Simulation Modelling of Warehouse Capacity Re-allocation to Improve Inbound Logistics Performance: A Study Case

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Abstract: The supply chain system in the fertilizer industry is quite complex because it involves many activities such as internal logistic, material transportation processes, a number of factories, and warehouse management. The process of raw materials handling that starting from the port to the warehouse is very influential on the company's ability to carry out operational activities in the production department. To improve the competitiveness of the company, the case company needs to take a number of strategic steps and to run a transformation program for becoming an efficient, integrated, and sustainable fertilizer producer. The problems that occur in the inbound logistics activities at the case company are the raw materials stored in warehouses often overcapacity, causing a material accumulation when there is new raw material arriving at the port. Therefore, warehouses need to periodically reorganize their storage in order to keep operating inefficient manner. This research aims to help overcome the problems that occur in the company by examining several alternative solutions in inbound logistics activities to reduce material transferred between port, production warehouses, and buffer warehouses by using model simulation method. The method that is going to be used to solve this problem is the Discrete Event Simulation (DES), in which the improvement system does not disrupt the existing system and doesn't cost too much time and money. This research proposed a scenario of warehouse capacity re-allocation for raw materials by prioritizing the highest frequency of raw material arrival. By using the improved system, it reduces the total average volume of material transferred from the port to production warehouses by 13.29%, from port to buffer warehouses by 10.21% and from buffer warehouses to production warehouses by 17.43%.

1 INTRODUCTION

The supply chain system in the fertilizer industry is quite complex because it involves many internal logistics activities, raw material transportation, and warehouse management. The costs absorbed by activities in supply chain functions are generally very dominant so that if the company has an efficiency program, then the greatest improvement potential is in activities related to supply chain functions. Thus, the product can be produced and distributed in the right amount and timely manner to minimize costs and provide service satisfaction to consumers with the aim of achieving a minimum overall cost of the system and also achieving the desired service level (Levi, 2000).

Successful supply chain management is a very complex job because there are numerous players involved, and each of them has different interests and goals. Those conditions are a challenge that must be faced by Pupuk Indonesia Holding Company as a fertilizer producer on behalf of the Indonesian Government, an agrarian country where the agricultural sector plays an important rule that influences the national economy. PT Petrokimia Gresik is one of the largest Indonesian fertilizer producers established under the auspices of PT Pupuk Indonesia. PT Petrokimia Gresik is the complete fertilizer producer in Indonesia, which produces various kinds of fertilizers and chemical products for agro-industrial solutions that have a cross-country supply chain network and distribution throughout the country.

The problem that occurs in the inbound logistics activities of the case company is the raw materials stored in warehouses are often overcapacity, causing a material accumulation when there are new raw materials arriving at the port. One indication that causes overcapacity in warehouses is the presence of several raw materials stored in warehouses that are

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not intended. This has a negative impact because it can cause the ship that has arrived at the port to have to wait to unload the material.

Due to seasonal fluctuations in demand or high inventory levels, initially assigned storage in the warehouse may become suboptimal from time to time. Fragmented storage is a particular issue, where the optimal storage location of a product is not only dependent on its turn-over rate but also on the storage locations of items that frequently occur in the same picking job (Kofler, 2010). Therefore, warehouses need to periodically reorganize their storage in order to keep operating inefficient manner.

Experiment with the operation of the real system to study the effects of the change can lead to a more efficient and advanced system than the current one. But it is not a wise idea to implement the change directly in the real system as it can cause unexpected results, which ultimately disrupts the working of the system. Therefore, a model is defined as a representation of a system for the purpose of studying the system. The model should be built so as to permit valid conclusions to be drawn about the real system. Sometimes, different models of the same system are required to be built to study different aspects of the real system.

2 LITERATURE REVIEW

This research is a development from some similar previous researches. The previous researches are mostly developed on the uncertain scope of inbound activity. Some similar previous research only discussed one or two of three the scope of inbound logistics activities such as ports, warehouses, and transportation. There is no research that combines these three scopes of inbound logistic activities. Therefore, to develop this research using three the scope of inbound logistics activities such as ports, warehouses, and transportation.

The purpose of this research is to find the best alternative solutions in order to improve the performance of the inbound logistic activity of the case company. This research is used Discrete Event Simulation (DES) because the improvement system does not disrupt the existing system and does not cost too much time and money. Besides that, DES can provide some information about the behavior and performance of real processes in the company and predict the occurrence of the problem in existing conditions.

2.1 Logistics and Supply Chain Management (SCM)

Effective management of infrastructure, materials, technology, and people is utterly needed to integrate the flows between material, money, and information because interruptions in any of the above four flows affect an organization's raw materials supply (purchasing), manufacturing (operations) and marketing (distribution) functions. According to the Council of Supply Chain Management Professionals (2010), activities that can be managed in the supply chain consist of planning, management, and coordination from procurement, conversion, and logistics management activities.

2.2 Inbound Logistics

Harrington (2008) explained that focusing on logistics and inbound logistics planning gives firms an opportunity for substantial savings and attains supply chain reliability. Even though there is no standard definition of inbound logistics, three significant inbound logistics practices can be identified, and these are transportation, inventory control, and warehousing (Baker et al., 2008).

Inbound logistics practices are reliant on existing infrastructure like warehouse building, terminuses, highways, communication networks, and energy supply amenities that need long-term investment from both governments and the private sector. They also involve long lead-times to develop and thereafter maintenance investments over time, which determine the quality of entire logistics operations (Blecker el at. 2014).

2.3 System and Model

There are several ways to design, analyze, and operate a system; one of those is by modeling the system. System modeling is a very useful tool for analyzing and designing systems. The model can show how an operation of the system works and analyze the problems and potential improvements that can be made. Model is defined as a logical description of how the system works or the components interact. By making a model of a system, it is expected to be easier to carry out analysis (Law and Kelton, 1991).

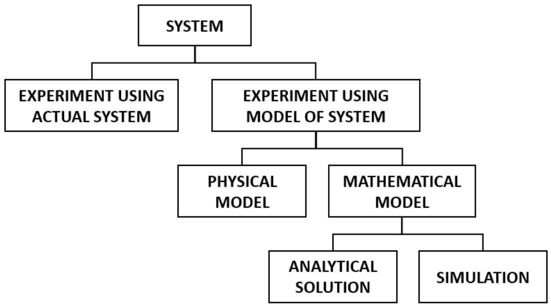

Figure 1: Various Ways to Learn System

(Law and Kelton, 1991)

Figure 1 shows an overview and an explanation about how to study the system. The system in this research can be explained as Experiment Using Actual System vs. Experiment Using Model of System. It means if a system physically allows and does not cost a lot to operate with the conditions (scenario) that we want, then this method is the best way because the results of this experiment really fit the system. But those systems rarely exist, and stopping the operation of the system for experimental purposes will be very costly. In addition, for systems that still not yet exist or systems that are still in design, experiments with actual systems clearly cannot be done, so the only way is to use the model as a representation of the actual system.

2.4 Model Simulation

2.4.1 Discrete Event Simulation (DES)

DES (Discrete Event Simulation) is the process of codifying the behavior of a complex system as an ordered sequence of well-defined events. In this context, an event comprises a specific change system's state at a specific point in time. DES modelers often invest a great deal of effort analyzing historical data to capture process means, variances, and distributions, but once entered into the model, these parameters often remain fixed. There is less emphasis on DES models on identifying events that might trigger changes in the model's parameters.

The experiment requires the operation of the real system to study the effects of the change, which can lead to a more efficient and advanced system than the current one. But it is not a wise idea to implement the change directly in the real system as it can cause unexpected results, which ultimately disrupts the working of the system. A model is defined as a representation of a system for the purpose of studying the system. The model should be built so as to permit valid conclusions to be drawn about the real system. Sometimes, different models of the same system are required to be built to study different aspects of the real system.

A discrete-event simulation model is both stochastic and dynamic with the special property that the changes occur at discrete times only. A stochastic simulation model has one or more random variables as inputs. Random inputs lead to random outputs. Since the outputs are random, they can be treated only as approximations of the true characteristics of a model.

2.4.2 Arena

The arena is a model builder program and also as a simulator. The arena is a mixture of two categories, a combination of ease of use that is owned by high-level programs and flexibility that characterizes general-purpose simulation language. Arena users can build models, templates and can even create their own modules if needed using the help of programs such as Visual Basic, FORTRAN, and C / C ++.

2.4.3 Verification and Validating

The verification and validation process is a simulation phase that is carried out to test whether the simulation model and the conceptual model have represented the system in its actual state. In the process of converting conceptual models into simulation models, there are many possible errors.

2.5 Similar Research

The previous researches are mostly developed on the uncertain scope of inbound activity. Some similar previous research only discussed one or two of three the scope of inbound logistics activities such as ports, warehouses, and transportation. There is no research that combines these three scopes of inbound logistics activities, such as:

1. Jean Philippe et al., 2007. “A Simulation Model to Improve Warehouse Operations." The scope is the warehouse. Develops a DES model of the logistic operations that could help managers in assessing the performance of different storing and picking strategies and evaluate the specific strategies to share the storage space.
2. Lauri Lattila, 2012. “Improving Transportation and Warehousing Efficiency with Simulation-Based Decision Support System." Scopes are transportation and warehouse. Argued that

simulation-based decision support systems need to take various issues into account to make a functioning decision support system.

3. Mariam Kotachi et al., 2013. “Simulation Modelling and Analysis of Complex Port Operations with Multimodal Transportation." The scope is port. Analyze the complex operations involved, as well as the utilization of resources. The outcome of the port flow is various scenarios motivated by changes in different inputs to measure their impact on the outputs that include throughput, resource utilization, and waiting times.

This research is a development from some similar previous researches and discussed three the scope of inbound logistics activities such as ports, warehouses, and transportation. This research is to find the best alternative solutions in order to improve the performance of the inbound logistic activity of the fertilizer company.

3 RESEARCH METHODOLOGY

3.1 Preliminary Study Phase

The preliminary study is performed for studying the system element in the research object. The system elements are system objectives, system boundaries, input and output, and system activities.

3.2 Data Collection & Processing Phase

The collection of data is done to support the conducted research. Data is collected through historical data of the case company, interviews with related parties, and supporting sources on the internet.

All data that has been collected then processed to find the type of distribution fitting. The results of this data processing are the results of distribution fitting for material arrival and material transfer. Numerical data that need to be done with the fitting distribution before became the input variable are the inter-arrival time of raw material in port, raw material supply, and raw material demand. Fitting distribution needed to describe the uncertain event, so the distribution will describe the frequencies of future repetitions of the experiment. Fitting distribution is done by input the two years of historical data into the input analyzer in Arena Software. The distribution will follow the best fit distribution or the theoretical distribution, which has been used before for certain conditions.

3.3 Simulation Phase

At this stage, the design of the conceptual model and simulation model is designed, which describes the actual process activities. The real system is built into a model through several processes.

3.3.1 Conceptual Model Development

A conceptual model is made in accordance with the current conditions of ship unloading system at the Port of company case, the transportation scheme of raw materials to storage warehouses, and material transfers that occur between production warehouses and buffer warehouses. This conceptual model will later be used as a reference for the simulation model carried out on Arena software.

3.3.2 Simulation Model Development

This research uses Arena Software to run the simulation. Based on the modules chosen in the simulation model built, the data that has been collected acts as the input in the development of the model.

3.3.3 Verification

There are three ways to do the verification process. First, debug the model to know whether the model has a syntax error. Second, by observing the animation movement between models. Third, check the output reasonableness from the simulation result.

3.3.4 Number of Replication Calculation

The number of replications and half-width should be determined so that the simulation results in a good estimation interval that is convincing for decision making. Determining the number of replications is started by setting the initial number of replication (n). After the result of running n replications is obtained, the half-width (hw) should be calculated. Then the desired half-width (hw’) should be calculated by setting the absolute error (e) to be compared later.

3.3.5 Validation

Validation is done by comparing the results of the demand fulfillment material in the simulation running model with the historic data of 2017-2018 demand fulfillment material obtained from the Port Department. Paired-t-test is done to know whether the real system and simulation model are not significantly different so that the simulation model can be declared as valid.

3.3.6 Scenario Design and Run Experiments

This research proposes a scenario for improvement that will be used as a recommendation for improvement in the systems. The scenario made into a condition to prioritizing the allocation of materials that have the highest frequency of arrival.

The scenario is developed by taking into account the frequency of raw materials arrival. Raw materials that have the highest frequency of arrival will be prioritized to be stored in the nearest Production warehouse, and if possible, it not stored in buffer warehouses.

3.3.7 Output Analysis

The output result of the scenarios is calculated as the total volume of material transferred. Then, Paired-t-test or ANOVA hypothesis analysis is used to know whether the scenario shows a significant difference with the existing condition. Paired-t-test or ANOVA hypothesis testing analysis is performed based on the number of population or scenario compared.

4 MODEL CONCEPTUALIZATION

4.1 Overview of Inbound Logistic Process

The raw material used to produce fertilizer is Phosphate Rock High Grade (PR HG), Phosphate Rock Medium Grade (PR MG), Red KCl, White KCl, DAP, and ZA. When raw materials arrive at the port, the company receives raw materials and carries out unloading operations using port facilities. After being dismantled, the raw materials are then distributed using transportation modes in the form of conveyors and trucks. The choice of transport mode prioritizes the use of a conveyor. Since not all warehouses are connected with conveyors and if the conveyor line has been used to transport another raw material, then the transportation mode used in the truck.

The raw material will later be transported to the production warehouse in each production unit to be used as a basic material in the fertilizer production process. The Production Warehouse, which is located directly in contact with the factory, has the highest priority to receive the arrival of raw materials from the port. If these Production Warehouses are unable to accommodate the incoming raw materials, the Buffer Warehouse is used as a second-choice destination for raw materials that cannot be accommodated in the Production Warehouse. The detailed process of raw material handling at inbound logistics in case the company is shown in Figure 2.

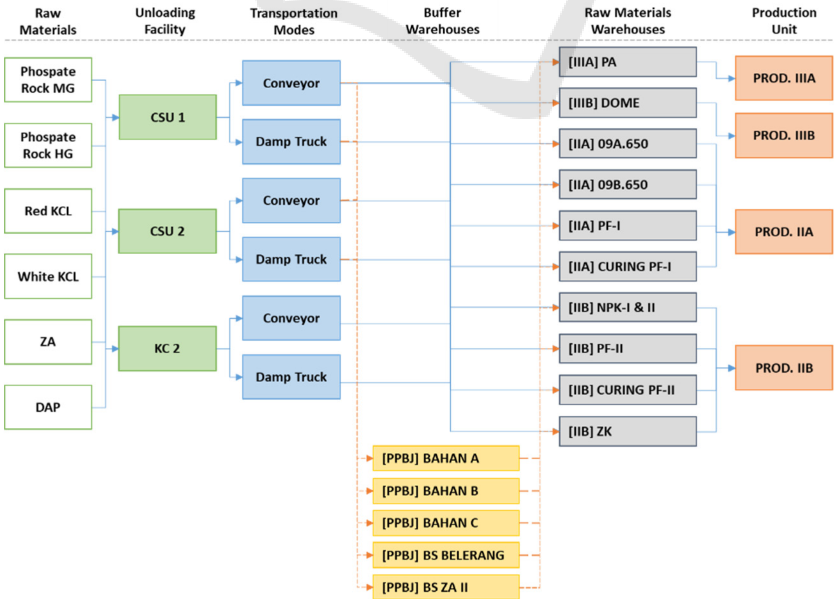

Figure 2: Raw Material Handling Process Flow

4.2 Element of System

Elements of systems include entities, activities, resources, and controls.

1. The entity used in this system is the raw material used for fertilizer production. The type of raw material are, Phosphate Rock High Grade (PR HG), Phosphate Rock Medium Grade (PR MG), Red KCl, White KCl, DAP, and ZA.
2. Activities observed in the system are systems for raw materials handling from unloading in ports, transportation from ports with conveyors or trucks, to placement in raw material warehouses.
3. The resources used in this system are facilities at the port (material unloading facilities; Kangaroo Crane and CSU), transportation modes (conveyors and trucks) and raw material warehousing facilities
4. The control used in this handling system is the assignment of allocating material carried out from port to the raw material warehouse, which has the highest availability of space and readiness by considering the volume transported.

4.3 Variable of Systems

The variables of systems in this research's simulation consist of decision variables and response variables. More detailed, as seen in Table 1.

Table 1: Variables System for Raw Material Handling

Scope	Decision Variables	Response Variables
Transporting to Warehouses	Raw Material Allocation Volume	The volume of Transferred Raw Materials
Warehouse Allocation		

5 SIMULATION MODEL AND ANALYSIS

5.1 Model Verification

The model's verification implies that the simulation model is error-free, and according to the conceptual model, the logic is right. To check the syntax error in the simulation model is by debugging in the software. The verification of semantic error is done by verifying whether the logic in the model is in accordance with the logic it is supposed to be.

Checking the reasonableness in the simulation report in the research is done by checking the total demand fulfillment in the factory for two years, where it must be less than or equals with total entities created by creating a module as the factory demand.

Another way to check for reasonableness in the simulation report is to see if there's an entity that needs to be allocated to one of the production warehouses, it should be allocated to the one that is the nearest one from the port. In a simulation report, it can be seen from the results in two years that there is no allocation of entities in the production warehouse that skips the order of the nearest warehouse. For example, red KCl is allocated in warehouse 09A.650, 09B.650, and 02.650 for production warehouse IIA, arranged from the nearest one, respectively. It is impossible if in two years total red KCl entities are allocated in warehouse 09B.650 is equal to zero while the total red KCl entities allocated in warehouse 02.650 is more than zero.

5.2 Number of Replications

The number of replications is determined to know how many replications are needed in the simulation, so the simulation results will represent different patterns of supply and demand every day. The method used to determine the number of replications in this research is using the total demand fulfillment of raw material. In this research, the method that is used to determine the number of replication is an absolute error with α = 5%.

The simulation is run with ten replications (n) and resulting the total demand fulfillment for one year in ten replications. Then the half-width of the result of ten replications simulation is calculated with equation 1 for all raw materials with hw' has the desired error value does not exceed 5% from historical data as shown at equation 2. The number of replications (n') is calculated with equation 3. The result of the calculation can be seen in Table 2.

Based on the calculation in Table 2, every raw material has a different value of n'. To fulfill the requirement for every raw material, then the highest value of n' is used as the number of replications for simulation. Therefore, the number of replications used in this research is 10 replications.

$$\boldsymbol{hw} = \frac{\boldsymbol{t_{N-1,\alpha/2}} \times \boldsymbol{S}}{\sqrt{\boldsymbol{n}}} \quad (1)$$

$$\boldsymbol{hw'} = \boldsymbol{5}\%\ (\text{total demand fulfillment}) \quad (2)$$

$$n' = \left[\frac{Z\alpha/_2 \times S}{hw'}\right]^2 \quad (3)$$

Table 2: Result of Demand Fulfilment Simulation with 10 Replications

Replication	Demand Fulfillment (Tons)								
	DAP	Red KCl		White KCl	PR HG		PR MG	ZA	
	IIB	IIA	IIB	IIB	IIIB	IIIA	IIA	IIA	IIB
Existing	182,586	318,630	249,964	84,552	538,697	501,567	294,716	251,833	190,140
1	186,600	330,700	254,800	85,150	472,550	516,250	313,650	257,200	192,700
2	171,500	333,200	251,150	87,100	479,900	509,700	296,350	208,700	160,400
3	168,350	301,550	246,100	90,000	526,100	481,500	301,650	250,900	193,500
4	179,450	324,550	252,600	85,650	512,400	504,250	295,050	239,600	178,650
5	183,050	296,850	226,150	90,450	543,300	505,900	256,250	250,050	178,750
6	166,250	323,650	245,150	80,950	481,900	509,600	296,300	238,900	180,500
7	165,650	323,100	248,350	80,050	557,250	528,350	288,100	254,250	190,800
8	178,000	286,000	252,700	84,300	553,200	511,300	248,800	252,650	182,850
9	147,950	264,400	232,100	84,100	530,750	481,750	292,300	254,000	185,100
10	194,150	323,450	242,800	80,200	543,800	464,650	275,150	258,600	194,300
Average	174,095	310,745	245,190	84,795	520,115	501,325	286,360	246,485	183,755
Standard Deviation	13,076	22,636	9,366	3,718	31,834	19,270	20,369	14,837	10,250
hw	0.05	0.05	0.03	0.03	0.04	0.03	0.05	0.04	0.04
hw'	9,129	15931.48	12498.08	4227.60	26934.84	25078.33	14735.80	12591.66	9506.99
n’	10	10	3	4	7	3	10	7	6

5.3 Validation

The method used for validation is using Paired-t-test hypothesis testing with a parameter used for validation is the demand fulfillment of each raw material in each factory. The demand fulfillment of each raw material in each factory considered can capture the whole behavior of the system, starts from the supply up to the demand. The recapitulation of total raw material demand fulfillment in factories is presented in Table 2.

In this hypothesis testing Paired-t-test, the null hypothesis is that there is no significant difference between the average results of the simulation results with the existing condition. The alternative hypothesis is that there is a significant difference between the average results of the simulation results with the existing condition.

$$\text{H0: } \boldsymbol{\mu_1 = \mu_2}$$
$$\text{H1: } \boldsymbol{\mu_1 \neq \mu_2}$$

The recapitulation of hypothesis testing using the Paired-t-test is simplified in Table 3. Based on the result of hypothesis testing, the null hypothesis is accepted because the t stat falls between the range -2.101 < t Stat < 2.101. Such a condition shows that there is no significant difference between the actual and the simulation system.

Table 3: Validation Hypothesis Testing Result

Validation Parameter	t Stat	t Critical two-tail		Conclusion
		Lower Limit	Upper Limit	
DAP at IIB	-2.054	-2.101	2.101	Accept Ho
Red KCl at IIA	-1.101	-2.101	2.101	Accept Ho
Red KCl at IIB	-1.611	-2.101	2.101	Accept Ho
White KCl at IIB	0.207	-2.101	2.101	Accept Ho
PR HG at IIIB	-1.864	-2.101	2.101	Accept Ho
PR HG at IIIA	-0.040	-2.101	2.101	Accept Ho
PR MG at IIA	-1.297	-2.101	2.101	Accept Ho
ZA at IIA	0.104	-2.101	2.101	Accept Ho
ZA at IIB	-1.970	-2.101	2.101	Accept Ho

6 SCENARIO DEVELOPMENT AND ANALYSIS

6.1 Scenario Development

The proposed scenario in this study aims to minimize the total transferred volume of raw material that occurs between the warehouses, especially in the buffer warehouses, by finding the best configuration of raw material composition. Scenarios are developed by taking into account the variables that cause the accumulation of raw materials when in port, transportation, and storage. This is in the spotlight because to place raw materials in buffer warehouses requires a considerable distance of transportation while the production warehouse capacity is insufficient to accommodate all existing raw materials. The scenario condition design in this research is by prioritizing raw material movement based on the highest frequency of shipment arrival.

The scenario is developed by taking into account the frequency of raw materials arrival. Raw materials that have the highest frequency of arrival will be prioritized to be stored in the nearest Production warehouse, and if possible, it not stored in buffer warehouses. Table 4 shows the rank of the material's arrival frequency until August 2018.

For scenario development, Phosphate Rock High Grade must be prioritized to be stored in the nearest production warehouse from the port and has a larger storage portion than the other raw materials. The raw material in the next priority then placed in the nearest production warehouse, which still has storage capacity for its type as the previous scenario adjustment method. Table 5 shows the new raw material allocation.

Table 4: Rank of Raw Material Arrival Frequency

Arrival Frequency	
Phosphate Rock HG	66
ZA	38
Red KCl	35
DAP	13
Phosphate Rock MG	12
White KCl	5

Table 5: New Raw Material Capacity Allocation

Dept	Warehouses	New Capacity Allocation (Tons)					
		PR (HG)	PR (MG)	Red KCl	White KCl	ZA	DAP
IIA	09A.650					16,000	
IIA	09B.650				2,000	23,000	
IIA	02.650			7,000		9,000	
IIA	PF-I		40,000				
IIB	ZK				500		
IIA	CURING PF-I					4,000	
IIB	CURING PF-II			3,197		4,803	
IIIA	PA	110,000					
IIIB	DOME	50,000					
IIB	NPK-I & 2			14,000		2,000	2,000
Buffer	PF-II			45,000			
Buffer	BS BELERANG			8,000			
Buffer	BUFFER A	10,850	12,934	24,216			
Buffer	BUFFER B			19,262			19,301
Buffer	BUFFER C				32,500		

6.2 Scenario Significance Test

A significance test between the existing system and scenario is performed to provide better decision making on the selected scenario. Simulation of scenario resulting in 3 parameters of volume transferred material, which will be tested by using ANOVA (Analysis of Variance). ANOVA Test is the method used to compare the scenarios with confidence level 95%. This significance test is to use the hypothesis statement as follows.

H0: $\mu_1 = \mu_2$

H1: $at\ least\ one\ population\ is\ significant\ different$

The result of the parameters significance test between existing conditions and scenarios can be seen in Table 6. It shows that the F value is larger than F critical only on Parameter 1. It can be said, there is at least one population is significantly different in Parameter 1. Meanwhile, for Parameter 2 and 3, there is no significant different. Therefore, scenario can only be performed for Parameter 1

Table 6: Parameter Validation Hypothesis Testing Result

No	Parameter	F	F crit	Conclusion
1	Material Transferred from Buffer Warehouse to Production Warehouse	4.467	2.579	Reject Ho
2	Material Transferred from Port Warehouse to Buffer Warehouse	2.033	2.579	Accept Ho
3	Material Transferred from Port Warehouse to Production Warehouse	2.079	2.579	Accept Ho

6.3 Scenario Analysis

The scenario model is developed by modifying the raw material allocation in each production warehouse and buffer warehouse. There is an obvious interest in identifying the best out of a group of scenarios by inspecting the mean results for each scenario. Table 7 shows that the proposed scenario gives the decreasing result for the mean value for material transferred from buffer warehouse to production warehouse.

Table 7: Comparison of Mean Value

	Parameters		
	3	2	1
Existing	2,012,385	1,665,415	425,130
Scenario	1,744,895	1,495,345	351,050
	-13.29%	-10.21%	-17.43%

The proposed scenario shows the minimum result of the total volume of materials transferred under the same condition of supply, demand, and material handling equipment resources are available. The scenario might show different performances if the input of the system changes.

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

Based on calculations and discussions that have been done, it can be concluded that:

1. The best warehouse capacity allocation is by prioritizing the raw material that has the highest frequency of shipment arrival to be allocated in the nearest production warehouse and nearest buffer warehouse from the port.
2. The improvement in warehouse allocation is reduced an average of 17.43% of raw material transferred from buffer warehouse to production warehouse compared to the existing condition.
3. The improvement in warehouse allocation has reduced an average of 10.21% of raw material transferred from the port to buffer warehouse compared to the existing condition.
4. The improvement in warehouse allocation is reduced an average of 13.29% of raw material transferred from port to production warehouse compared to the existing condition.

7.2 Recommendations

Recommendation for future similar research are:

1 Consider the improvement based on the cost that occurs during the material transferred activity.

2. Develop scenarios by investing additional handling equipment such as conveyor line and discharging equipment at the port.

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