a changing environment. In our study we adhere to cost reduction as a performance measurement.

B. Supply Chain Simulation

Simulation has been used on numerous researches for evaluating performance of supply chain. Since the advent of supply chain and the realization of the advantages of using simulation in supply chain environments, there have been many efforts aiming to apply these benefits within their supply chains for specific supply chain problems (i.e. inventory planning, supply chain design, etc.).

Banks et al [8] held a panel session were they discussed the opportunities for simulation modelling in supply chain. Their paper presents opportunities and challenges in the area. The topics of discussion were: the use of simulation in process control, decision support, and proactive planning; simulation use through the supply chain life cycle; the characteristics of firms for which simulation is feasible for SCM; and opportunities for simulation in SCM.

Many authors discuss the promise, issues and requirements associated with using simulation in a supply chain domain. Similarly such as [9-11], many efforts have been conducted to develop simulation models and simulation modelling tools to address different needs within supply chain domains. Biswas and Narahari [11] developed DESSCOM, an object oriented supply chain simulation modelling methodology. Narayanan and Srinivasan [12], developed a decision support system consisting of a user interface and an object oriented simulation model. Ingalls and Kasales [13] describe CSCAT, an internal supply chain simulation analysis tool. CSCAT is based on Rockwell Software’s ARENA. In our study we use ARENA software modelling for representing the transportation system.

III. SIMULATION STUDY METHODOLOGY

The simulation methodology used for this paper is obtained from Chung [14]. The methodology that was applied is a seven-step model, consisting of seven separate activities in which the observation and modelling are combined together. The use of such a methodology ensures a valid simulation result and helps the modelling group in the development of the model.

The activities used are listed below in the order they should be performed.

1) Problem formulation: the first step of the methodology is to analyse the problem itself. Activities in this step are defining the problem statement, observation or orientation of the system, and the establishment of specific project objectives.
2) Conceptual modelling: The real system, under examination is described in an event graph. The objective is to capture the system logic and data necessary for the simulation modelling activity.
3) Simulation Modelling: The conceptual model is transformed to a computer-based simulation model. This can be done in a simulation language or in a simulation software packages.
4) Verification: Verification aims at testing the computer-based model against the conceptual model. The model is corrected if necessary.
5) Validation: Validation aims at testing the computer-based model against the system itself. The model is corrected if necessary.
6) Experimentation and analyzing output data: The experiments defined earlier are run and output data is collected and analyzed. If necessary, a new set of experiments can be defined and the experimentation phase repeated.
7) Implementation: The analysed output data is used to recommend some decision or help in an implementation. Of vital importance are the validation and verification activities. If these activities fail to correct all model errors, the result of the simulation study can be questionable. It is therefore of the utmost importance to use proven methods for these activities.

IV. MODELLING AND SIMULATION

The purpose of modelling the real system is to understand how the system works. What variables interact in the system, and at the end the performance of the system can be measured. In this study is the performance of the rental vessels transportation management. The initial observation reveals that the high rate of the transportation costs are resulted from the penalties that forfeited to the vessel companies. By modelling the system it is discovered that the high rate of transportation costs are due to longer waiting time of the
vessels, which leads to lower rate of number of trips. This also due that the ports not only serve the rental vessels but also other vessels e.g.: exports, bags or commercial. From the initial observations, it is analysed that there are several variables contribute to the waiting time of rental vessels i.e.:
- Problems at loading and unloading process.
- Problems occurred from utilities breakdown.
- Problems occurred from factory breakdown i.e. inventory empty, factory breakdown.
- Disturbances occurred on the vessel’s journey.

A. Conceptual Modelling

Conceptual model is a stage where the actual system converted into logic model which represent relationship among variables influencing the system. In this study the conceptual model is described by event graph and flow chart diagram. The event graph is developed to identify needed state variables and to determine a minimal set of events that must be scheduled at model initiation [15].

![Event graph of the transportation system](image)

Fig. 2. Event graph of the transportation system

Fig. 2 shows the event graph model for this study. The event graph models the event of one cycle transportation of a rental vessel (V). The initialisation of simulation (T0) starts at the arrival of vessel (i) at the loading port (k). If no idle haven available (Sm = 0) then the vessel has to wait (TQk), if there is an idle haven the vessel docks (TSk) and the setup for loading process begins (TM).

If the loading process is completed, the vessel sails (TDk) to packing plant port (j). The vessel arrives at unloading port (TAj) and waits for docking at the port. If the vessel docks (TSj), the unloading process starts (TB). The unloading completes the vessel sails back to loading port. This process is called one trip of the rental vessel journey or cycle time and also the simulation time for the whole process.

In this stage the events for the simulation model are obtained and the simulation variables are defined. The input variables are:
- Number of vessels arrivals
  1) Rental Vessels arrivals
  2) Other Vessels arrivals
- Loading time process
- Unloading time process
- Travel time

The output variables are:
- Waiting time
- Cycle time
- Number of trips

A. Simulation Modelling

The simulation model is implemented with the arena software from Law and Kelton [16]. In this model, numerous modules are used which can be categorised into several templates i.e.:
- Basic Process panel
- Advanced Process panel
- Advanced Transfer panel

The processes are developed based on the previous event graphs, and modelled with arena modules added with animation.

B. Verification and Validation of Simulation Model

The simulation model will be validated with black box validation methodology i.e comparing the simulation result with the actual result from the observation. In this case the T test is conducted to compare the average value of the simulation output with value from the observation of the secondary data. The assumption used in this T test is the sample populations of both data have the same average value while the competitor hypotheses of both populations have unequal average value.

<table>
<thead>
<tr>
<th>Vessels</th>
<th>Average loading (hour)</th>
<th>Average waiting (hour)</th>
<th>Cycle time (hour)</th>
<th>Number of trips</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS</td>
<td>52</td>
<td>50.9</td>
<td>25.59</td>
<td>412</td>
</tr>
<tr>
<td>RV</td>
<td>31.8</td>
<td>30</td>
<td>27.5</td>
<td>429</td>
</tr>
<tr>
<td>PR 1</td>
<td>32.3</td>
<td>32.9</td>
<td>11.9</td>
<td>408</td>
</tr>
<tr>
<td>PR 2</td>
<td>29.4</td>
<td>27.2</td>
<td>23</td>
<td>395</td>
</tr>
<tr>
<td>SP</td>
<td>31</td>
<td>31</td>
<td>20.4</td>
<td>443</td>
</tr>
<tr>
<td>SL</td>
<td>37</td>
<td>37</td>
<td>14.6</td>
<td>417</td>
</tr>
<tr>
<td>PP</td>
<td>25</td>
<td>26</td>
<td>24</td>
<td>466</td>
</tr>
</tbody>
</table>

a = actual, s = simulation
The comparison result between simulation output and the observation can be seen on Table II. For the result of T test with SPSS 13 can be seen on Table III.

<table>
<thead>
<tr>
<th>TABLE III: PAIR SAMPLE TEST RESULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paired Differences</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>Std Deviation</td>
</tr>
<tr>
<td>Std Error Mean</td>
</tr>
<tr>
<td>95 % CI of the diff</td>
</tr>
<tr>
<td>Lower</td>
</tr>
<tr>
<td>Upper</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
</tr>
</tbody>
</table>

Hypotheses null will be accepted if the significance level above the value which is 0.05. The significance level values from the Table III are above 0.05; therefore it can be concluded that the hypotheses null can be accepted. It means that there is no significant difference between the average values of the simulation with average values of the real system. This conclusion shows that the simulation model is valid and can be used for system performance analysis.

V. EXPERIMENTAL DESIGNS

Experimental design is a stage where possible elements of the system can be altered to fit the purpose of the study in this study is to reduce the rental vessel’s penalty costs. Nevertheless the penalty cost is not used to measure the performance solution in this study but the waiting time and number of vessel’s trip are employed instead. Because the penalty cost is due to the high rate of waiting time, and lessening of the number of trips.

The development of experimental design in this study is not intended to solve the internal problems at the ports which cause longer waiting time e.g.: factory breakdown, silo empty, but the experimental study is designed to explore solutions in cement bulks shipment with the purpose of obtaining lower penalty cost. Therefore it will explore interactions of rental vessels reaction towards the emptiness of silo, or longer queue on the loading port when they finish shipping the cements by adding an alternative loading port. In this case we use TBN as another loading port located in Java Island as a buffer for cement loading. TBN is employed with the assumption the port is always available for the vessels.

For this purpose, the vessels should be allocated optimally based on the distance, demand of the unloading ports and the capacity of the vessels. The calculation can be seen on Table IV. Based on this calculation the allocation of the vessel in this scenario are as follow:
- Two vessels will be allocated for DKI port i.e : CS and SL.
- Two vessels will be allocated for BTM port i.e : SP and PP.
- Three vessels will be allocated for MDN port i.e: RV, PR 1 and PR 2.

![Fig. 3. Distance between ports](image)

To choose whether a vessel will choose to load at TBN or TLB, will follow this rule:
- If \( V_{o1} \) at port \( i \) finishes unloading check if \( S_m > 0 \),
- Check if Silo > 0
- If \( S_m > 0 \) sails and Silo > 0 to TLB
- If \( S_m = 0 \) sails to TBN.

The constraint of this scenario that the distance between TLB to unloading ports and TBN to loading ports are various (please see Fig. 3). It is not identified which vessels are allowed to load at TBN. Therefore there are four scenarios designed for this condition, they are as follows:
1. All the DKI vessels are allowed to load at TBN if the TLB ports are not available
2. The DKI and BTM vessels are allowed to load at TBN if the TLB ports are not available
3. All the vessels are able to load at TBN port if the TLB ports are not available.
4. None of the vessels are allowed to load at TBN.

VI. SIMULATION RESULT

From simulation result of these four scenarios the scenario three shows the decreasing of vessel waiting time 12%, and the increasing of trip number for 22%. The summary of the result can be seen on Table V.
VII. DISCUSSION AND CONCLUSIONS

From this study, it is identified that the CPC rental vessels transportation management via sea line is not effective and efficient. The high penalty costs spent by CPC show the low performance of its transportation system. The high penalty costs are as a result of high waiting time of the vessels, which are caused by internal and external variables.

The experimental study shows that the performance measurements indicators are related to each other. In this case the reduced of operational cost relate to the time spent on operations. And the flexibility of the process relates to the reducing of operational time. The solution given in this study implies that when the capacity of a system is not able to satisfy the demand, the flexibility of the system is a mandatory. In this case the flexibility of the system is obtained by port collaboration.

This performance research is an initial study to investigate the collaboration behaviour between three cement companies. However the study does not describe more detail interaction between the vessels providers and the three cement companies. Thereof as a part of future work to have a valid solution for supply chain collaboration, we intend to develop an integration agent based model for supply chain between those companies therefore a decision support can be established.

REFERENCES


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