Re-Design Layout and Allocation of Raw Material Warehouses Using Simulation Methods to Minimize the Handling Cost from Port to Warehouses

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Abstract—**The high cost of raw materials handling from the port to the warehouses at PT. Petrokimia Gresik has encouraged this research to find solutions to reduce costs in raw material unloading activities. The location of factories and raw material warehouses that are separated from each other, the number of warehouses that are not yet connected with conveyor belts as well as the diverse types of raw materials become its own challenges in operating unloading activities to be more efficient. The layout and allocation of raw materials in the existing warehouses creates high cost of raw materials handling because slow moving raw materials are close to the production location, while fast moving raw materials are far from the production location. In addition, the differences in the existing unloading methods also affect the cost of raw materials unloading, the use of vessel cranes and dump trucks will increase costs, otherwise the use of conveyor belts will minimize the cost of raw materials handling. This research is important to find the layout and allocation of raw materials that have the most efficient handling costs. The steps in this study include (1) data collecting and processing; (2) making conceptual and simulation models, (3) verification and validation tests; (4) developing alternative scenarios; (5) running simulations based on alternative scenarios; (6) comparing scenarios using anova test and cost and benefit analysis. The simulation is done using Arena 14.0 software. The simulation results show that the re-design layout and allocation of 5 warehouses in Factory 2A and Factory 2B is the best alternative scenario. This scenario is proven to be able to minimize the cost of raw materials handling with savings of Rp. 10.958.028.455 per year with an ROI of 108% and a Payback Period of 0,48 years.**

Keywords—**Warehouse, Layout, Raw Material Handling Costs, Simulation, Arena.**

I. INTRODUCTION

THE WAREHOUSE is a point in the logistics system where a firm stores or holds raw materials, semifinished products, or finished products. With the evolution of supply chain philosophies, strategic alliances, and just-in-time; the last few decades have seen a new role for warehousing. Today's warehouse is not a classical long-term storage facility. Attention is given to the warehousing role in attaining the logistics goals of shorter cycle time, lower costs, lower inventories, and better customer service. Warehouses operations and layouts are being redesigned to achieve cost and order-processing goals [1].

Layout planning and resource allocation in a facility can significantly affect business productivity [2]. Layout is the location of any raw material that must be in the raw material warehouse which is close to the production process and what raw materials do not need to be placed close to the production process [3]. Whereas allocation is slot capacity or the proportion of raw materials in one raw material warehouse. This is because, the warehouse of existing raw materials, can be filled with more than one type of raw material. Therefore, to get cost-efficient handling, the layout and allocation of appropriate raw materials will be the key to the success of this improvement [4]. Based on previous research, a good layout can reduce the distance of moving goods in the process of putaway and picking [5]. Garside, et al., also conducted a study on the process of handling raw materials, by redesigning the layout and slot allocation of raw materials using the method of dedicated storage, proved to be able to minimize the distance of material movement [6].

The layout has a major influence in determining efficiency in long-term operations. The layout has a strategic influence to improve the competitiveness of companies from various aspects, namely aspects of capacity, process, flexibility of movement of goods, productivity, so that it leads to the effectiveness and efficiency of time and cost. With an optimal layout it will clearly help companies in developing differentiation strategies, cost leadership and rapid responses to market demand [7]

PT. Petrokimia Gresik is the largest and the most complete fertilizer producer in Indonesia which is a subsidiary of PT. Pupuk Indonesia (Persero). The company is committed to providing quality fertilizer at affordable costs to all farmers in Indonesia. Therefore, PT. Petrokimia Gresik pays special attention to supply chain activities. This is because most of PT Petrokimia Gresik's raw materials have been imported from abroad, such as Egypt, Jordan, Morocco, Canada and Russia. Bulk raw materials used in making fertilizer include Rock Phosphate, Zwavelzuur Ammonium (ZA), Red Potassium Chloride (Red KCl), White Potassium Chloride (White KCl), Diammonium Phosphate (DAP), Sulfur (Sulfur) and Urea. In one year the raw materials being unloaded at Port of Petrokimia Gresik can reach 3,186,280
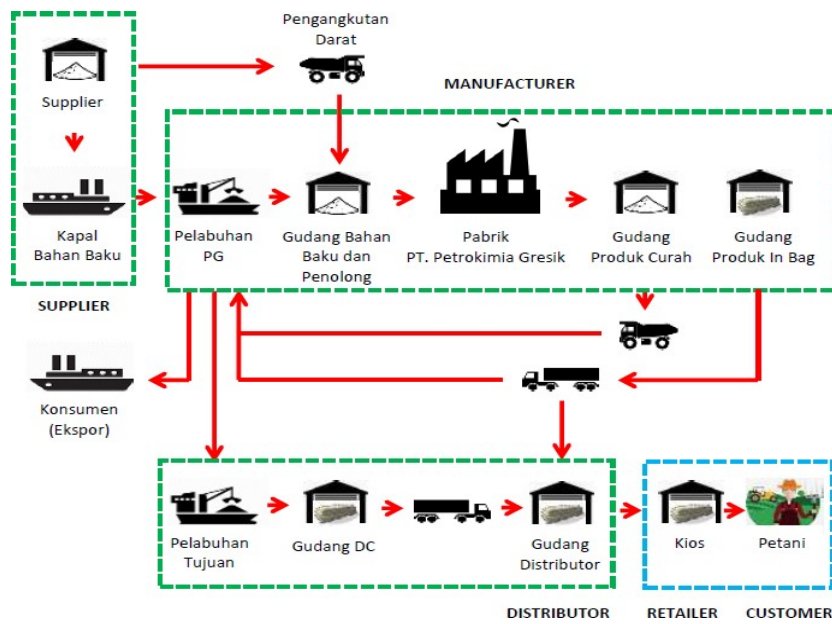
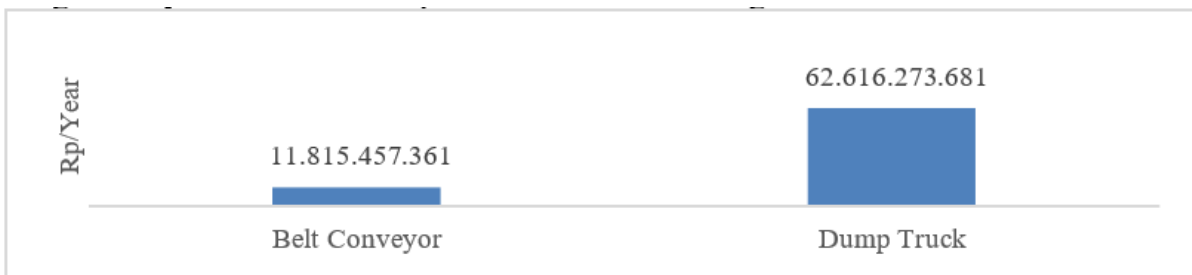Figure 1. The supply chain channel of PT. Petrokimia Gresik.

Figure 2. Raw materials handling costs in 2018.

Figure 3. Warehouse and port layout.

tons. The raw materials are then sent and stored in the raw material warehouses. These raw material warehouses can be used to store more than one kind of raw material with different layouts and allocations.

In addition, fertilizer products produced by PT. Petrokimia Gresik must also be distributed both to meet the needs of subsidies and to be sold commercially domestically and exported abroad. With the wide range of fertilizer distribution, causing logistics costs to be one component of cost of good sales of fertilizer which has an important role in providing more competitive product prices. This, confirms that, logistics costs are one component that contributes
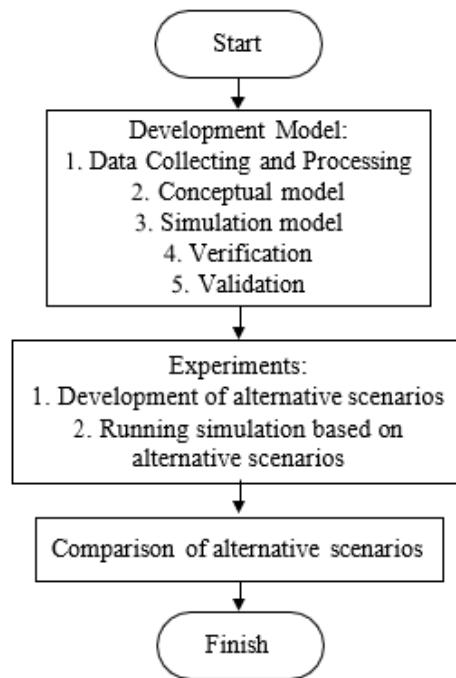
Figure 4. Research methodology scheme.

Table 1.

Comparison of Real Condition Handling Costs and Simulation Results with 10 Times Replication

No	Real Condition Handling Cost (Rp/Year)	Simulation Result Handling Cost (Rp/Year)
1	74.431.731.041,59	64.056.164.563,97
2		68.973.418.046,89
.		.
.		.
9		69.917.290.841,65
10		76.119.041.265,76
	Average (x)	**73.939.240.878,67**
	Standard Deviation (s)	**9.547.730.205,90**

Table 2.

Comparison of Real Condition Handling Costs and Simulation Results with 50 Times Replication

No	Real Condition Handling Cost (Rp/Year)	Simulation Result Handling Cost (Rp/Year)
1	74.431.731.041,59	64.056.164.563,97
2		68.973.418.046,89
.		.
.		.
49		58.016.962.667,59
50		97.175.102.204,70
	Average (x)	**75.671.915.793,51**
	Standard Deviation (s)	**9.217.600.894,78**

greatly to the availability of competitive and affordable fertilizer prices. Figure 1 below is the supply chain channel at PT Petrokimia Gresik from raw materials to finished products.

One of the supply chain activities at PT. Petrokimia Gresik that needs attention is the unloading of bulk raw materials from the port to the warehouses, because the cost of this activity is the largest cost component in inbound logistics. Factors that influence the high and low costs of raw materials handling include the use of raw material handling equipments [8] as well as the layout conditions and warehouse allocation of raw materials [9]. The use of internal equipments such as continuous ship unloaders, kangaroo cranes and conveyor belts [10] will further reduce the cost of raw materials handling and conversely the use of external equipments such as vessel cranes and dump trucks will increase the cost of raw materials handling [11].

The tonnage of transferred raw materials using dump trucks from the port to the production warehouse is more dominant compared to the tonnage of transferred raw materials using belt conveyor. This is because the layout and allocation of warehouses have not yet considered the FSN classification [12], therefore slow moving raw materials are located close to the production location while fast moving
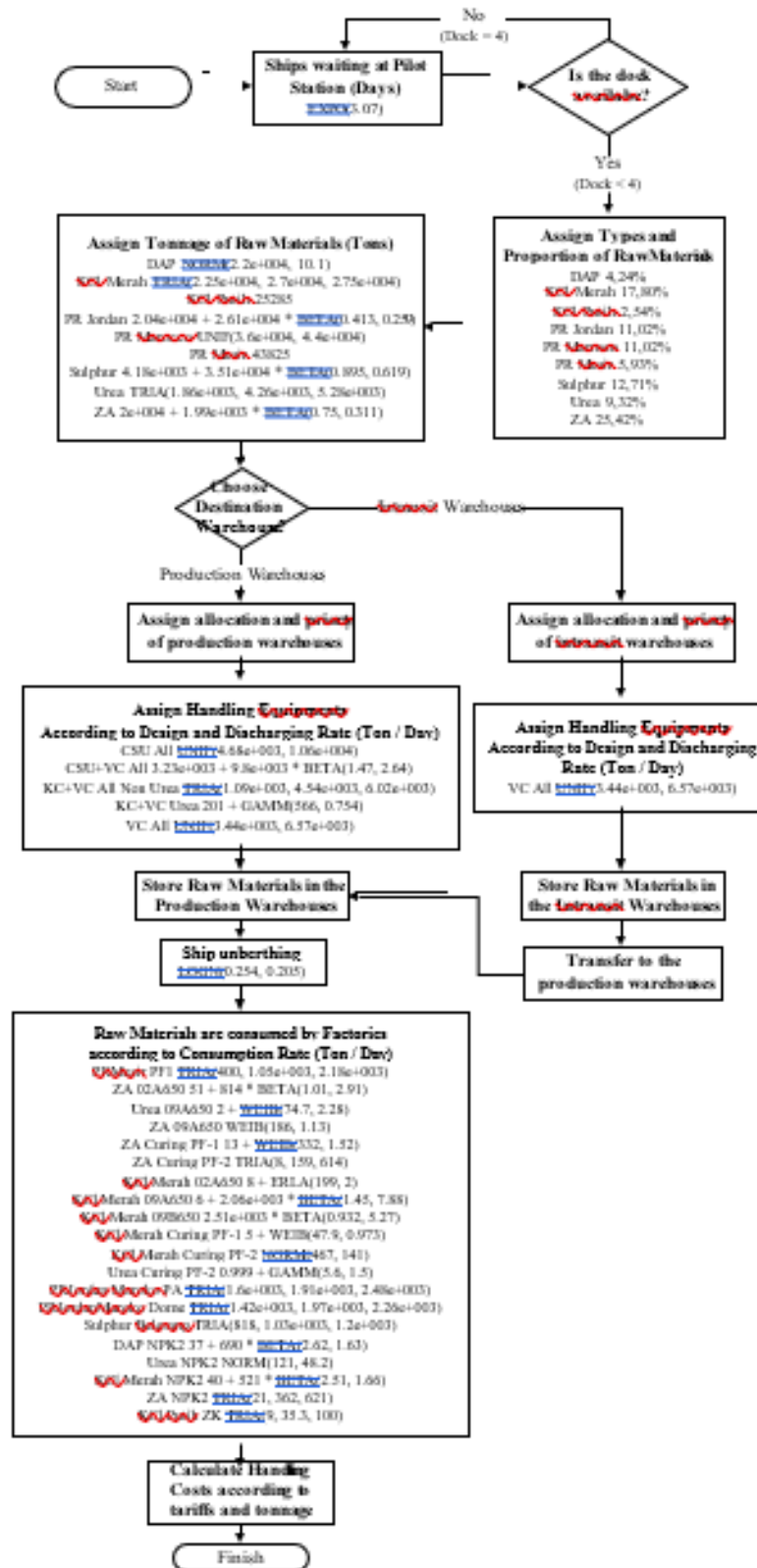
Figure 5. Model of raw materials handling flowchart.

raw materials are far from the production location. The high tonnage of raw materials moved using dump trucks causes the high cost of handling raw materials from the port to the production warehouses. In 2018 the cost of raw materials

handling reaches Rp 74,431,731,042, - with comparison between the handling costs using conveyor belts and dump trucks as shown in Figure 2. The high cost of raw materials handling from the port to the raw materials warehouses for

Table 4.
Changes in Layout and Allocation of Raw Material Warehouses Alternative Scenario 2

Warehouses	Raw Materials	Existing Capacity	New Capacity
Gudang NPK2	KCl Merah	11.000	5.000
	ZA	2.000	5.000
	Urea	3.000	2.000
	DAP	3.000	7.000
Gudang PF-2	P. Rock	40.000	-
	KCl Merah	-	10.000
	ZA	-	10.000
	Urea	-	4.000
	DAP	-	14.000
	KCl Putih	-	2.000
Gudang Curing PF-2	KCl Merah	5.000	6.000
	ZA	4.000	3.000
	Urea	500	500
Total		68.500	68.500

Table 5.
Changes in Layout and Allocation of Raw Material Warehouses Alternative Scenario 2

Warehouses	Raw Materials	Existing Capacity	New Capacity
Gudang 02A650	KCl Merah	10.000	11.000
	ZA	7.000	6.000
Gudang 09A650	KCl Merah	10.000	8.000
	ZA	3.000	4.000
	Urea	1.000	2.000
Gudang NPK2	KCl Merah	11.000	5.000
	ZA	2.000	5.000
	Urea	3.000	2.000
	DAP	3.000	7.000
Gudang PF-2	P. Rock	40.000	-
	KCl Merah	-	10.000
	ZA	-	10.000
	Urea	-	4.000
	DAP	-	14.000
	KCl Putih	-	2.000
Gudang Curing PF-2	KCl Merah	5.000	6.000
	ZA	4.000	3.000
	Urea	500	500
Total		99.500	99.500

Table 6.
Comparison of Difference and Critical Range between Alternative Scenarios

Scenario Comparison	Difference (Savings)	Critical Range	Conclusion
|Existing Condition – Scenario 1|	2.179.385.535,51	4.548.091.918,95	The difference is not significant
|Existing Condition – Scenario 2|	7.911.794.693,10	4.548.091.918,95	The difference is significant
|Existing Condition – Scenario 3|	10.958.028.455,19	4.548.091.918,95	The difference is significant

production at PT. Petrokimia Gresik, has encouraged this research to find solutions to reduce costs in raw material unloading activities. PT. Petrokimia Gresik has 15 separate bulk raw material warehouses to serve 4 factories, namely Factory 2A, Plant 2B, Plant 3A and Plant 3B as shown in Figure 3, as well as different loading methods and different types of raw materials. This has become a challenge in managing this raw material handling activity.

The aim of this research is to make a layout design and allocation of raw materials in the warehouses with a simulation method that can reduce overall material handling cost. The process of handling raw materials from the port to the warehouse is a complex system which contains variability and interdependence between one element and another. This process variability can be seen from the different ship arrival schedules, different types of raw materials and varying tonnage of raw materials. The process of handling raw

materials from ship docked at the port to storage in the warehouse is also a discrete event system, where the status variable only changes when there is a certain event as a trigger [13].

To evaluate the improvement scenarios that provide the most savings on the raw material handling process, the right method is needed. Discrete event simulation is the right method to investigate this improvement scenario. Simulation models are good visual tools to explain and illustrate the suggested changes in a system [14]. With this simulation method, the improvement process does not have to be done by intervening in a real system [15]. In addition, the simulation method is also efficient in terms of time and cost utilization [16].

Simulation methods are widely used in port systems, warehousing and other production facilities. Tahar and Hussain used a simulation method in their research, to model
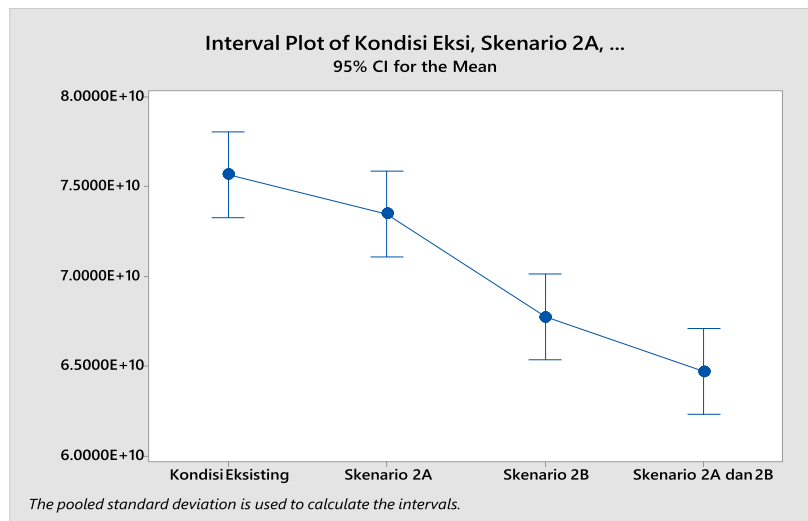
Figure 6. Interval plot of existing condition vs. alternative scenario

Table 7.
Cost and Savings Comparison between Alternative Scenarios

Information	Alternative Scenarios		
	Scenario 1	Scenario 2	Scenario 3
a. Investments (Rp)	1.249.876.402	4.184.405.481	5.275.658.815
b. Savings (Rp)	2.179.385.536	7.911.794.693	10.958.028.455

Table 8.
Comparison of Cost and Benefit Analysis between Alternative Scenarios

Information	Alternative Scenarios		
	Scenario 1	Scenario 2	Scenario 3
Tukey Cramer test	Not Significant	Significant	Significant
ROI	74%	89%	108%
Payback Period	0,57 Years	0,53 Years	0,48 Years

and simulate port operations in Kelangport Malaysia [17]. Simulation methods are also used by Deshpande, et al., to model and analyze truck load terminal operations to experiment with alternative docking scenarios [18]. Abedinzadeh, et al., used a simulation method to study warehouse loading and unloading systems at an automotive company in Tehran in Iran in order to reduce the average waiting time of personnel[19]. This simulation method is also used by Na and Shinozuka to model and simulate terminal operation processes that involve arrival, loading, unloading, and other discrete events [20]. In addition, Liong and Loo also conducted a study on the process of loading and unloading in warehouses to reduce customer waiting times and overtime costs [21]. Emami, et al., conducted a study on loading and unloading systems using a simulation method to optimize handling time on loading and unloading [22]. This research will also use a simulation method to model and simulate the process of handling raw materials from the Port to the warehouse in order to reduce the cost of handling raw materials.

II. METHOD

Simulation has been considered as an appropriate research method for modeling and experimenting complex system, including logistics and supply chain problems. Furthermore,

simulation models are often used when the characteristics of the supply chain are impractical and difficult to model with analytical approaches [15] or when the systems incorporates stochastic variables and uncertainty [23]. This research begins with data collection using secondary data that already exists. The data is then processed to see the appropriate data distribution. Based on the raw material unloading flowchart, a simulation model is made so that it can represent real conditions. After the simulation model is valid, the next step is to develop alternative scenarios for improvement. The alternative scenarios that have been made are then run a simulation to find out the cost of raw materials handling of each scenario, which will then be tested using ANOVA test to test for significant differences between class means [24]. To get the best alternative scenario, a cost and benefit analysis is performed to compare the benefits or savings produced with the costs or efforts spent to make improvements [25]. This research methodology scheme is generally shown in accordance with Figure 4.

III. RESULT AND DISCUSSION

A. Model Development

The method of constructing a conceptual model is a flowchart that describes the sequence of processes. Figure 5 below is a model of raw materials handling flowchart from

the port to the warehouses. The raw materials of KCl, ZA, DAP, Urea, Rock Phosphate Egypt, Morocco and Jordan are carried by ships from the port of origin. When it reaches the pilot station, the ship will wait for the dock to be able to enter the Port of Petrokimia Gresik. The number of unloading vessels at the Petrokimia Gresik Port is a maximum of 4 ships at the same time, so that when there are 4 ships that dock at the Port, the ship must wait at the pilot station. After berthing position is available, the ship will immediately dock at the port according to the empty dock. Furthermore, the ship will be identified the proportion of raw materials according to the type of raw materials that come, based on previous historical data.

In accordance with the plotting allocation of the placement of raw materials that have been done, then the destination warehouse will be identified. There are two clusters of raw material destination warehouses, the first priority is to send raw materials to the production warehouses, only afterwards to the intransit warehouses (A, B and C warehouses). Production warehouses consists of 9 warehouses namely PF-1, Curing PF-1, 02A650, 09A650, 09B650, PF-2. Curing PF-2, NPK-2 and ZK warehouse. Next, assign the destination warehouses for each type of raw material and each priority.

Based on the destination warehouse that has been assigned, the handling equipment is chosen according to the design of its use and with the most efficient rates. After assigning the warehouse allocation and handling equipment selection, the unloading process can be carried out.

When unloading process is complete, raw materials will be stored for later consumption by factories. Raw materials in the production warehouses can be directly consumed with different consumption rates according to the distribution of their respective data. The raw materials in the intransit warehouse are used as a buffer, when the stock in the production warehouse is depleted and the raw material vessels have not arrived yet, then the raw materials in the intransit warehouse will be sent to the production warehouses. After all the series of raw material handling processes from the Port to the production warehouses are completed, the handling costs can be calculated periodically.

Furthermore, the conceptual model above, is converted into a simulation model using Arena 14.0 software. The simulation model is created by inserting the process flowchart according to the conceptual model into the arena software using the required simulation elements. So that the simulation can run in accordance with the existing conditions, then the unloading process data input into the existing condition simulation model that has been made in the simulation software. The input of the existing condition simulation model is the distribution data for each activity and other attributes.

B. Verification

Verification is carried out on the simulation model that has been made, to ensure that the model created, can be simulated using Arena 14.0 software in accordance with real conditions in the field. Verification is done by seeing whether there are syntax errors (technical errors) and semantic errors (logic errors) when running the simulation model. Verification is successful if the simulation does not experience syntax errors or semantic errors. Verification results show that there is no error from the model that has been made, so that it can be stated that the conceptual model created has been in accordance with the desired simulation model.

C. Validation

After the simulation model is verified and there are no errors, then the validation test is performed on the model created. Validation test is used to prove that the model that has been created, is able to represent real conditions. The expected simulation results are in the form of total raw material handling costs. Validation is done by comparing the cost of handling raw material simulation results with real costs using one sample t-test. Simulation data is said to be valid if the P-value of t-test results> 0.05. Before one sample t-test is conducted, first find the right number of replications with initial trials n = 10 times the replication, with the results as in Table 1.

To be able to determine the number of replications, it needs to be calculated so that the number of valid replications is obtained if the simulation error value is relative relative error (5%). From the calculation results, a simulation error of 9.24% is obtained so that the simulation error> relative error, it is necessary to increase the number of replications.

With a relative error (γ) = 5%, **$z\alpha/2$** = 1,96, dan (s) = 9.547.730.205,90 then the number of new replications is calculated so that the number of new replications is obtained at least 28 times. Taking this into account, the researchers increased the number of new replications up to 50 times. The results of calculation of handling costs with 50 times the replication can be seen in Table 2.

With the same formula, the simulation error is then calculated again. Errors simulation from the calculation is 3.46%. Therefore simulation error is less than relative error, then the number of replications meets the validation requirements. So that the number of replications used is as much as 50 times. Furthermore, then to determine the valid simulation model is to test the hypothesis with one sample t-test.

Determine H0 and H1
- H0 : μ_0 = 74.431.731.041,59
- H1 : $\mu_1 \neq$ 74.431.731.041,59

The level of significance used is α = 0.05. By using one sample t-test in Microsoft Excel, a P-value of 0.346 can be obtained. It can be seen that P value > 0.05, then accept H0, it means that there is not enough evidence to state that the cost of the simulation results is not the same as Rp. 74,431,731,041.59 or in other words there is no difference between the simulation results and the real conditions. So it can be concluded that the simulations model is valid.

D. Development of Alternative Scenarios

After the simulation model in the existing condition is created, verified, and validated, the next step is to develop alternative improvement scenarios along with the simulation model for improvement. From the improvement scenarios

carried out, it is expected that the best improvement scenarios can be obtained to overcome the problem of high raw material handling costs. An alternative scenario is to make an alternative layout scenario and the allocation of new raw materials. First, an evaluation of raw material consumption will be carried out using the FSN (Fast Moving, Slow Moving and Nonmoving) method to determine what raw materials need to be changed. Raw materials with high consumption frequency are placed close to the production unit. Next determine the allocation of slots or the proportion of raw materials that must be placed in each warehouse, because in one warehouse can contain more than one type of raw material. There are several alternative scenarios for determining raw material slots to be simulated. The alternative scenario is chosen by considering the actual handling costs of raw materials. Warehouse area with high raw material handling costs will be prioritized for improvement.

The following are alternative scenarios that arise by considering the above:

1) Alternative scenario 1

Alternative scenario 1 is done by arranging the layout and allocation of raw material slots serving Factory 2A. There are 5 warehouses serving the needs of Factory 2A, namely warehouse 02A650, 09A650, 09B650, PF-1 and PF-1 curing warehouse. Table 3 below is a change in layout and allocation of alternative scenario 1. Changes in the layout and layout of Factory 2A raw material warehouse are done by redesigning the layout and allocation of warehouse 02A650 and 09A650 in accordance with the new proportion of capacity by making the boundaries or a new wall to separate raw materials from one another. Whereas the old wall wall must be demolished first.

2) Alternative scenario 2

Alternative scenario 2 is done by arranging the layout and allocation of raw material slots serving Factory 2B. There are 4 warehouses serving 2B factories namely NPK2, PF-2, ZK and CF-2 Curing warehouses. Table 4 below is a change in the layout and allocation of raw materials for alternative scenarios 2. Changes in the allocation and layout of raw materials warehouse for Factory 2B are done by redesigning the layout and allocation of warehouse NPK2, PF-2 and Curing PF-2.

3) Alternative scenario 3

Alternative scenario 3 is done by arranging the layout and allocation of raw material slots serving Factory 2A and Factory 2B. There are a total of 9 raw materials warehouses that will be re-arranged as well as their layout according to the FSN Analysis adjusting the consumption rate of Factory 2A and 2B raw materials. Considering the improvement steps taken at Factory 2A and Factory 2B, the following table 5 is an improvement step for alternative scenario 3.

E. Comparison of Alternative Scenarios

After running simulations of various alternative scenarios, then a scenario comparison is performed using the ANOVA test to see the significance of the scenario results with the real simulation results. After that, a cost and benefit analysis

is performed on each alternative scenario to compare the benefits or savings produced with the costs or efforts incurred to make improvements. So that the best alternative scenario is obtained which has the effect of saving on the cost of raw materials handling and with the cost of repairs or feasible efforts to do.

Next, to determine whether there is a mean difference between alternative scenarios is to do ANOVA test as follows. Determine H0 and H1

- H0: $\mu 1 = \mu 2 = \mu 3 = \mu 4$
- H1: there is a minimum of 1 different population

The level of significance used is $\alpha = 0.05$. By using the single factor ANOVA test (oneway ANOVA) in Microsoft Excel is known that the P value is 4.980×10^{-10} and it can be concluded that the P value <0.05, then reject H0, which means there are differences between populations.

After conducting the ANOVA test, a subsequent tukey cramer test is used to determine which inter-population average is the most significant and which is not significant. the critical range of results from the tukey kramer test is 4.548.091.918,95.

From the tukey cramer test it can be seen that a significant alternative scenario is an alternative scenario that has a difference (savings) > of the critical range value, the results of the tukey cramer test. Table 4 follows the comparison of the difference value and the critical range value of each improvement.

From Table 6, it can be concluded that, alternative scenario 2 and alternative scenario 3 are alternative scenarios that have significant differences. While the alternative improvement scenario 1, the difference is not significant. This is clearly seen in the interval plot like Figure 6.

Next is to conduct a cost and benefit analysis to determine the best alternative improvement scenario. Table 7 below is the cost of repairs needed to do a re-layout the warehouse of raw materials as well as savings or benefits or revenue generated from this repair. Based on the data in table 6 and 7 above, it can be calculated Return on Investment (ROI) and Payback Period (PP) from each alternative improvement scenario and compare it with the result of tukey cramer test as follows Table 8.

Based on Table 8, the best alternative scenario is scenario 3, which is layout improvement and raw material allocation done at the raw material warehouses in Factory 2A and Factory 2B. This is based on the following things:

1. Based on the tukey cramer test, alternative scenario 3 has a significant difference compared to the existing conditions.
2. ROI from scenario 3 is the biggest compared to alternative improvement in scenario 1 and scenario 2 which is 108%.
3. Payback Period of scenario 3 is the fastest compared to alternative scenario 1 and scenario 2 which is 0.48 years.

IV. CONCLUSION

This research was conducted by redesigning the layout and allocation of the warehouses using FSN analysis and then running it with simulation methods. This study has been proven to be able to minimize the cost of handling raw materials from the port to the warehouse. Based on the simulation results of all alternative scenarios, scenario 3 is the best. This scenario is carried out by redesigning the layout and allocation of warehouses in Factory 2A and Factory 2B which includes 5 warehouses, namely 02A650 warehouse, 09A650 warehouse, NPK2 warehouse, PF-2 warehouse and PF-2 curing warehouse. Scenario 3 results in savings of IDR 10,958,028,455 per year with an ROI of 108% and a Payback Period of 0.48 years.

The company is expected to implement the best alternative improvement scenario to solve the high cost of handling raw material. To be able to carry out these improvements, it is necessary to modify the boundaries or boundaries between one raw material and another, adjusting to the layout and allocation or new capacity according to scenario 3. In carrying out this improvement there will be a risk of reducing the space or capacity of raw materials to a while when repairs are done. The impact of this risk is that during the repair period, there will be an increase in the cost of handling raw materials due to reduced warehouse capacity. So that these improvements can run well and all risks can be controlled, the company needs to create a task force team to carry out this project. The team is expected to be able to redefine the design of repairs, develop a repair schedule, monitor its implementation and make mitigation of risks that arise so that these improvements go according to plan.

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