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.

Fig. 1. Destination of the transportations

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Asmuliardi Muluk is with the Department Andalas University, West Sumatera Indonesia (e-mail: amuluk@ft.unand.ac.id).

Suhaiza Hanim Mohamad Zailani is with the Graduate School of Business, Universiti Sains Malaysia.

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.

TABLE I: Vessel Types and Capacities

	Vessel's Name	Rental Type	Ton	LOA (m)
1	CS	Freight Basis	14500	157
2	RV	Freight Basis	8000	119
3	PR 1	Freight Basis	8000	115
4	PR 2	Time Charter	8000	115
5	SP	Time Charter	5800	113
6	SL	Time Charter	9000	126
7	PP	Time Charter	5600	110

It is discovered that the distribution cost spent largely on penalties forfeited to rental vessels. Around 30% of the transportation cost are spent to covers the operational of rental vessels [1]. Penalties are occurred because the vessels have to wait for loading/unloading process longer than the standard time. The longer waiting time can be triggered by several variables which are not related to vessels constraints such as: empty silo, busy ports, electricity off, and others. From this condition an evaluation of its transportation performance is mandatory since a high operational cost is related to a deprived operational performance. This study evaluates the performance of rental vessels management which aims to search for the variables which leads to high penalties of the rental vessels. Afterward solutions are explored with the purpose to reduce the penalty costs of the rental vessels.

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 performance measurement. Such as Neely et al [2] categorize supply chain performance measurement including: quality, time, flexibility, and cost.

Beamon [3] provides a literature survey of performance measures used in supply chain environments. Two types of performance measures dominate; namely cost and customer responsiveness. Costs may include inventory and operating costs. Customer responsiveness measures include lead-time, stock-out probability, and fill rate. Berry and Naim [4] and Li and O'Brien [5] provide analytical models of supply chains. Berry and Naim [4] use customer service level, stock and production costs, in a case-based supply chain redesign effort involving just-in-time manufacturing, interplant planning and logistics integration, vendor integration, and time-based management. Li and O'Brien [5] use four performance criteria; profit, lead-time, delivery promptness, and inventory cost, when proposing a hierarchical approach to supply chain modelling. When simulating supply chains, Bhaskaran [6], and Petrovic et al. [7] use subsets of these performance measures. Bhakaran [6] uses inventory levels as performance measure when studying the impact of forecast errors and the use of MRP versus Kanban, in a stamping pipeline at an automobile plant. Petrovic et al. [7] use total cost and fill-rate when simulating a made-up, serial supply chain with infinite capacity.

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].

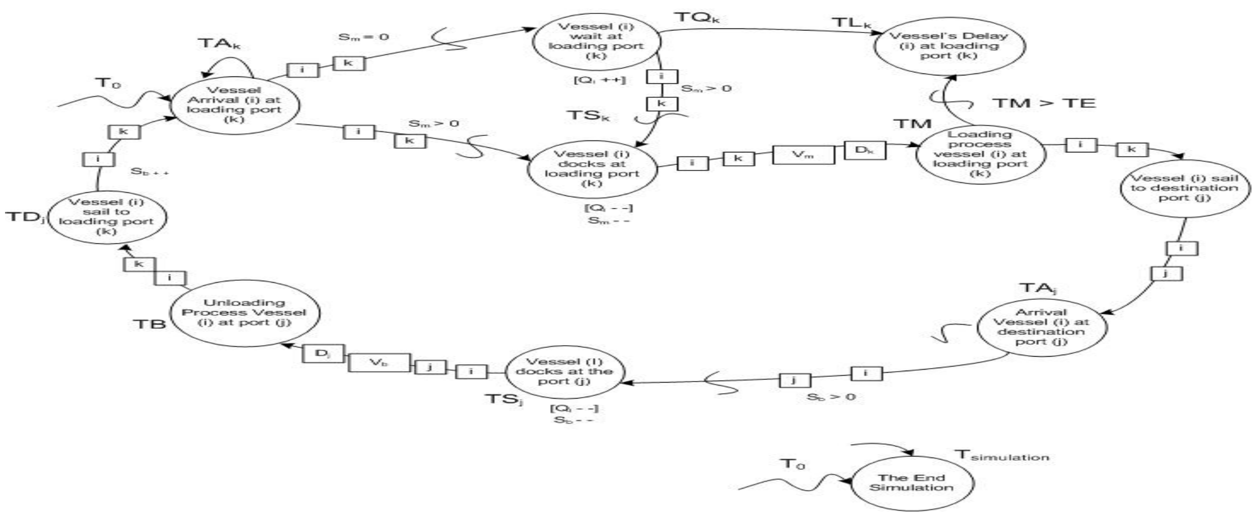

Fig. 2. Event graph of the transportation system

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 II: COMPARISON BETWEEN THE SIMULATION OUTPUT AND THE OBSERVATION RESULT

i	Vessels	Average loading (hour)		Average waiting (hour)		Cycle time (hour)		Number of trips	
		a	s	a	s	a	s	a	s
1	CS	52	50.9	12.1	25.59	412	525	64	50
2	RV	31.8	30	27.5	27.7	429	414	65	63
3	PR 1	32.3	32.9	11.9	14.2	408	400	65	66
4	PR 2	29.4	27.2	23	19.2	395	449	54	59
5	SP	31	31	20.4	17.7	443	478	60	54
6	SL	37	37	14.6	25	417	528	46	50
7	PP	25	26	24	31	466	484	40	52

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 III: PAIR SAMPLE TEST RESULT

Paired Differences	Simulation vs. Actual			
	Loading time	***Waiting time***	***Cycle time***	***Number of trips***
Mean	0.323	-3.819	-44.053	0.000
Std Deviation	1.322	6.585	52.022	8.386
Std Error Mean	0.500	2.489	19.662	3.170
95 % CI of the diff	-0.899	-9.909	-92.165	-7.756
Lower	1.545	2.271	4.059	7.756
Upper	0.646	-1.534	-2.240	0.000
Sig. (2-tailed)	0.542	0.176	0.066	1.000

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 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 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

TABLE IV: AVERAGE CEMENT ALLOCATION FOR DESTINATION

Capacity (ton)	Destination	De-mand (ton) x	time (hour) y	x*y (10000)	x*y/ total	average (ton)
58,900	DKI	550000	57.3	31515	0.3305	19,467
	BTM	250000	104.5	26125	0.2739	16,138
	MDN	450000	83.8	37710	0.3954	23,294
	Total			95350		

To choose whether a vessel will choose to load at TBN or TLB, will follow this rule:

- If $V_{(i)}$ at $port_{(j)}$ 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.

It the Vessel finished unloading cement at the loading port it has to check the TLB port whether on the time of its arrival the port will be available, the silo is not empty, the sail will be to TLB, if just one of that condition is not satisfied the sail will to TBN.

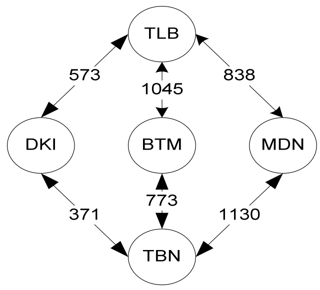

Fig. 3. Distance between ports

The constraints 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.

TABLE V: SUMMARY OF THE SCENARIO

No	Scenario	Scenario Result	
		Waiting Time	***Number of Trip***
1	First	5%	12%
2	Second	8%	14%
3	Third	12%	22%
5	Forth	-6%	10%

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

[1] A. Muluk and R. Fahmi, Project Report for Transportation Departement, PT Semen Padang. 2009, Andalas University: Padang.

[2] A. Neely, M. Gregory, and K. Platts, "Performance measurement system design: A literature review and research agenda." *International Journal of Operations & Production Management*, vol. 25, no. 12, pp. 1228 – 1263, 2005.

[3] B. M. Beamon, "Supply chain design and analysis:" *Models and methods. International Journal of Production Economics*, vol. 55, no. 3, pp. 281-294, 1998.

[4] D. Berry and M. M. Naim, "Quantifying the relative improvements of redesign strategies in a P.C. supply chain." *International Journal of Production Economics*, no. 46-47, pp. 181-196, 1996.

[5] D. Li and C. O'Brien, "Integrated decision modelling of supply chain efficiency. International Journal of Production Economics, " vol. 59, no. 1-3 , pp. 147-157, 1999.

[6] S. Bhaskaran, "Simulation Analysis of a Manufacturing Supply Chain." *Decision Sciences*, vol. 29, no. 3, pp. 633-657, 1998.

[7] D. Petrovic, R. Roy, and R. Petrovic, "Modelling and simulation of a supply chain in an uncertain environment." *European Journal of Operational Research*, vol. 109, no. 2, pp. 299-309, 1998.

[8] J. Banks, *etal.* "Opportunities for Simulation in Supply Chain Management." in *Winter Simulation Conference*. 2002.

[9] Yoon Chang, H. M., "Supply Chain Modelling Using Simulation." *International Journal of Simulation*, vol. 2, no. 1, 2001.

[10] S. Terzi and S. Cavalieri, "Simulation in the supply chain context: a survey." *Computers in Industry*, vol. 53, no. 1, pp. 3-16, 2004.

[11] S. Biswas and Y. Narahari, "object oriented modeling and decision support for supply chains." *European Journal of Operational Research*, vol. 153, no. 3, pp. 704-726 , 2004.

[12] S. Ganapathy, S. Narayanan, and K. Srinivasan. "Simulation based decision support for supply chain logistics." in *Simulation Conference*, 2003. Proceedings of the 2003 Winter 2003 IEEE.

[13] R. G. Ingalls and C. Kasales. CSCAT: "the Compaq Supply Chain Analysis Tool." in *Simulation Conference Proceedings*, 1999 Winter 1999: IEEE.

[14] C. A. Chung, "Simulation Modeling Handbook:" *A Practical Approach*. 1st ed. 2003: CRC Press.

[15] L. Schruben, "Simulation modeling with event graphs. Commun:" *ACM*, vol. 26, no. 11, pp. 957-963 , 1983.

[16] A. M. Law and W. D. Kelton, "Simulation Modeling and Analysis." 3rd Edition. 1991, Tucson, Arizona USA: Mc Graw Hill.

Asmuliardi Muluk is a lecturer at Industrial Engineering Department Andalas University, West Sumatera Indonesia. He received his B. Eng in Industrial engineering from Bandung institute of Technology in 1984, hi Masters degrees in Manufacturing Engineering also from Bandung Institute of Technology in 1999. His research interests include simulation, multi agent system, decision support system, supply chain management and operation management.

Suhaiza Hanim Mohamad Zailani is an Associate Professor of Supply Chain with the Graduate School of Business, Universiti Sains Malaysia. She received her PhD in Management Science from Lancaster University, England, UK in 1998. Her research interest is mainly on the development of 3 key areas of operations management, namely: 1). Quality Management, (e.g. quality improvement, quality standards, EMS 14001, QS 9000 and ISO 9000); 2). Supply Chain Management (e.g. logistics and purchasing); and 3). Halal Issues (Halal Supply Chain, Halal Logistics, Halal Orientation, Halal Commitment and Halal Tourism). Her field of expertise, nevertheless, is in the area of Supply Chain Management by embedding the issues of quality and halal into supply chain.