Improving Warehouse Management System at The Largest Heavy Equipment Distributor Company in Indonesia with Simulation-Based Optimization Approach

[1,2] Nur Kamaarum Adiwida Hemas
[1]United Tractors, Jakarta – Indonesia
[2] Master of Mechanical Engineering
Swiss German University
Tangerang City, Indonesia
nurkamaarum@unitedtractors.com

Sumarsono Sudarto
Department of Industrial Engineering
Mercubuana University
Jakarta Barat, Indonesia
sumarsono@elite-tutors.co.id

Aditya Tirta Pratama
Department of Industrial Engineering
Swiss German University
Tangerang City, Indonesia
aditya.pratama@sgu.ac.id

Abstract*—Warehouses play a significant role in supply chains, so it is needed to be excellent in customer service, and organizations have to create more productive warehouses to fulfill customer needs. Warehouse productivity is not optimal, as seen from the SLA achievement and manpower utilization, leading to inefficiencies in the warehouse management system. This research aims to find out and analyze the cause of the problem and design an improved warehouse management system for better productivity in terms of SLA, manpower utilization and cost-efficiency. In doing this research, a simulation was carried out because of the complexity. After processing the data and simulating existing conditions, the results obtained are the manpower utilization is quite low on average, caused by some critical positions that have very low utilization. There are 9.46% of processed items during overtime hours, and the average achievement value of incoming SLA is deficient. If the company considers manpower utilization and employee cost efficiency as priorities, adjusting number of manpower and merging some roles can be considered as the best scenario. Suppose the company prioritizes the number of overtime items and SLA achievement as an indicator of success. In that case, the flow process simplification scenario and defining new time standard could be carried out.

***Keywords*—warehouse management system, simulation, utilization, service level agreement, cost-efficiency**

I. Introduction

In today's exceedingly competitive industrial markets, warehouses progressively play a significant role in supply chains. With the expanding request for excellent customer service, organizations are beneath weight to create more productive warehouses to fulfill customer necessities and secure companies against varieties in both productivity and request rate [1]. The transportation & storage industry contributed 5.8% of Indonesian GDP in 2019, the amount is 881 trillion, where it was increased by around 0.63% from 2015. This industry has an average growth rate higher than Indonesia's national GDP's average growth rate, which is 7.22% in the last five years. The warehousing industry's contribution increases every year, up to 0.8% in total of Transport & Storage GDP from 2015 to 2019 [2].

In the observed company, it doesn't not only sell units in its business processes, but also provides product support, namely parts and service. Therefore, warehouse management has a vital role in the supply chain flow that is carried out. The decline in the company's revenue & recurring profit this year impacts the decrease in the company's productivity. In order to survive, the company has to do some efficiency projects to control operating expense (OPEX) and employee cost prudently through the Cost Reduction Program and other efficiency programs. However, we still have to increase productivity. Warehouse & shipping expense (WSE) occupies the second-largest percentage (17%) among the entire account that forms the Master Budget (MB) OPEX of the company. The warehouse management process is quite important because maximizing productivity will impact cost efficiency, which will also affect the company's expense that affects business performance.

A warehouse must have productivity standards that describe the achievement of daily targets to maintain operational performance. In the observed warehouse, the standard is in the form of a Service Level Agreement (SLA). SLA is the number of items that meet the predetermined lead time standards or criteria in the processing time at certain activity points. This standard has become an agreement between the company and the warehouse management team. For Incoming SLA, it seems above the target, but in the direct observation, the observer found that the data sometimes was adjusted, and for the outgoing SLA, the target was achieved only in the last two months' data. Improving the efficiency in every aspect of warehousing activities should be done by eliminating any waste from a warehouse, including eliminating unnecessary processes or activities that have impact on decreasing productivity.

Based on the results of preliminary observations that have been made, it still often found repetition of work at several points of the process. Besides, resource or manpower utilization is also an important objective in this study. In reality, it still often found idle time and downtime (time to do activities that do not produce added value for the warehouse). As a result, the daily targets that should have been reached were not met because turnaround time or lead times were longer and not infrequently, which often caused overtime resulting in extra costs. Based on the above explanation, it can be concluded that the problem that must be resolved in this research is that warehouse productivity is not optimal, as seen from the SLA achievement and manpower utilization which lead to inefficiencies in the warehouse management system. The objective of this research is to find out and analyze the cause of the problem and design an improved warehouse management system at The Largest Heavy Equipment Distributor Company for better productivity in terms of SLA, manpower utilization and cost-efficiency.

Since the actual condition is very complex, it needs to be described in a model and easily analyzed for improvement. In doing this research, a simulation of an industrial system will be carried out so that a system can be studied and look for problems in it. One reason for the increasingly widespread use of this simulation is that simulations can save costs and time [1]. Simulations allow assessing work organization without physical intervention in the system before the changes are implemented in real life and can bring up several possibilities and alternatives. One can see the effect of different problems and experiment with alternative solutions [3].

II. Literature Review

Comprehensive researches have been done to improve the issue of warehouse productivity. The majority of research found discusses the layout and routing optimization in the picking product process to minimize processing time, then the product can be processed immediately to meet customer needs. However, the solution strategy and approach of each different researchers. A simulation approach was used to minimize retrieval time and travel distance orders using a strategy class-based storage for scenarios [4]. Another case with [5] that chose to develop a heuristic-based mathematical optimization model, namely by using the Iterated Local Search Algorithms in order to be used to measure performance on the condition of multiple pickers, high-level storage locations, and to avoid tardiness. A combination of several mathematical optimization models such as Multidimensional Scaling Algorithm and Random Assignment were used to shorten the total distance, the total waiting time of an order in the system, maximize the average quantity of order, and minimize average order picking time [9]. The disadvantage of these three research is that they do not conduct discussions regarding cost efficiency as the impact of the improvement that has been done so that the trade-off will be challenging to see.

According to [6] and [8], simulation approaches were used and provide analysis related to the cost impact incurred, but have different performance criteria at the end of their research. The research scope was limited to only inbound processes with the parameters of truck queue spillover onto the city roads, detention fees, and CO_2 emissions [8]. In the proposed scenario, determining the dispatching rules is considered the optimal strategy for obtaining the highest cost-efficiency. Meanwhile, [6] used service level parameters, storage cost, and production cycle as performance criteria and used Augmented Reality Technology as the proposed solution strategy. The advantage of this proposed research is that later will accommodate the entire process of both inbound and outbound, determining the productivity standard for both Manpower and the overall process, keeping the SLA for a customer order, and calculating the impact of the cost efficiency generated. Some updates related to business processes and manpower policy will also be generated at the end of this research.

III. Research Methodology

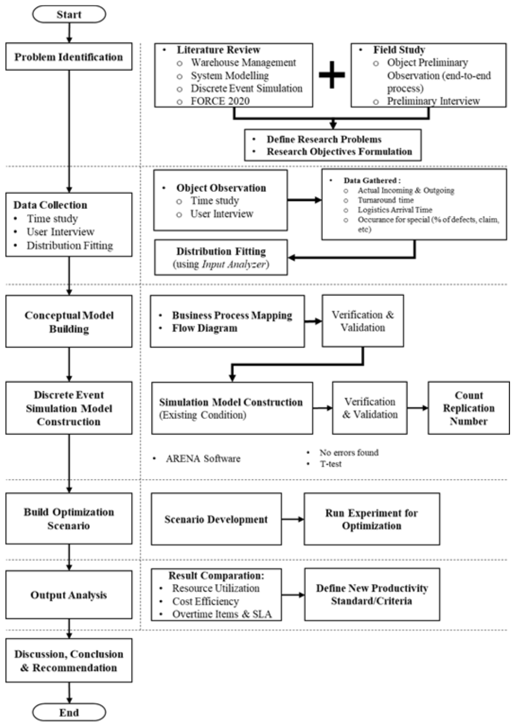

Fig. 1. Flow diagram of research methods

The research stages generally consist of seven steps, as shown in the flow diagram in Fig. 1. Field studies and literature studies are conducted at the problem identification stage to determine the research problems and objectives. Data collection is performed to support the construction of the simulation model. This process also aims to identify all the variables involved in the system and its parameters. Data collected include actual incoming and outgoing process time, turnaround time, logistics arrival time and quantity, occurrence for special condition (% of defects, claim, Etc.) After the data is collected, a distribution fitting is performed to find the data's distribution pattern for each variable obtained.

In making the conceptual model, the flow diagram is utilized to describe the sequence of existing processes in the system based on the business process breakdown. After making the conceptual model, a simulation model is made using ARENA software. Simulation models are based on logic and the workings of conceptual models to represent system conditions. The generated simulation model is run by following the conditions of the system in its existing state. In simulating this model, it can be seen whether the existing model that has been created can represent the state of the system.

After the simulation model is constructed, the following steps are doing verification and validation. Determination of the number of replications is intended to find out the minimum number of replications used in the system to represent the actual conditions. After several scenarios were built, an analysis of all outputs generated from the simulation model will determine whether the running system is productive. Also, a comparison is made between existing simulation models and simulation models resulting from scenario development. This analysis is carried out to determine the best decision related to the system with certain selection criteria related to productivity analysis. In the end, the comparison of output must hit the key performance indicator of the system.

IV. Results And Discussions

The entities of the Warehouse Jakarta Branch are TO (Transfer Order) number supplier and TO number customer. The attributes of TO number supplier are the quantity of spare parts and arrival time. For the TO number customer, the attributes are demand arrival time and the quantity of spare parts. Table 1 shows the details of the existing workers in the system.

TABLE 1
MANPOWER & ROLES

Roles	Number of Manpower
Receiving & QI	2
Binning	3
Picking	2
QC	1
Packing	1
Shipping	1
TOTAL	10

There are two primary processes in this system, incoming and outgoing. The incoming process consists of three main processes, the first is receiving process, then proceed to the quality inspection (QI) process, and the last is the binning process. The outgoing process consists of three main processes: the picking process, the quality control (QC) process, and the last is shipping process. Table 2 will explain the detailed description of the process.

TABLE 2
DETAIL DESCRIPTION OF PROCESS IN WAREHOUSE JAKARTA BRANCH

Primary Process	Sub Process	Description
Incoming	Receiving	The process of receiving goods from the expedition to the document of receipt of goods is stamped and received back by the expedition, until the process of inputting goods data into the SAP system
	QI	The process of checking the quality & quantity of goods is in accordance with the attached documents, including attaching bin labels, marking which ones are classified as emergency orders and require claims due to defects or rejects
	Binning	The process of placing goods into the Bin Area that has been determined according to the location of the bin label
Outgoing	Picking	The process of taking goods according to the Picking List and recording the Bin Card according to the goods that come out, and informing if the available goods are less than demand
	QC	The process of checking the quality & quantity of goods according to the attached documents or picking list before delivery to the customer
	Shipping	The process of measuring the weight & dimensions of the goods to be sent, making manifest and Delivery Letter, packing, until the delivery of goods to the expedition

The work schedule for manpower is six days/week, with working hours from 07.30 a.m. – 04.30 p.m., and the overtime is allowed until 05.30 p.m.

A. Specific Key Performance Indicator

The performance metrics for the warehouse management system in Jakarta Branch are manpower utilization, employee cost, number of overtime items, and Service Level Agreement (SLA). The manpower utilization used is scheduled utilization which is calculated by dividing the average number busy with the average number scheduled. The number of employees in the system, apart from having an effect on utilization, will certainly affect the employee costs that the company must incur. The projection used is the amount of employee costs in one year, using the 2020 Jakarta regional minimum wage as a reference for calculation.

In carrying out the process, the system has main working hours and working hours included in the overtime category. The number of items, in this case the TO Number, processed during overtime hours will be a measure of the effectiveness of the system. In addition to the number of overtime items, the system performance indicator influenced by the processing time is the Service Level Agreement (SLA), which is the number of items that meet the predetermined lead time standards or criteria in the processing time at certain activity points. This standard has become an agreement between the company and the warehouse management team.

B. Data Collection

The method used to gather primary data is through time study observation and interviews with the warehouse coordinator. All process time data collected has been verified and validated by the process owner and warehouse coordinator at the end of the observation process. The other method is through secondary data gathered from the historical data saved by the warehouse's system. After the data is collected and the data uniformity test is carried out, the distribution fitting was performed using the Input Analyzer software. As a whole, the sub-process times are fitted into triangular distribution. For goods arrival and customer demand, the data used is the company's historical data, from January to November 2020. Table 3 shows the recapitulation of fitting distribution result for TO number and quantity of goods arrival and customer demand.

TABLE 3
DISTRIBUTION FITTING RECAPITULATION

	Goods Arrival	
TOTAL/year	**TO Number**	**Qty**
	12.068	165.552
Entities Distribution	0.999+GAMM(30.1,1.45)	-0.001+EXPO(14)
Inter arrival Distribution	0.5+EXPO(0.733)	
	Customer Demand	
TOTAL/year	**TO Number**	**Qty**
	13.881	182.925
Entities Distribution	0.999+EXPO(40.6)	0.999+EXPO(10.2)
Inter arrival Distribution	0.5+EXPO(0.506)	

C. *Existing System Simulation & Analysis*

After the conceptual and simulation model has been constructed, the next determines the number of replications, verification, and validation.

1) *Number of Replication*

Determining the number of replications is used to know the minimum number of replications used in the system. So, it is able to represent its real conditions. The data needed is the simulation model output from the number of initial replications, in the form of a number out of goods picked and demand fulfilled. Furthermore, to get the value of n' (n replications required) using a confidence level of 95%, the following calculations are performed.

$$Half\ width = \frac{(t_{n-1,\alpha/2}) \times s}{\sqrt{n}} \quad (1)$$

TABLE 4
HALF WIDTH CALCULATION

	Goods Picked	Demand Fulfilled
a (relative error)	0,05	0,05
Mean	182128,8	44045
Std Dev (s)	12068,38	2503,17
n	10	10
t(n-1,a/2)	2,26	2,26
Half Width	8633,20	1790,66
% error to Mean	0,047	0,041

TABLE 5
NUMBER OF REPLICATION CALCULATION

	Goods Picked	Demand Fulfilled
Relative error (gamma)	5%	5%
n'	9,908887757	7,289053922
Round up n'	**10**	**8**

Using the relative error formula, the number of replication that needs to be done can be obtained. With the relative error of 5%, Table 5 shows the recapitulation of the calculation result. The result is n' ≤ n, so the replication number is enough at 10.

2) *Verification & Validation*

One method of verification is to determine whether there is an error in creating a simulation model using Arena software. Fig. 2 shows that there are no errors or warnings found in the model.

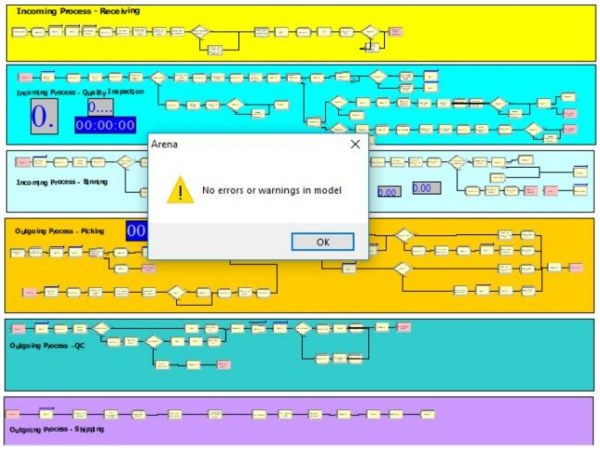

Fig. 2. Syntax Error Verification

The validation process serves to ascertain whether the simulation model represents the existing system. Because each sample is independent, the statistical method of *Student's t* hypothesis testing is used to compare the population mean of the existing system and the simulation system. The following is the initial hypothesis and determined alternative hypothesis.

H_0: $\mu_1 = \mu_2$

H_1: $\mu_1 \neq \mu_2$

Where:

μ_1 = the population mean of the simulation results

μ_2 = existing population mean

TABLE 6
T-TEST RESULT FOR GOODS PICKED DATA

t-Test: Two-Sample Assuming Equal Variances		
	Variable 1	**Variable 2**
Mean	16623,27	17859,9
Variance	25096405	5758766
Observations	11	10
Pooled Variance	15936471	
Hypothesized Mean Difference	0	
df	19	
t Stat	-0,70897	
P(T<=t) one-tail	0,243475	
t Critical one-tail	1,729133	
P(T<=t) two-tail	**0,486951**	
t Critical two-tail	2,093024	

The null hypothesis in this validation process is that there is no significant difference between the population mean of the simulation results and the existing system. With α

(degree of error) of 5% and *df* of 19, the value of $t_{(\alpha,\ df)}$ is 2.093. In this validation process, data is the number of goods picked in the actual system and the simulation output result. Table 6 provides the results of the *Student's t* hypothesis test using data analysis in Microsoft Excel. It shows that p-value > 0.05, then the hypothesis that the real system and system model are the same is accepted, and the model can be valid.

3) Existing System Analysis

In this existing system analysis, the result of 10 times replication report is used as the source of analysis.

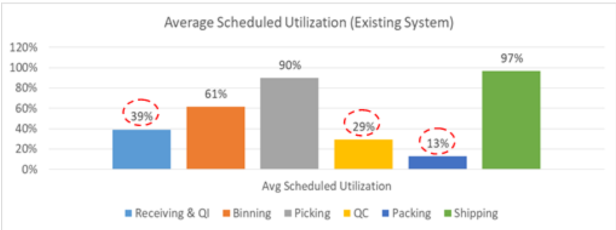

Fig. 3. Existing Manpower Utilization

Fig. 3 shows several resources or manpower that have very low utilization compared to the overall average, 54.89%. The overall manpower utilization rate in the system can also be categorized as quite low. Several critical positions with low utilization include Receiving & QI workers, QC workers, and Packing workers. The low utilization value can be due to the number of too many resources, and the processing time is relatively short. So that in everyday life, it allows a fairly high idle time. Currently, the total number of warehouse crews is ten people. Using the 2020 Jakarta regional minimum wage reference, which is IDR 4,276,349.00 per month, the projection of employee cost per year hit IDR 513,161,880,00.

In completing the daily processing cycle, the average number of items (TO number) processed by taking overtime is 9.46% among all processed items. With the increasing number of overtime items in the system, it can be an illustration of the higher overtime costs that will be incurred by the company so that the warehouse crew can still meet customer needs.

Apart from the cost, something that the warehouse must fulfill in providing services is SLA. From each item that is processed, time measurements are taken at certain activity points, and a calculation of how many items meet the standard is made. The average SLA achievement for the Incoming process is very low at 59.68%, where the critical sub-process is during the Good Receipt process to Quality Inspection complete (GR-QI) in the QI process, as well as Transfer Order to Transfer Order Confirm (TO-TOC) on the Binning process. Overall, the average SLA achievement for Incoming and Outgoing processes was 71.52%.

D. Proposed Scenario

Several alternative scenarios are proposed to improve the existing system.

1) Scenario 1: Number of Manpower Adjustment & Merging of Roles

In the existing conditions, the total number of resources that play a role in the system is ten manpower, but several critical positions have quite low utilization values, such as Receiving & QI workers, Binning workers, QC workers, and Packing workers. For this reason, there will be an adjustment in the number of manpower in that position in this scenario. The impact of the adjustment is that the QC and Packing process will merge roles because there will only be one person assigned to work so that it requires more competency development in the bearer of these duties and responsibilities. For the receiving & QI process, the number of workers is adjusted from two to one person, while the binning process was adjusted from three to two persons. In the existing system, the packing and QC process was done by one person each, and in this scenario, it was merged into one person only.

2) Scenario 2: Flow Process Simplification & Time Standard Adjustment

When analyzing SLA achievement on the simulation results of the existing model, it is known that the SLA achievement for the Incoming process is relatively low, so this scenario tries further to deploy each process, especially the Incoming process. Several findings were found, among others, that several processes could be eliminated, in the sense that preparations could be made outside of the cycle time or that they could be combined with the previous process, thereby minimizing the occurrence of delays between processes. The QI form file can be printed or prepared during the warming up period or outside the cycle time because the inspection results on all TO Numbers are written in the same QI Form format. Next is the complete QI process by inputting data into SAP, which can be combined when verifying documents so that the potential for inter-process delays can be minimized. Before carrying out the Binning process, the warehouse crew usually carries out the Goods Checking by sorting the items in the Binning area that are prioritized for Binning first so that it is enough to delay the time to start the Binning process. Therefore, the Goods Checking process can be eliminated on the condition that after attaching the Bin Label (the end of the QI process), the goods are immediately grouped into booths according to their respective types or priorities. In addition to simplifying several processes, in scenario 2 there is also a standard time adjustment for TO scanning and bin location scanning in the binning process.

3) Scenario 3: Combination between Scenario 1 & Scenario 2

This scenario tries to combine scenario 1 and scenario 2.

E. *Comparing System Analysis*

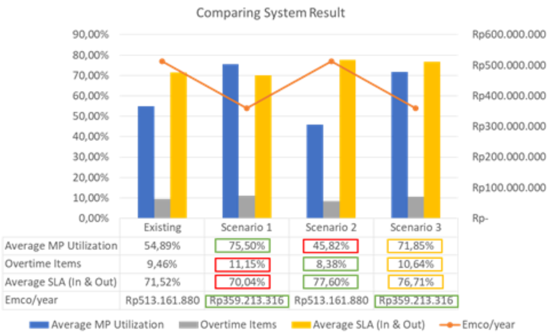

Fig. 4. All System Comparison Result

Based on Fig. 4, Scenario 1 shows the best performance on manpower utilization and employee cost efficiency. However, the average SLA and total overtime items' achievement is the worst, even though they are not significantly far from the existing value.

Scenario 2 shows the best performance on the achievement of average SLA and total overtime items. Nevertheless, on average, the resources seem very under-utilized because the number and role of manpower were not adjusted. In contrast, the flow process and time standard are adjusted to become simpler and shorter.

Scenario 3 can be said to be the safest solution because it shows the significant improvement of manpower utilization compared to the existing condition (although it is still lower than the scenario 1 result). The overtime items and SLA achievement are also better than the existing condition (although they are not as well as scenario 2 result). In this scenario, we can also see the employee cost-efficiency as well as scenario 1.

V. Conclusions

After processing the data and simulating existing conditions, the results obtained are the manpower utilization is relatively low on average, caused by some critical positions that have very low utilization. Using the total number of 10 employees, the projected cost of employees is Rp. 513,161,880 per year. There are 9.46% of processed items during overtime hours, and the average achievement value of incoming SLA is very low. Some of these findings can be categorized as the cause that leads to inefficiencies in managing the warehouse system.

Each alternative scenario has advantages and disadvantages for each response variable in the system. If the company considers manpower utilization and employee cost efficiency as priorities, scenarios 1 and 3 can be considered. However, between the two scenarios, the one that has the highest positive impact is scenario 1. Whereas, if the company prioritizes the number of overtime items and SLA achievement as an indicator of success, scenarios 2 and 3 can be considered, where scenario 2 is the best alternative scenario that provides the most significant positive impact than the existing system conditions.

This research contributes to the academic area by providing manpower composition policy, business process simplification, and manpower cost reduction to improve better productivity in warehouse management system. For further research, it is suggested to expand the scope of the model development, so more variables that affect system performance can be defined and improvement proposals can be deeper and more varied. Breakdown and analysis of the cost structure can be carried out more deeply related to the warehouse management system. Cost efficiency can be cultivated not only through the employee cost aspect. The application or investment of technology is an alternative that can be done in further research to see the increase in efficiency or productivity in the warehouse management system.

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