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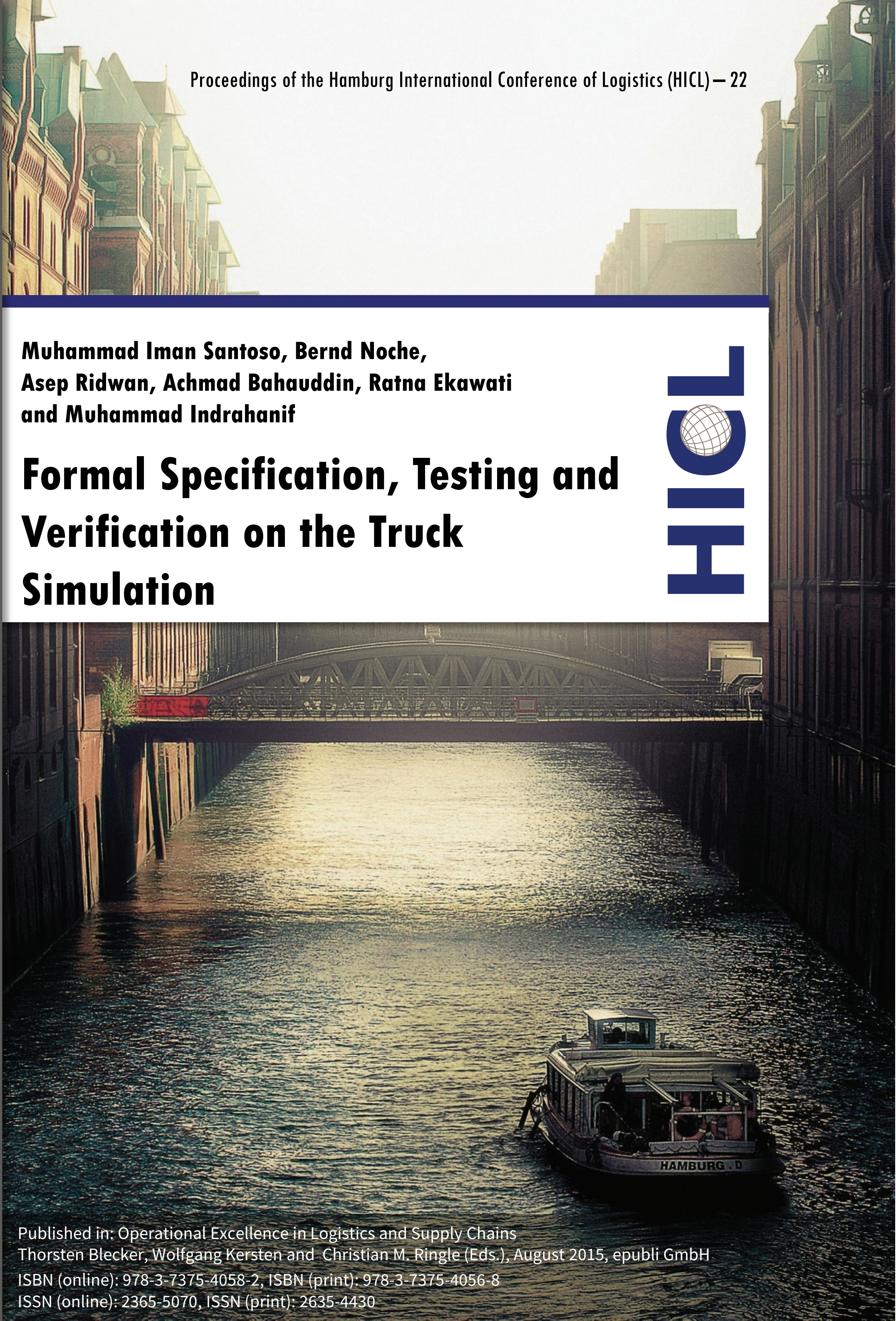

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Formal Specification, Testing and Verification on the Truck Simulation

Muhammad Iman Santoso, Bernd Noche, Asep Ridwan, Achmad Bahauddin, Ratna Ekawati and Muhammad Indrahanif

Truck operation for the fertilizer handling in the one of Indonesia's Port turned out to be inefficient and produced long queues (1.3 hours) when operated in the maximum number of trucks, i.e. 30 units - 30 tons load capacity per unit. This paper presents a simulation-based optimization for scheduling quantity and capacity of the fertilizer trucks to achieve handling-target within 24 hours and reduce queue. New procedural technique that combine statistical, modeling, simulation and verification have been developed employing several tools and managed in a structural way using formal specification. Those techniques optimize the truck operation turn into 8 units and also decrease the round trip operation from 220 rounds into 217 rounds. It generates a daily productivity of 6516 tons and minimize truck queue until 0.14 hour. The reduction of resources utilization and queue time will diminish the total fertilizer handling cost.

Keywords: Fertilizer Truck, Formal Specification, Simulation, Verification

1 Introduction

The Port is a critical facility that supports economic activities, particularly for Indonesia, an archipelago country. Delays of the service in the port, notably in the high-volume goods loading/unloading will affect the profit. Therefore, the necessity of quality enhancement in terms of time and optimum resources becomes very urgent.

This paper presents a joint research between the University of Duisburg-Essen (Germany), the University of Sultan Ageng Tirtayasa (Indonesia) and one of the Port Services Company located in Banten - Indonesia. This partner-port is established in the strategic geographic position on the western side of Java that connects the Indian Ocean to South-China Sea and the Pacific Ocean. The most benefit of the area is that location proven as the deepest port in Indonesia. The port customers are multi-enterprises located in Cilegon, Jakarta, and the surrounding area. Their services are docking ships, loading/unloading of goods and warehousing. Particularly, their business core is focusing on the dry bulk products such as fertilizer (FZ), corn, soy, salt, and sugar. The loading and unloading processes have the same pattern, starting from fetching products using the crane toward the hopper (HP), transporting to the tailgate (TG), and then weighing.

Afterward, the product is either unloaded from the truck, then relocated into a temporary warehouse (WH) in the port or directly going to customer warehouse. The loading and unloading activities are addressed as the material handling process. Material handling is an activity of lifting, transporting, and put the material by using means of transportation (Purnomo, 2004).

According to the partner-port experience, fertilizer is one of the products that are sensitive to be handled. It particles are small, lightweight, and easily mixed with water. Fertilizer ship comes to the port jetty in a large capacity, typically taken by more than 10,000 tons. The customers are always asking very quick fertilizer handling time. Due to this demand, the port operates the maximum number of trucks (i.e. 30 units - 30 tons capacity per unit) to perform handling process faster.

In fact, a maximum truck operation becomes counterproductive. It generates a new problem in the truck queue, particularly in the weighing process. This issue is getting worse by back/forth trucks that carry other dry/liquid bulk operated by many forwarders.

The model that built in this paper simulates the existing productivity of fertilizer handling process and then optimizes it. More than calculate the efficient truck capacity, the author also validates the optimum productivity of 24 hours fertilizer unloading.

2 Port Simulation Model for Bulk-Cargo - The State of the Arts

Small paper simulates bulk cargo operation in the port. Utmost studies are usually model bulk cargo services in macro-perspective. Scientists are trying to improve efficiency when the cargo unloaded goods, bulk-port expansion plans and discuss the parameters/values characteristic of port simulation using specific tool or software. Such procedures found in (Agerschou & Sørensen, 1983) (Bugaric. U, 2007) (Cassettari, 2012) (Dahal, 2007) (El Sheikh, J.R. Paul, S.A. Harding, & Balmer, 1987) (Esmer, 2010)

(Kondratowicz, 1990) (Park & Noh, 1987) (Pjevčević D., 2013). Nevertheless, those papers have not verified the data, model and the simulation results in a structural way. (Harrell, 2000) examines data and conducts verification/validation but only dependent on the ProModel. In this paper, (Harrell, 2000) theory and simulation method are extended by implementing multivariate tools and techniques that customizable.

The documentation of all procedures is written as clear as possible before running the simulation. Furthermore, the simulation procedures are managed thoroughly by a strict control mechanism of adequacy as well as verification tests. The tests are performed both manually (hand-calculations) and automated taken by some tools.

3 Research Methodology

This paper enhances several procedures and techniques in the field of material handling process and simulation that are initially invented by (Harrell, 2000). The following methods are carried out to pursue the research objectives: 1) Observation and Interview, 2) Problem identification and Scope, 3) Data Collection and Analysis, 4) Model Design, 5) Model Verification and Validation, 6) Simulation Development and Validation, 7) Running Simulation and Experiment, 8) Output testing and Alternative Comparison (see

Figure 1) The authors present the procedures more flexible using diverse (alternative) tools and introduce the set of “formal-specifications” to conduct the simulation better.

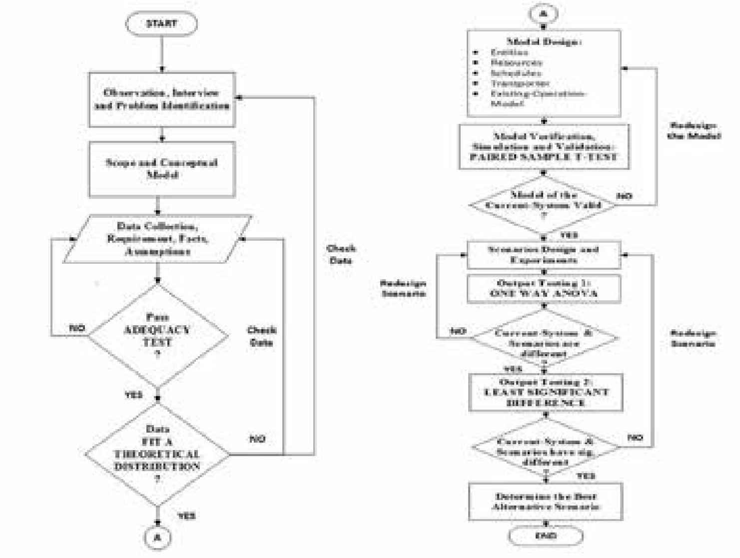


Figure 1 Flowchart of the Research Methodology

Formal Specification (FS) is defined as a systematic and procedural technique that specifies terms/vocabularies of the system and then verifies that design specification through the planning and construction phase. Commonly, FS used to guide the developer (in the field of computer science) during the design, testing and implementation of the systems or software as stated by (Sargent, 2005) (Zengin & Ozturk, 2012) (Zhao & Rozier, 2014) (Navimipour, 2015). Anyone can overview the milestone of FS various techniques in (Edgar & David, 2014).

This paper employs such technique to enhance simulation in the field of operation research instead of computer science.

4 Result and Discussion

This section provides all results obtained from the research. Ultimately, the discussion and analysis are given to deliver a scientific judgment of the result.

4.1 Result

4.1.1 Observation, Interview and Problem Identification

The company has found a problem in the weighbridge (WB). There are many queues of the truck and the peak traffic increase when many ships from other Forwarder unloaded various dry bulk products (e.g. sugar, corn, salt, soy, etc.) at the same time. Such situation will later multiply the number of trucks that exist in the system and causing long queues of vehicles around the WB.

4.1.2 Scope and Conceptual Model

The author set boundary of the research (scope) and the conceptual model in the form of entity diagram (see Figure 2 and 3).

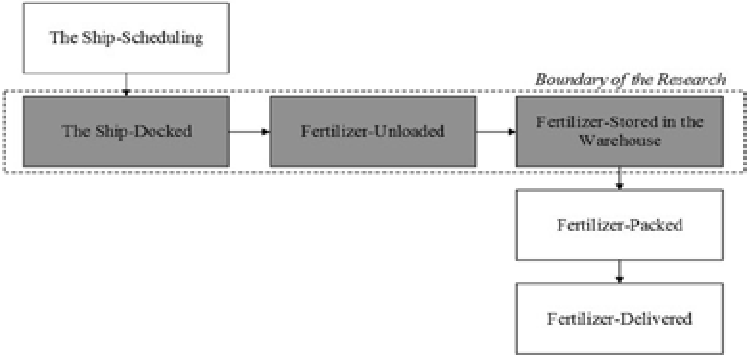


Figure 2 The Boundary of the Research

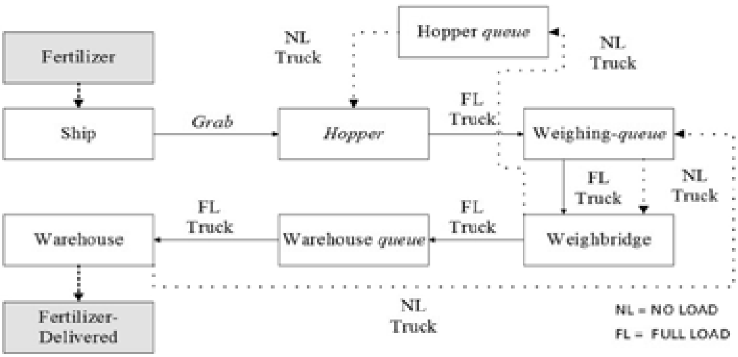


Figure 3 The Entity Diagram of the Process

4.1.3 Data Collection, Facts, Assumptions and Analysis

The research area coverage from the fertilizer discharges out of the ship and transfers it using the truck into the warehouse. The simulation stops when the model mimics the fertilizer handling for 24 hours. Each process employed 50 data samples, which has been collected during the March-2013 to January-2014.

The result of data collection is documented on the following formal specification (see Table 1,2,3).

Table 1 List of Requirements

	Requirements
R1	How to model and simulate existing fertilizer handling system in the partner-port?
R2	How many quantity and optimal truck capacity should be operated to improve quality of the actual process?
R3	How to set optimum productivity of fertilizer-handling in 24 hours that could reduce queue time?

Table 2 List of Facts

	Facts
F1	The simulation entities: Fertilizer (FZ) in a unit of tons and Dummy (used to model empty truck)
F2	Dynamic-Resources: Truck that is currently carrying 30 tons capacity of FZ in amount of 30 units and Grab which is transporting FZ from the ship into the Hopper (HP).
F3	Station: Ship, HP which has 50 ton capacity (2 units), Weighbridge (WB) that can only weighing 1 truck (1 unit) and the warehouse (WH).
F4	Arrival: The fertilizer capacity per ship-arrival, i.e. 12992 tons, and it should unloaded in 2 (two) days. Thus, daily unloaded target is 6496 tons.
F5	Simulation: It is started from 07:00 at March, 5th 2014 and considers four breaking-times in the port, i.e. 12:00 – 13:00, 18:00 – 19:00, 00:00 – 01:00 and 05:00 – 07:00
F6	The processing-time series: 1) Time to fetch FZ from the ship towards the HP using the grab. 2) The travel-time of FZ from the HP into the TG. 3) The travel-time of the FZ truck from the dock into WB. 4) Weighing-time. 5) The travel-time of the FZ truck from the WB into the WH. 6) The unloading time of FZ in the WH. 7) The travel-time of the FZ truck from the WH into the WB. 8) The travel-time of the FZ truck from the WB into the dock.

Table 3 List of Assumptions

	Assumptions
A1	The simulation is started after the fertilizer freighter-ship has come (to jetty) and fertilizer ready to be released
A2	There are three kinds of ships loaded a different number of fertilizers.
A3	The ship has two hatches.
A4	The weather influences are not considered
A5	The break-time during unloading operations is calculated.
A6	Weighing process-time whether full-load or empty-load is assumed equal.
A7	Grab capacity is 12 tons, and the number of grabs is considered to be equal to the number of hatches, i.e. two units
A8	The decision variables are set to be truck quantity (units) and truck capacity (tons).

The facts and assumptions are then verified using ProModel 7.5 feature called "stat-fit". This feature determines the statistical data distribution. Hence, data collection and assumptions were valid, and available to be used directly in the next step of simulation. Furthermore, the input data have to pass adequacy test prior the "stat-fit" calculation.

The adequacy test data is needed to verify the validity of sample data. Adequacy Test Data (Harrell, 2000) formula:

$$N' = \left[\frac{K/_{S}\sqrt{N(\sum Xi\,2) - (\sum Xi\,2)^2}}{\sum Xi}\right]^2 ;\ N > N' \tag{1}$$

where

N' = The number of observations should be done.

K = The level of confidence in the observations. (k = 2, 1-α=95%)

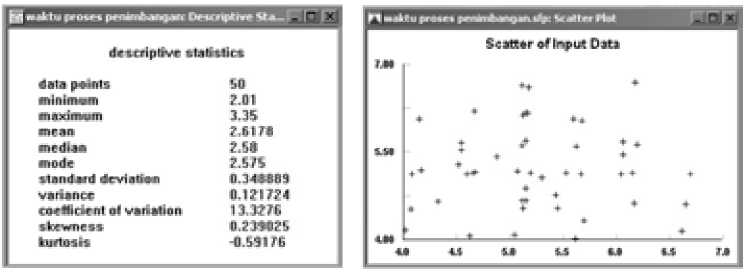
S = The degree of accuracy in the observation (5%)

N = The number of observations that have been made.

Xi = Observation Data

The adequacy of the data achieved if qualifies: N > N'

The data have to be "fit a theoretical distribution", such as normal distribution or beta, etc. There are specific tests (see Figure 4,5,6,7,8) that can be performed to determine whether the data is independent and identically distributed (Harrell, 2000).



(a) (b)

Figure 4 Data Independency and Distribution Test: (a) Descriptive Statistics (b) Scatter-Plot

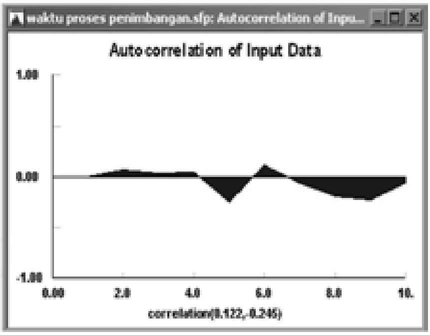
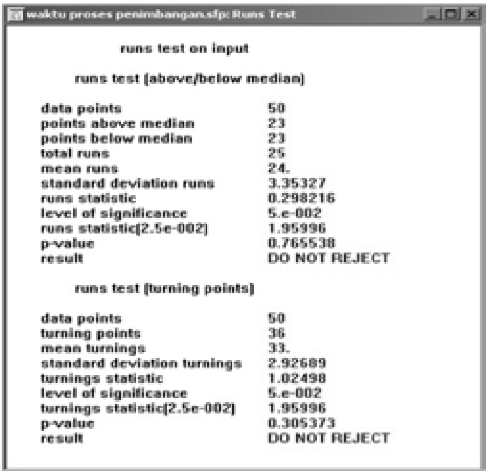


Figure 5 Data Independency and Distribution Test: Correlation of Input Data



waktu proses penimbangan.sfp: Runs Test

runs test on input

runs test (above/below median)

data points	50
points above median	23
points below median	23
total runs	25
mean runs	24.
standard deviation runs	3.35327
runs statistic	0.298216
level of significance	5.e-002
runs statistic(2.5e-002)	1.95996
p-value	0.765538
result	DO NOT REJECT

runs test (turning points)

data points	50
turning points	36
mean turnings	33.
standard deviation turnings	2.92689
turnings statistic	1.02498
level of significance	5.e-002
turnings statistic(2.5e-002)	1.95996
p-value	0.305373
result	DO NOT REJECT

Figure 6 Data Independency and Distribution Test: Input Data Testing


waktu proses penimbangan: Automatic Fitting

Auto::Fit of Distributions

distribution	rank	acceptance
Lognormal(-0.131, 1., 0.126)	100	do not reject
Normal(2.62, 0.345)	62.3	do not reject
Uniform(2.01, 3.35)	1.99	do not reject
Exponential(2.01, 0.608)	3.04e-003	reject

Figure 7 Data Independency and Distribution Test: Fit of Data Distribution

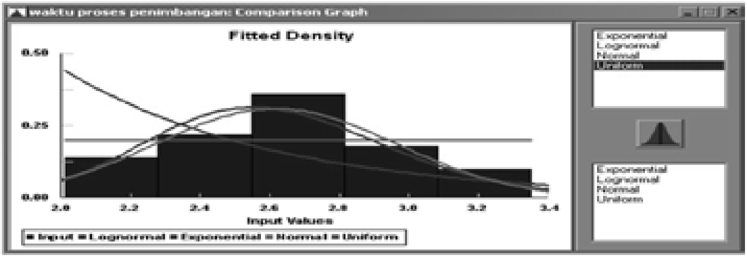


Figure 8 Data Independency and Distribution Test: Fitted Density

The next operation is fitting a theoretical distribution of the data. This step is important to identify which is the most suitable distribution of the sample data. In Promodel 7.5., this basic procedure is divided into three steps checkpoint: (1) One or more distribution selected as a suitable candidate to represent the data samples; (2) Calculate the estimation of the parameters on each distribution (3) Goodness of fit (virtue the data-distribution). The results of input data statistical test are reported in the Table 4.

Table 4 Examination of Data Distribution using Stat Fit

Input Data	Time
The ship towards the hopper	Normal (1.27, 0.141) minutes
The hopper into the truck-tailgate	8.68 seconds/ton
Weighing	Lognormal (2.63, 0.35) minutes
The Warehouse unloading	Uniform (3.32, 3.82) minutes
Transport from the Hopper to the Weigh-bridge	Lognormal (6.42, 1.17) minutes
Transport from the Weighbridge to the Warehouse	Lognormal (4.33, 0.65) minutes
Transport from the Warehouse to the Weighbridge	Uniform (5.02, 7.9) minutes
Transport from the Weighbridge to the Dock	Uniform (7, 10) minutes

4.1.4 Model Design

The modeling phase is conducted using ARENA 14. The model divided into four main modules of data, i.e., entities, resources, schedule and transporters. Besides that, there are also two panels of flowchart modules, namely the Basic and Advanced Process Transfer. Samples of those models are depicted in Figure 9.

Entity - Basic Process

	Entity Type	Initial Picture	Holding Cost / Hour	Initial VA Cost	Initial NVA Cost	Initial Waiting Cost	Initial Tran Cost	Initial Other Cost	Report Statistics
1 ▶	Pupuk	Picture.Report	0.0	0.0	0.0	0.0	0.0	0.0	☑
2	Dummy	Picture.Report	0.0	0.0	0.0	0.0	0.0	0.0	☑

(a)

Transporter - Advanced Transfer

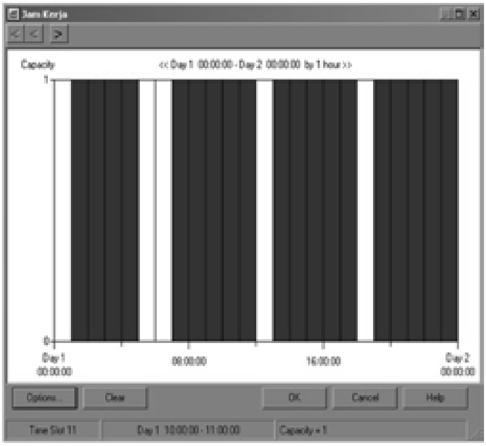
	Name	Number of Units	Type	Distance Set	Velocity	Units	Initial Position Status	Report Statistics
1 ▶	Grab	2	Free Path	Grab.Distance	1.0	Per Second	1 rows	☑
2	Truk	30	Free Path	Truk.Distance	1.0	Per Second	0 rows	☑

(b)

Schedule - Basic Process

	Name	Type	Time Units	Scale Factor	Durations
1 ▶	Jam Kerja	Capacity	Hours	1.0	8 rows

(c)



(d)

Figure 9 Sample of Arena Modules, (a) Module Data – Entities (b) Module Data – Transporter (c) Module Data – Schedule (d) Module Data Chart-Schedule

4.1.5 Model Verification, Simulation and Validation

This section simulates the actual operation of the partner-port using the designed model. Then, simulation is executed by a replication for 10 times. Replication also named as "several randomized runs" to get accurate estimates because each run varies statistically. Harrell equation (Harrell, 2000) is employed to calculate adequate replication. The result of this calculation is shown in Table 5.

Table 5 Adequate Replication Test

Replication	Unloaded Level (Xi)	$\bar{X}$	Xi-$\bar{X}$	(Xi-$\bar{X}$)2
1	6660	6600	60	3600
2	6570		-30	900
3	6600		0	0
4	6570		-30	900
5	6660		60	3600
6	6660		60	3600
7	6690		90	8100
8	6570		-30	900
9	6450		-150	22500
10	6570		-30	900
Total				45000

$$\mathrm{s} = \sqrt{\frac{\sum(\mathrm{Xi} - \bar{X})^2}{n-1}} \tag{2}$$

$$\mathrm{e} = \frac{(tn-1, \alpha)S}{\sqrt{n}} \tag{3}$$

$$\text{then,} \quad \mathrm{n'} = \left[\frac{Z\left(\frac{\alpha}{2}\right)s}{e}\right]^2 \tag{4}$$

n = replication number

Consider Table 5:

$$\bar{X} = (6660 + 6570 + \ldots + 6570)/10 = 6600 \quad (5)$$

$$X1-\bar{X} = 6660 - 6600 = 60 \quad (6)$$

$$(X1-\bar{X})2 = (60)2 = 3600 \quad (7)$$

$$\text{Total} = \sum(\text{Xi} - \bar{X})^2 = 45000 \quad (8)$$

$$s = \sqrt{\frac{\sum(45000)^2}{10-1}} = 70.71 \quad (9)$$

$$e = \frac{2.26\ x\ 70.71}{\sqrt{10}} = 50.58 \quad (10)$$

$$n' = \left[\frac{Z\left(\frac{\alpha}{2}\right)S}{e}\right]^2 = \left[\frac{1,96\ x\ 70.71}{50.58}\right]^2 = 7.51 \approx 8 \quad (11)$$

The minimum required of replication is equal to 8. Thus, 10 replications tested in Table 5 are more than enough.

After the replication has confirmed, the simulation performance is compared to the field data. The authors conduct this step using SPSS which perform the Paired Sample T – test (see Table 6).

Table 6 Pair Sample T – test Result using SPSS

	Paired Differences							
	Mean	Std.Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper	t	df	Sig. (2-tailed)
Pair 1 Real Simu-lation	-60.7	522.99	165.38	-434.82	313.42	-.367	[illegible]	0.722

Consider Table 6:

The 2-tailed significance value (0.722) is larger than the α significance α (0.05), and its confidence interval exceed 0. It can be concluded that H_0 (the initial hypothesis) accepted. Thus, fertilizer-handling model is nearly identical with the field data that manually calculated. Hence, it is stated that the model of existing fertilizer-handling in the partner-port has already approached the target. The summary of the simulation outcome of this model is given in the Table 7.

Table 7 The Simulation of the Existing Fertilizer Handling in Partner-Port

Total Unloaded Fertilizer Per 24 hours (Tons)	The Average Queue Time (Hours)
6600	1.3

4.1.6 Scenarios and Experiments

Experiments are conducted by adjusting decision variables, i.e. the number of trucks and truck capacity. While, the response variable is the target amount of fertilizer unloaded within 24 hours, i.e. 6496 tons. The current number of trucks available is 30 units. Each truck has a minimum allowed capacity in the amount of 28 tons and the maximum allowed capacity in the amount of 30 tons.

Furthermore, scenario is set to minimize the amount of truck in duty without additional costs.

Set Scenario-1: 8 units operation, capacity of each truck is 30 ton.

Set scenario-2: 25 units operation, capacity of each truck is 29 ton.

Those two scenarios simulation-result is reported in Table 8.

Table 8 Scenarios 1 & 2 Execution Summary Compared to Existing Operation

Replication	Existing Operation	Scenario 1	Scenario 2
1	6660	6480	6554
2	6570	6480	6554
3	6600	6570	6554
4	6570	6570	6554
5	6660	6540	6554
6	6660	6510	6554
7	6690	6510	6554
8	6570	6510	6525
9	6450	6510	6554
10	6570	6480	6554
Average	6600	6516	6551.1

4.1.7 Scenarios and Output Testing

The scenarios and output are then compared using one-way_ANOVA. This technique is conducted to check the difference between the outputs of the existing fertilizer models with the proposed scenarios.

Analysis of Variance (ANOVA) separates the total variability in the data sample into two parts. Then, hypothesis is tested to compare two independent estimation of the population variance. The total variability in the data is described as a total sum of squares (Montgomery, 2003). The author employs SPSS to manage such test and the result is reported in the Table 9.

Table 9 One-Way-ANOVA-test using SPSS 16

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	35597.400	2	17798.700	8.551	.001
Within Groups	56196.900	27	2081.367		
Total	91794.300	29			

Consider Table 9, the significance value is less than the value of α (<0.05). Thus, the H0 (the initial hypothesis) is rejected. It means that the result of scenario 1 and 2 have the significant difference value with the value of existing operation. Then, examine those differences by Least Significance Difference (LSD) method (Harrell, 2000), and the result is given by the following calculation:

$$t_{(df(error),\alpha/2)} = t_{(27,0.025)} = 2.05 \tag{5}$$

$$LSD_{(\alpha)} = t_{(df(error,\frac{\alpha}{2})}\sqrt{\frac{2(MSE)}{n}} = 2.05 \times \sqrt{\frac{2 \times 208136}{10}} = 41.86 \tag{6}$$

Furthermore, the authors calculate the absolute value of the difference between two compared models. The significant value is achieved when:

$$|\overline{x_1} - \overline{x}_2| > LSD_{(\alpha)} \tag{7}$$

Table 10 Least Significance Difference Test Result (manual-calculation)

	Scenario 2	Scenario 1
	$\bar{x}3 = 6551.1$	$\bar{x}2 = 6516$
Existing Operation $\bar{x}1 = 6600$	$\lvert \bar{x}1 - \bar{x}3 \rvert = 48.9$ Significant (48.9 > 41.86)	$\lvert \bar{x}1 - \bar{x}2 \rvert = 84$ Significant (84 > 41.86)
Scenario 1 $\bar{x}2 = 6516$	$\lvert \bar{x}2 - \bar{x}3 \rvert = 34.9$ Insignificant (34.9 < 41.86)	

According to the Table 10, it can be concluded that the existing models in compare to the both scenario 1 and 2 have significant different, but between scenario 1 and scenario 2 itself does not have a significant distinction. Afterward, SPSS 16 is employed to confirm the manual-calculation. The SPSS performance is given in the Table 11.

Table 11 SPSS Performance of LSD - Calculation

(I) Model	(J) Model	Mean Difference (I-J) *	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Existing Operation	Scen. 1	84.0*	20.402	.000	42.1370	125.8630
	Scen. 2	48.9*	20.402	.024	7.0370	90.7630
Scen. 1	Existing	-84.0*	20.402	.000	-125.8630	-42.1370
	Scen. 2	-35.1	20.402	.097	-76.9630	6.7630
Scen. 2	Existing	-48.9*	20.402	.024	-90.7630	-7.0370
	Scen. 1	35.1	20.402	.097	-6.7630	76.9630

*. The mean difference is significant at the 0.05 level

SPSS performance of LSD-calculation in Table 11 shows the same results with the prior manual calculation. It is seen that each model has a significant difference in the value $\alpha = 0{:}05$. However, the comparison between the model of scenario 1 and scenario 2 has no significant difference. So, it can be concluded that the result of scenario 1 and 2 have a prospective contribution to produce a better operation and productivity since it has significant difference values to the existing operation. The summary of all simulation results is presented in Table 12. It also considers the average queue time that occurs in the system. This queue time is calculated from a simulation of processing time which is provided in Table 4.

Table 12 The Summary of All Simulation Results

Model	Truck Quantity (Unit)	Truck Capacity (Ton)	Average Fertilizer Unloaded in 24 Hours (Ton)	Average Queue Time (Hour)
Existing Op.	30	30	6600	1.3
Scenario 1	8	30	6516	0.14
Scenario 2	25	29	6551.1	1.02

4.2 Discussion

There are six stages have to be performed in this study. These stages declared beforehand using formal specifications. Set of orders and performance-indicators are stated per stage in a matrix-form in order to conduct the research in a structural way (see Table 13, 14).

Table 13 Matrix of Research Stages I – IV

		Activities	Test & Verification
STAGE I	Order	Observation, Interview & Problem Identification	Conceptual Model Verification
	Performance Indicators	Scope (Research-boundary) Conceptual Model (Entity-Diagram)	Interview
STAGE II	Order	Data Collection	Data Testing
	Performance Indicators	Requirements Facts Assumptions	Data-adequacy Test Data-fit Test (ProModel)
STAGE III	Order	Model Design (ARENA)	Model Verification (ProModel)
	Performance Indicators	Determine the modules Model the Existing Operation	Replication Adequacy Test
STAGE IV	Order	Simulation (ARENA)	Simulation Verification (SPSS)

Table 14 Matrix of Research Stages V – VI

		Activities	Test & Verification
STAGE V	Order	Scenarios Design and Experiments (ARENA)	Output Testing (SPSS)
	Performance Indicators	Set Scenario 1 Set Scenario 2 Set Scenario n	One Way ANOVA Least Significance Difference
STAGE VI	Order	Presentation	Discussion & Final Verification
	Performance Indicators	Determine the Best Scenario	Judgement from Expert / Community

The research stages have to be well documented. All detail occurs during preparation, research and experiments must record. The study is executed in a structural way using formal specification that has been defined earlier. Authors also practice simulations and verify using several tools, i.e. ProModel, ARENA and SPSS. Moreover, several verifications, e.g. data-fit test, replication test, One Way ANOVA and Least Significant Difference are double checked by manual calculation as well.

4.2.1 Simulation of the Actual Case

According to the existing-operation, it is noticed that the average queue time experienced by one truck in 24 hours is 1.3 hours.

Thus, it can be analyzed as follows:
*) The existing operation is handling 6600 tons per day.
*) 6496 tons / 30 tons = 220 rounds, carried by 30 trucks
*) 220 rounds / 30 trucks = 7.33 rounds ≈ 8 rounds

Therefore, in average 1 truck takes 3 hours to complete one round:
24 hours / 8 rounds = 3 hours per truck.
This calculation has proven that the existing operation meet the target (6496 tons) even by practicing waste of resources and time.

4.2.2 Simulation of the Proposed Scenario

The actual operation, Scenario 1 and Scenario 2 have unloaded 6600 tons, 6516 tons and 6551.1 tons respectively (see Table 9). All states meet the fertilizer handling target, because the firm only expects at least 6496 tons released per 24 hours.
The next performance should be considered is the queue time. Refers to the summary (see Table 9), the minimum queue time is produced by Scenario I. It uses 8 trucks in capacity of 30 tons per truck during 24 hours operation. Scenario 1 has able to handle fertilizer in average of 6516 tons during 24 hours and produce average queuing time only 0.14 hours. Eight trucks operation would not consume a lot of waiting time and keep transport round

by round without significant queue time. Such scenario could only be applied at the following assumptions: there is no down time; fair weather; and the truck driver breaks on the certain-schedule. Simple analysis of the scenario can be directed by the following calculation.

*) The scenario 1 is handling 6516 tons per day.
*) The laps made by 8 trucks are 6516 tons / 30 tons = 217.2 rounds. *) Each truck duty within 24 hours: 217.2 rounds / 8 trucks = 27.15 rounds.

Therefore, in average 1 truck takes 0.884 hours to complete one round: 24 hours / 217.15 rounds = 0.884 hours per truck.

There is a decreasing number of a round trip that performed by scenario 1. The actual operation creates 220 rounds and the scenario 1 only 217 rounds. The comparison becomes expressive when it is viewed from the reduction of the truck used, where the existing operation employ 30 units of trucks and the scenario 1 only use 8 trucks. The proposal of 8 trucks operation is significantly reduce 22 trucks utilization per day. These 22 trucks can be more productive to be used for another duty. The other significant improvement is that the Scenario 1 reduces the queue time on the weighbridge until 0.14 hours. Consequently, the reduction of resources utilization and queue time will diminish the total fertilizer handling cost in the Partner-Port Exactly at a certain point, a reduction in the waiting time and the cost of resources will produce the optimal total cost (see Figure 10).

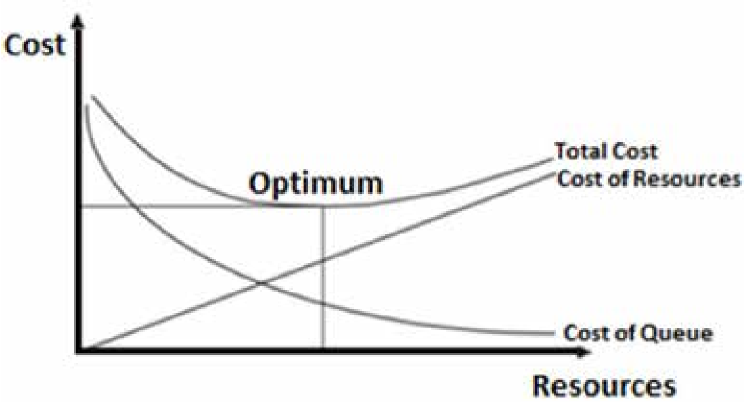


Figure 10 Cost vs Resources Relationship

5 Conclusion

The study of fertilizer handling process in the partner-port has been conducted. A new procedural technique that combines statistical, modeling, simulation and validation have been developed employing several tools and managed in a structural way using formal specification method.

Conceptual entity diagram, data collections - assumptions following by fitting a theoretical distribution of the data are demonstrated to models fertilizer handling. The handling process can be sequenced as handling fertilizer from the ship towards the hopper, from the hopper into the truck tailgate, weighing procedure, the warehouse unloading, transport from the Hopper to the Weighbridge, transport from the Weighbridge to the Warehouse, transport from the Warehouse to the Weighbridge and transport from the Weighbridge to the Dock.

In the last stage, all data that are resulted from the experiments are calculated. The outputs are then compared using ANOVA test group to examine the significant contribution of the alternative scenarios. Furthermore, the Least Significance Difference (LSD) used to review a significance difference value of that contribution.

The actual fertilizer handling has been simulated. It is found that the average productivity of the current system is 6600 tons using 30 units of trucks and generates average queue time of 1.3 hours. It is also reported that in the actual case, every truck takes 3 hours to complete one round.

After several experiments and validations, it can be reported that optimal truck to serve the daily fertilizer handling is eight units in the capacity of 30 tons per unit. The optimum productivity of daily fertilizer handling in the partner-port based on the best simulation result (scenario 1) and validation is 6516 tons. This operation reduces average queue time until 0.14 hours.

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