Analyzing the Relationship between Equipment Operation Time toward the Queueing Problem of the Head Truck During Loading and Unloading Activity in the Container Yard

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Abstract

Indonesia is one of the archipelago countries that has around 62% water area. To maximize the utilization of this condition, there are many freight and cargo shipping company that can be found in Indonesia. This paper is focusing on the stevedoring activity in the container yard. During the observation, researcher found a problem that is during the loading and unloading the container, the truck must wait in a long queue. It causes the stevedoring activity require a longer time to be completed. The goal of this paper is to find out the relationship between the operation time of each type of equipment in the container yard and the queueing problem of the head truck during loading and unloading activity. The method used in this paper is multiple linear regression with the combination of some tools in quality control. After one month collecting the data, the researcher come up with regression equation to understand the relationship between the equipment operation time and the queueing problem.

Keywords
Stevedoring activity, multiple linear regression, control chart, productivity

1. Introduction

As one of the archipelago countries, Indonesia has a very wide sea. It was stated by the Indonesian Coordinating Minister for Maritime Affairs that the area of inland waters and Indonesian archipelagic waters is 3,110,000 km^2 (Komunikasi, 2018). This condition can support economic development in Indonesia. One of the ways is by optimizing the performance of the seaport in Indonesia. One of the activities on the port is freight or cargo shipping which also common to be known as container transportation. Since 1961, container transportation already became one of the important transportation modes (Sha, et al., 2016). Many companies decide to distribute their product using cargo shipping because the cost is lower compared to other transportation modes.

One of the activities in cargo shipping is loading and unloading the container. Usually, this activity is done by a stevedoring company and it is located on the Container Yard (CY). A container yard system is a key facility temporarily accommodating outbound, inbound, and transshipment containers with a set of container handling equipment (Zhou, Lee, & Li, 2020). To support the loading and unloading process in a container yard there are several tools involved in the system. There are Container Crane (CC), Rubber Tyred Gantry (RTG), Head Truck/Trailer, and others.

This research is done in PT X, one of the stevedoring companies in Indonesia. PT X uses four types of equipment to support their stevedoring activity in the container yard. Those are Harbor Mobile Crane (HMC), Container Crane (CC), Rubber Tyred Gantry (RTG), and Head Truck (HT). During the observation stage, the researcher found that there are several times, the Head Truck must wait in a long queue to do the loading and unloading activity of the container. The queue can happen when the truck will be stacking the container to the vessel, receiving a container

from the vessel, stacking a container to the container yard, or receiving a container from the container yard. This research is done to find out the cause of the queueing problem of the head truck during the stevedoring activity in the container yard.

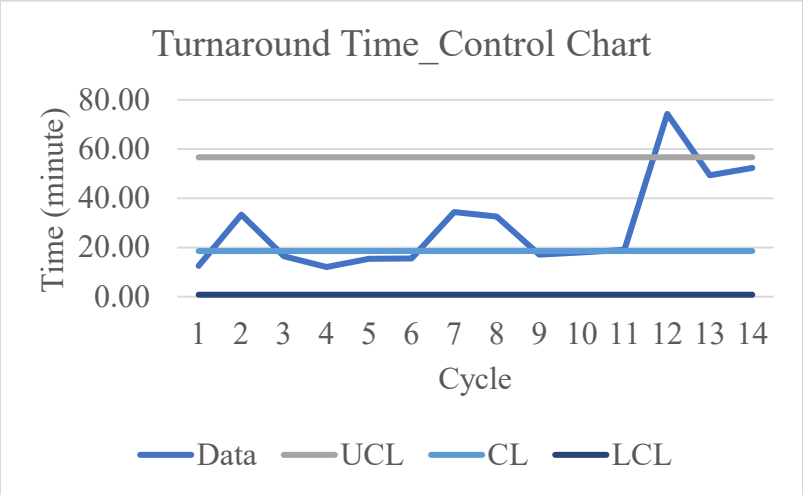

Figure 1: Turnaround Time Control Chart

From the chart, in figure 1 it can be known that the upper control limit (UCL) for this graph is 56.66 and the lower control limit (LCL) is 0.81. The control chart in figure 1 shows that there is data that exceeds the upper control limit. It means, there is a problem that happens in the field that makes the data time exceed the UCL. This is the reason why this study is conducted, which is to find out the impact given by the performance time of the equipment in the container yard toward the queueing line made by the Head Truck in the container yard during the stevedoring activity.

2. Literature Review

2.1 Container Port

Port as a node of the supply chain has an important role to support a shipment of goods from one point of economic activity to another point (Wirjodirjo Et Al, 2020). There is three main activity in a container port which are Stevedoring, Cargodoring, and Receiving/Delivery. Stevedoring is the activity of moving goods or containers from the dock/truck onto and off ships to the duck/truck. Cargodoring is the activity of moving the container from the dock to the storage yard. Receiving/delivery is the activity of receiving goods in a stacking field that soon the container will be loaded to the ship or delivering the goods from the container that have been shipped to the shipper. To visualizing the process, (Wirjodirjo Et Al, 2020) also give an illustration of the three main activity on a container port that can be seen in figure 2

Since the port is the place where ships completing the load and unload activity, port traffic is increasingly crowded with the number of boats coming to the load and unload process (Rahman, Sarno, & Efendi, 2018). To handle the process and keep it to be always in control, the system must be created as effectively and efficiently as possible. Here, all the parties involved such as the shipping company, the stevedoring company, the laborer, and others should work together and have good coordination so that all the processes can run smoothly.

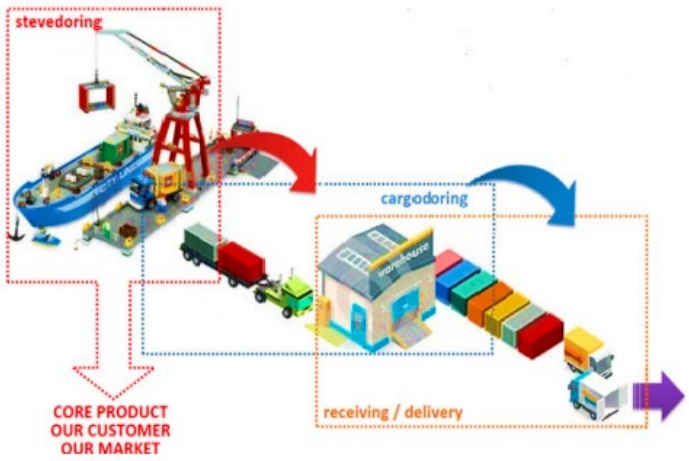

Figure 2: Container port activity (Wirjodirjo Et Al, 2020)

2.2 Stevedoring Company

Stevedoring company in the Indonesian language known as *Perusahaan Bongkar Muat (PBM)*. It is a company in charge of loading and unloading activity in the container port. Since stevedoring is the main activity in a container port, the stevedoring company is playing an important role in the system. In Indonesia, because there are so many companies related to this field, there is a law called *Istruksi Presiden (Inpres) No. 3 Tahun 1991* about *Kebijaksanaan Kelancaran Arus Barang Untuk Menunjang Kegiatan Ekonomi*. The stevedoring activity is mostly done near the Container Yard.

A Container Yard consists of many storage blocks for stacking containers, and each block is surrounded by aisles for a vehicle to travel and is equipped with yard cranes to perform the stacking and unstacking process (Zhou, Lee, & Li, 2020). There must be some equipment that has to be provided by a stevedoring company to do their jobs such as Gantry Crane/ Quay Container Crane, Rubber Tyred Gantry, Head Truck, Straddle Carrier, Container forklift, and others. Not all the equipment can be found in a stevedoring company. Mostly, they will adjust the type and the number of equipment that they have following the needs of the company.

2.3 Time Study

Time study is an approach introduced by Frederick W. Taylor to understand the behavior of each instrument in the process. By conducting a time study, the researcher will help to eliminate the wasted time and the bottlenecks possibility that might occur in the process (Yazdi, Azizi, & Hashemipour, 2018). To conduct the time study, the researcher needs some equipment such as stopwatch, recording system, video recorder, pen/pencil, calculator, and paper. However, in some conditions, the need might be different. It happens to the researcher of this paper. Since the time study here is conducted in a container yard to know the time needed by each equipment in completing their task, the researcher needs simple equipment. So, to conduct the time study, the researcher decided to use the only stopwatch in the handphone, pen, and notebook. Using time study is a good approach because it can help to analyze the root of the problem that will be very useful in improving a system.

2.4 Quality Control

Quality control is the operational technique and activity that used to fulfill the requirement of quality (Quality, 2021). Quality control is a good approach to do an improvement in a system. Improving quality is the key factor to business success, enhanced competitiveness, and growth (Montgomery, 2013). Both in product and service, quality is an important factor for a customer to decide. The quality of a product has eight dimensions which are performance, reliability, durability, serviceability, aesthetics, features, perceived quality, and conformance to standards. For the service, there are three dimensions which are responsiveness, professionalism, and attentiveness. Seven tools can be used to measure the quality, which are:

2.4.1 Cause and Effect (Fishbone diagram)
A Fishbone diagram is a tool that can help the researcher in discovering all the possible causes of a problem. No statistic will be involved in this tool. By using this tool, the researcher can map out the problem, and the improvement process becomes easier.

2.4.2 Histograms
A histogram is a bar chart that is used to graphically represent a group of data. To construct a histogram, the researcher needs to know the sum, mean, max value, min value, and range of the data. Then, the researcher should calculate the width of each column using the formula in equation 1.

$$Width = Range \; / \; Number \; of \; Column \quad (1)$$

2.4.3 Pareto Chart
Pareto chart is like a histogram, but this chart uses a percentage to show the importance of the data. In other words, the bar will be plot based on the order of its quantity. That is why using a Pareto chart, the researcher will be able to prioritize the problem, easier in analyzing the process, and identify the root causes. In the Pareto chart, there is a principle called the 80/20 rule. It said that 20% of the cause result in 80% of the quality problem.

2.4.4 Flowchart
A flowchart is a graphical representation that shows all the steps of a process. This chart also able to help the researcher in finding a possible problem or improvement.

2.4.5 Scatter Plots
Scatter Plot is a 2D x/y plot that shows the relationship between the independent variable (x) and dependent variable (y).

2.4.6 Run Chart
A run chart is a chart used to analyze a process according to time. It helps the researcher tracking whether the improvement has been sustained or not.

2.4.7 Control Chart
A control chart is a chart that can be used to track the output of a process and its conformance based on the company's standard. In the control chart, there are some elements, such as centerline (CL), upper control chart (UCL), and lower control chart (LCL). Equation 2, 3, and 4 is the formula of each element.

$$UCL = \mu_x + L\sigma_x \quad (2)$$
$$CL = \mu_x \quad (3)$$
$$LCL = \mu_x - L\sigma_x \quad (4)$$

Description:
μ_x: Mean of x
σ_x: Standard deviation of x
L: Distance of the control limit to the centerline
The process can be said in control when no data exceed the control limit. It also means that the process is safe and normal. If there is data that exceeds a control limit, it can be concluded that there is a problem that happens in the process. This is what will be solved by the researcher.

2.5 Multiple Linear Regression
In this paper, the data analysis method that is going to be used is multiple linear regression. The equation model of multiple linear regression is written in equation 5.

$$y = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \epsilon \quad (5)$$

Each of the symbols will stand for:
y = Productivity of the stevedoring activity
α = Constant
x_1 = CC & HMC
x_2 = Head Truck
x_3 = RTG
β_1 = Regression coefficient of the CC & HMC regression
β_2 = Regression coefficient of the Head Truck regression

β_3 = Regression coefficient of the RTG regression

Multiple linear regression analysis is used to show the linear relationship between response or predictor (Ogutende Et Al, 2018). To know that the regression fits the data, the researcher should consider the null hypothesis. H_0: The regression model does not fit the data significantly. By that, the H_1: The regression model fits the data. The null hypothesis will be rejected if the P-value is less than the level of significance. In this paper, the level of significance is 0.05.

In order to achieve the goal of this paper, researcher decide to use the concept of quality control, and multiple linear regression to figure out the relation between equipment operation time toward the queueing of the head truck. A brief explanation about container port, stevedoring activity, and time motion study also included in the literature review to help the reader understand the paper easily.

3. Method

Below is the visualization of the flow of study used in this research:

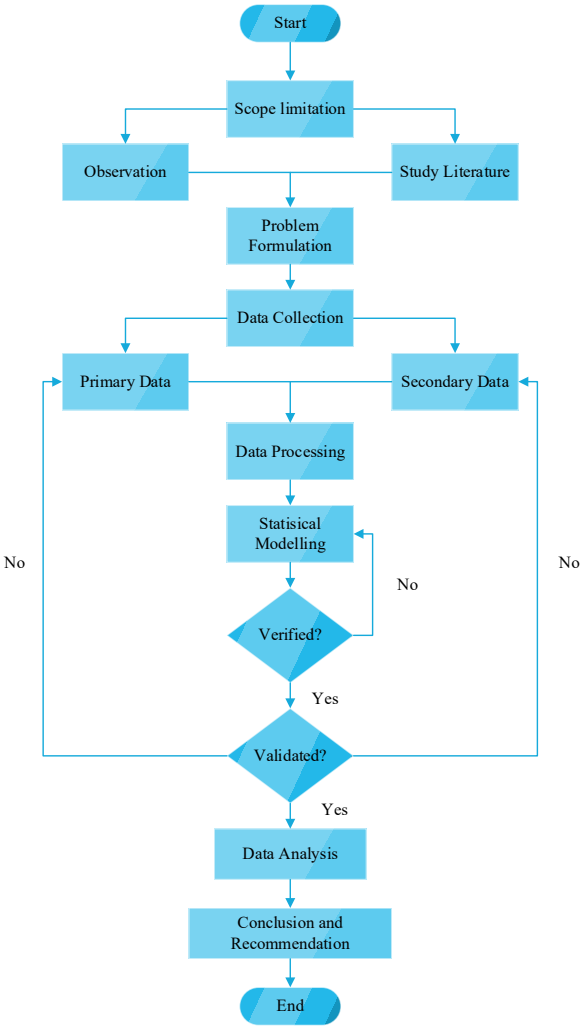

Figure 3: Study Flowchart

Industrial Engineering has so many disciplines that can be used as a topic in a study or research. That is why, to make the process of this study easier, the first step is determining the scope of the study. In this paper, the scope is related to the queueing time. This study will be focusing on the cause of the queueing time of a Head Truck in performing the stevedoring activity. In the observation stage, the activity is observing the process or system that is related to the topic

of the study. In this paper, the observation stage is done in one of the stevedoring companies in Indonesia. Some interviews and discussions will be done in this stage. It aims to find a clear description of the activity flow and some potential problems that might lead to the focus of this study. After the observation is done, the next step is gathering related information that can be used to help the author in understanding what must be done in the study.

The data collection stage was done in a specific range of time that has been proposed to the company. To achieve the objective of this study, two types of data will be used here. Those are primary data and secondary data. Primary data is any kind of information collected by the author for a specific purpose, while secondary data is data used by the author, but it was collected by someone else. The primary data in this paper will consist of some interviews between the author and the person in charge or related party of the study. The secondary data is about the raw data of the productivity of Head Truck, the productivity of RTG, the productivity of HMC, the productivity of STS, container yard layout, and Turnaround Time of the Head Truck. After the data needed is collected, the author proceed those data using the tools that have been decided. In this paper, the author decided to use Ms. Excel and Minitab as the tool or software to simulate the model.

4. Data Collection

4.1 Stevedoring Planning Concern

Every stevedoring activity is always done under the criteria of safety, effectiveness, and efficiency. Before a vessel mooring in a quay, this vessel will be guided by the pilot boat and the tugboat. The pilot boat will give a suggestion and information related to the condition of the port, the water condition, and the shipping lane so that the shipping navigation can be done safely. The tugboat will play a role in push, pull, hold, escort, and assist the vessel in the shipping lane. However, before doing the stevedoring activity, three concerns should be considered by PT X, which are berth planning concern, yard planning concern, vessel planning.

4.1.1 Berth Planning Concern

In Figure 4 Kade Coordinate there is a Kade coordinate used by PT X in planning the berthing of the vessel. There are some concerns and considerations to plan the vessel's berthing place. First, a vessel with a length overall (LOA) > 180 meters, equipped with a Ship Crane, the activity is only unloading, and having 20’ boxes to be unloaded near the Ship Crane will be berthed in the south Kade (209/210) to anticipate the 20’ boxes can be unloaded by the HMC. Second, a vessel with LOA < 120 meter, has loading and unloading activity, the total boxes are more than 200, and the range of time between the berthing and departing +/- 8 hours will be berthed in the south Kade (209/210) with the combination of CC and HMC to support the loading and unloading activity. Third, the clearance distance between the vessels is 10% from the LOA and a minimum of 15 meters. If there are two vessel berths at the same time, the maximum stern of the ship will be regulated in the KDM 760 to minimize the back reach of the PT X crane and other cranes. Then, if there are three-vessel berthing at the same time, the earliest vessel that comes will be berthed in the Kade 209 or 211.

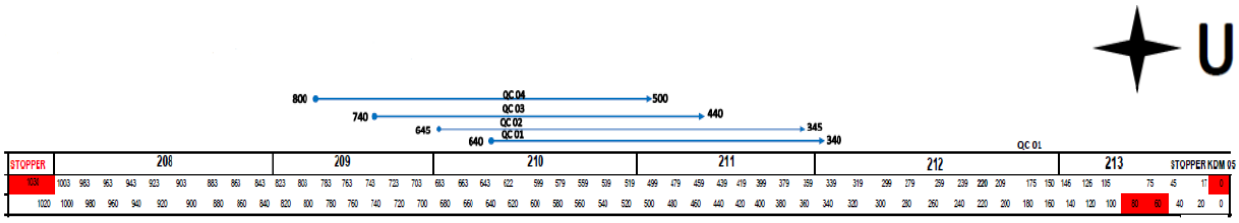

Figure 4: Kade Coordinate

4.1.2 Yard Planning Concern

To stack the container, PT X has two yards which are *Lini* 1 (213) and *Lini* 2 (217/218). In the 213 fields, there are six RTG, which are RTG01, RTG02, RTG05, RTG06, RTG07, and RTG08. In the 217/218 field, there are four types of equipment which are RTG03, RTG04, RS TPK, and RTG TPK. In the yard planning (figure 5), all the boxes will be maximized to be placed in the 213 fields based on the route. To optimize the utilization of the RTG owned by PT

X, the unloading buffer stack will be provided in the 213 fields. To anticipate the clashing, the yard planner will relocate the container to another block by considering the RTG support and the potential cargo that will stack.

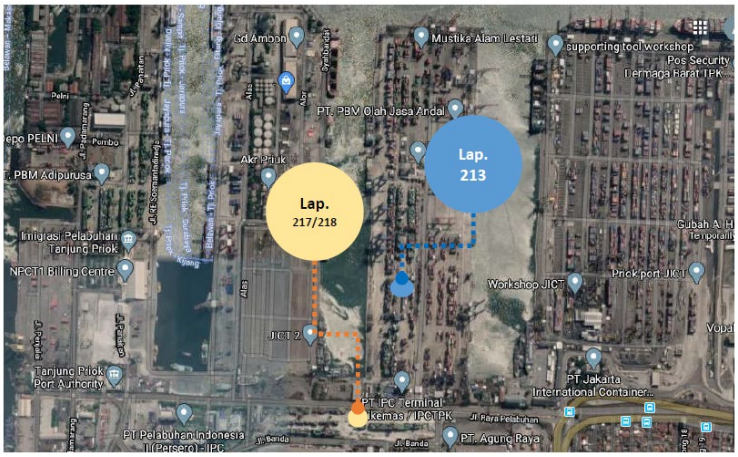

Figure 5: PT X's Yard Map (Perencanaan Bongkar Muat PT X)

4.1.3 Vessel Planning Concern

Vessel planning concerns mostly will be related to document. First, checking the unloaded container and make sure the ESY is already proposed except for the transshipment boxes, Dangerous Goods (DG) boxes, reefer empty boxes, and Over Dimension (OVD) that needs a supporting device. Second, make sure the permission letter for the DG is already sent to the shipping company. Third, print and distribute the discharge list and load list from the shipping company. Fourth, prepare the manual Bayplan following the Bayplan of the vessel that being working on. Fifth, make sure the realization of the tally sheet is matching with the discharge list or the load list of the vessel. Sixth, make sure to record the up normal or damaged container in the EIR B/M. Last, create the Statement of Fact (SOF) following the realization of the loading and unloading activity in the field.

4.2 Control Chart

To evaluate the problem, the researcher decides to take the operation time of each activity during the stevedoring activity. The collected data is coming from the haulage, and the performance done by the CC, HMC, and RTG. Figure 6 is the control chart for the haulage done by the Head Truck. From the data gathered, it can be known that the UCL for this chart is 27.06 and the LCL is -5.26. After the data plotted in the chart, no data exceeds the LCL. However, three data exceed the UCL which are 40.1, 39.24, and 30.53. This data shows that there is a problem that happens during the haulage that makes the time taken by the truck exceed the limit.

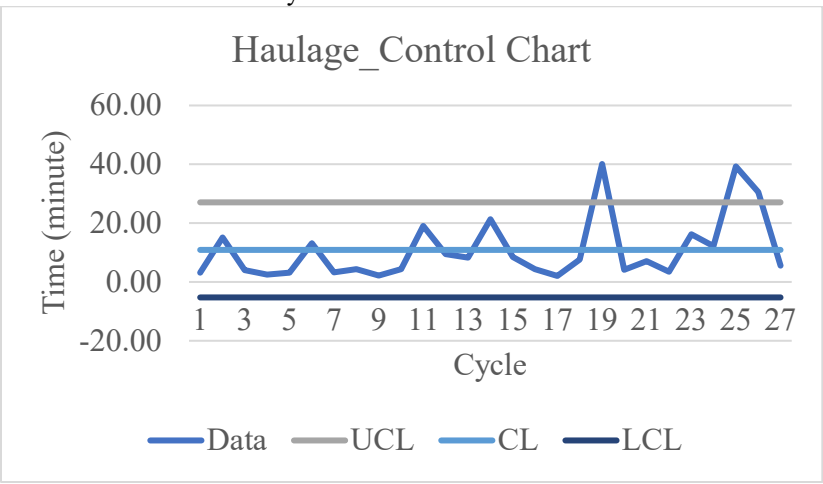

Figure 6: Haulage Control Chart

Another data collected is the LOLO time needed by the RTG in moving the container from the head truck to the container yard or vice versa. The control chart for the LOLO RTG in figure 7 is quite interesting. It is because there is data that exceeds the LCL, which is 0.17, while the LCL for this chart is 0.32. It is good for the overall time needed because it can make the process a bit faster. Unfortunately, even if there is data that indicates the process can be done faster, there are also some data that exceed the UCL, which are 3.3, 3.39, and 3.5. The UCL for this data is 3.25.

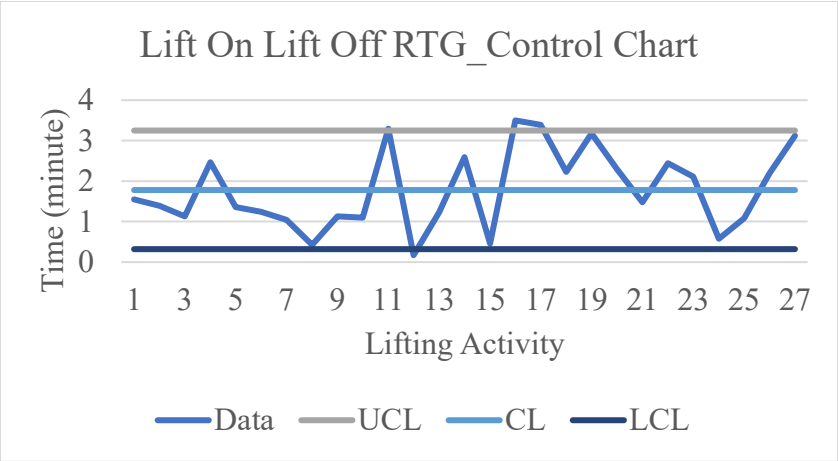

Figure 7: Lift On Lift Off RTG Control Chart

The other data collected is the time to lift on and lift off by the Container Crane. In the control chart in figure 8, there is one data that exceeds the upper control limit (UCL). The value of the UCL is 6.34 and the value of LCL is -1.26. Whereas the value of the exceeded data is 10.17.

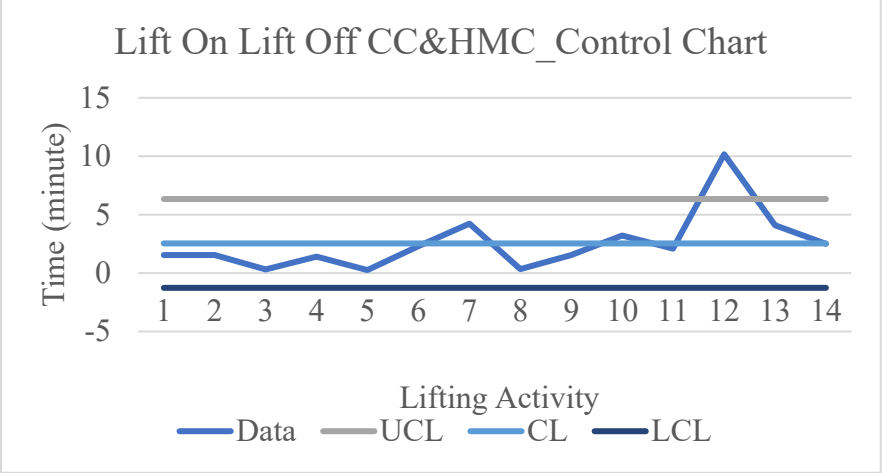

Figure 8: Lift On Lift Off CC&HMC Control Chart

5. Results and Discussion

5.1 Fishbone Diagram

After plotting the data using the control chart, figure 9 is the fishbone diagram to help the researcher in mapping the cause of the problem.

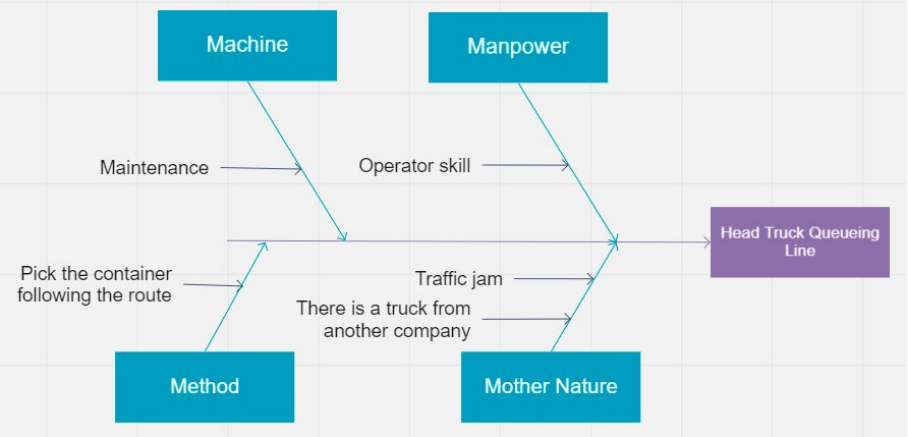

Figure 9: Fishbone diagram

On the fishbone diagram in figure 9, it can be seen there are four sources of the problem that can cause a queue for the Head Truck, which is classified into 4 out of 6 M in the fishbone diagram. First, from mother nature or the environment, there is a traffic jam and there is another truck from another company that disturbs the flow of the Head Truck. Second, from the method, there is a container from the prioritized route that will affect the time needed by the operator to become longer. Third, in the manpower category, the skill of the operator also has an important role in causing the queue of the Head Truck. Fourth, from the machine side, periodic maintenance also gives an impact on the performance of the equipment. Looking at the cause of the problem, it is divided into two, which are the cause that coming from the internal and the external. For the external factor, such as the traffic jam, it is difficult to be controlled. However, we can control the internal factor, such as the operator skill, maintenance, and container placement. As time goes by, the operator skill will be improved. The company can help to make this improvement process become faster by conducting a training program for the operator. For the maintenance, the planner of the operation needs to have a good plan so that everything in the field is synchronized and there would be no problem. For the container placement, the company can discuss with another port to plan the container placed in the ship, so that the unloading activity in PT X becomes faster.

5.2 Multiple Linear Regression Analysis

To know the relationship of the independent variable with the dependent variable, regression analysis is one of the methods that can be used. Equation 6 is the result after doing a multiple linear regression analysis using the Minitab:

Regression Equation

$$Y = 1992 + 0.314\,x_1 - 1.007\,x_2 - 0.127\,x_3 \quad (6)$$

From the regression equation in equation 6, it can be known that from the three independent variables, only one variable has a positive relationship, which is x_1. It means that every 1% improvement of x_1, the value of y will be increase as much as the number of the coefficient of the x_1, which is 0.314 with the assumption the value of the other variable is constant. For a variable that has a negative relationship, x_2 and x_3, every 1% increase of x_2 will decrease the value of the productivity around 1.007. For x_3, every 1% increase of this variable, will decrease the productivity until 0.127.

Model Summary

Table 1: Model Summary Table

S	R-sq	R-sq(adj)	R-sq(pred)
893.736	16.15%	6.09%	0.00%

In the model summary in table 1, the number shows the correlation or the variable and the regression model. In this paper, the result is not so good because the number of correlation coefficients (R) is small, only 16%. It means the correlation between the time needed by CC, HMC, RTG, and Head Truck with the productivity of the stevedoring

activity is weak. It can be seen the percentage of the determination coefficient only 6.09%. It means that it is only 6.09% of the stevedoring productivity can be seen from the operation time of the stevedoring equipment. The rest 93.91% variable is outside this research.

Analysis of Variance

Table 2: ANOVA Table

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	3845604	1281868	1.60	0.213
X1	1	1128301	1128301	1.41	0.246
X2	1	3487667	3487667	4.37	0.047
X3	1	40088	40088	0.05	0.825
Error	25	19969119	798765		
Total	28	23814723			

The ANOVA table (table 2) gives the information that in the Regression part, the P-Value is equal to 0.213 which is higher than the point of significance that is 0.05. It means the null hypothesis fails to be rejected. Then, among the three variables, the only variable that has P-value less than 0.05 is x_2. It means, x_2 has a significant impact on the productivity of the stevedoring activity.

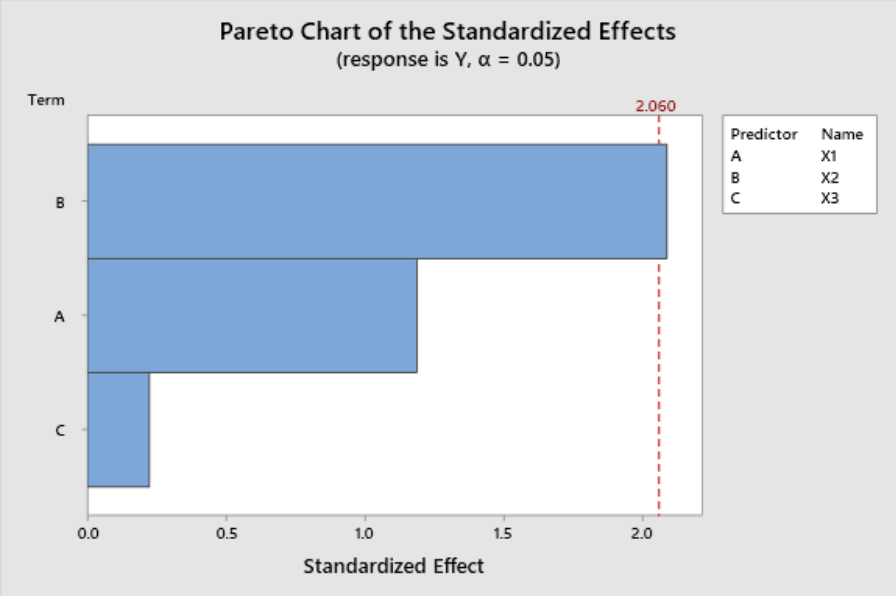

Figure 10: Pareto Chart od the Observation

The Pareto Chart in figure 10 shown that the variable that has the highest standardized effect is variable x_2 or the Head Truck. So, it can be said that Head Truck will give a significant impact on productivity.

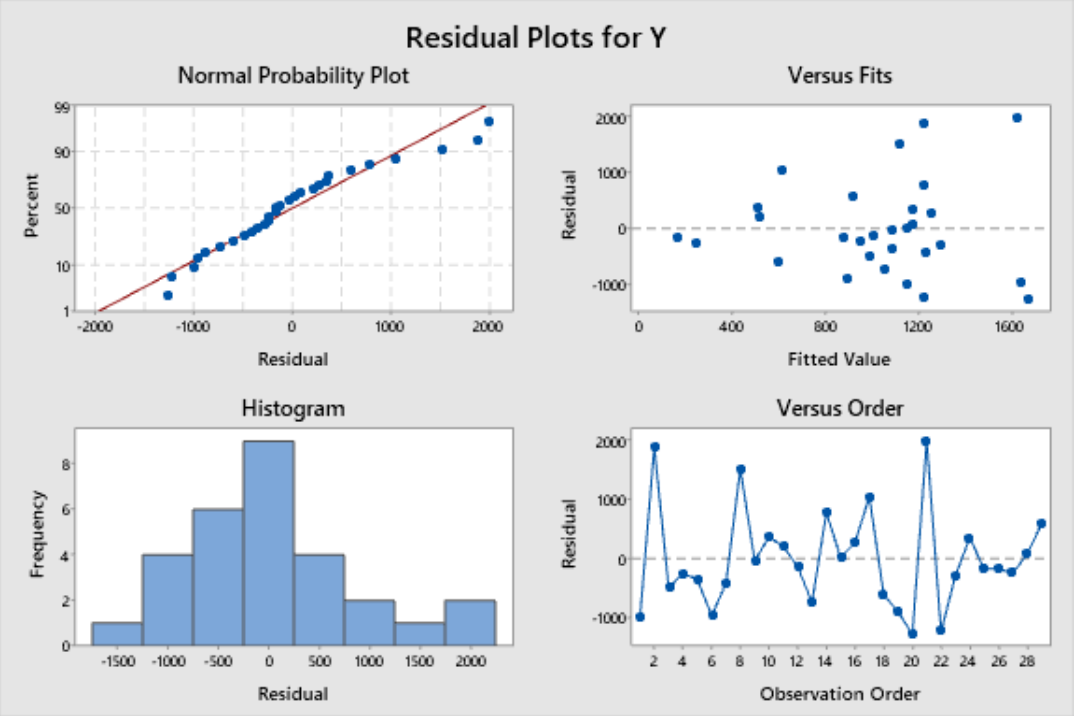

Figure 11: Residual Plot for the Observation Data

In the Residual Plot result (figure 11), the data used for the regression model can be evaluated. The graph for the Normal Probability Plot shows that the data is normally distributed because most of the data is plotted near the diagonal line. It means that this regression model is good. Then, the versus fit shows that there is no heteroskedasticity or the error in the data used. There is no specific pattern in the graph. So, it indicates that the data is good. The histogram also shows that the data has a normal distribution with a bit skewed to the left. Last, the Versus Order plot shows there is no specific pattern created. It means that the data used is residual independent.

6. Conclusion

Based on the data analysis and findings, below is the conclusion that can be derived from this paper:

1. From the control chart constructed from the data of TRT, Haulage, LOLO RTG, and LOLO CC, it can be said that some data exceed the upper control limit (UCL). Since the data used is the time needed by the equipment to complete the task, when there is data that exceeds the UCL, it means the related equipment needs a longer time to do the activity. Exceeding a control limit can also be concluded that there is a problem that happens during the operations.
2. The fishbone diagram shows that there are two types of causes which are internal and external. The internal cause is from the operator skill, maintenance, and container placement. The external cause is the traffic jam.
3. The linear regression equation said that the CC & HMC has a positive significant influence on productivity. From the equation, it can be concluded that every increase of the CC & HMC will contribute to productivity by 0.314.
4. The Analysis of Variance (ANOVA) table shows that the variable that has the most significant impact in the model is the Head Truck because the P-value of this variable is less than 0.05.
5. Based on the value in the model summary, the model used in this paper is not the best one. It is because the correlation between the operation time spent by the equipment with the productivity is only 16%. The determination coefficient also only 6.09%, which means that there are 93.91% of factors of productivity have not covered in this paper yet. By that, it can be concluded that the equipment operation time only contributes around 6.09% to the queueing problem that happens in the container yard.

Recommendation

For future research recommendations, the researcher of this paper highly suggests that the researcher can spend a long time during the observation time and data collection stage than this paper. This is very important because it will significantly impact the result of the experiment. Another recommendation is it will be better to find a reference from a different paper so that the resource to construct the paper is diverse. Also, it is highly recommended to try and test the model of the experiment repeatedly and using different tools to ensure the accuracy of the result.

References

ASQ, A. S. (2021, April 7). About Flowchart. Diambil kembali dari LEARN ABOUT QUALITY: https://asq.org/quality-resources/flowchart

Ananda et al. (2015). Implant Analysis on the Lumbar-Sacrum Vertebrae Using Finite Element Method. 10.1007/978-981-10-0812-2.

Komunikasi, B. (2018, Agustus 10). Menko Maritim Luncurkan Data Rujukan Wilayah Kelautan Indonesia. Diambil kembali dari KEMENTRIAN KOORDINATOR BIDANG KEMARITIMAN DAN INVESTASI: https://maritim.go.id/menko-maritim-luncurkan-data-rujukan-wilayah-kelautan-indonesia/

Mardiko, I. A., & Sulistyowati. (2020). Optimasi Kapasitas Armada Dengan Menggunakan Metode Linear Programming. INTEGER: Journal of Information Technology, 49-55.

Marsudi, M., & Arifin, J. (2019). KAJIAN OPERASIONAL TERMINAL PETI KEMAS PELABUHAN LAUT MENGGUNAKAN SOFTWARE ARENA. Prosiding Hasil-Hasil Penelitian tahun 2019 Dosen-Dosen Universitas Islam Kalimantan, 463-469.

Montgomery, D. C. (2013). The Meaning of Quality and Quality Improvement. United States of America: John Wiley & Sons, Inc.

Nahmias, S., & Olsen, T. L. (2015). Forecasting. Dalam S. Nahmias, & T. L. Olsen, Production and Operation Analysis (hal. 56). Long Grove, Illinois: Waveland Press, Inc.

Oguntende, P. E., Okagblue, H. I., Oguntende, O. A., Opanuga, A. A., & Oluwatunde, S. J. (2018). Analysis of the inter-relationship between students' first year results and their final graduating grades. International Journal of Advanced and Applied Sciences, 1-6. doi:https://doi.org/10.21833/ijaas.2018.10.001

Quality, A. S. (2021, April 7). Quality Assurance & Quality Control. Diambil kembali dari LEARN ABOUT QUALITY: https://asq.org/quality-resources/quality-assurance-vs-control

Rahman, A. T., Sarno, R., & Efendi, Y. A. (2018). Goal Programming to Optimize Time and Cost for each Activity in Port Container Handling. International Conference on Information and Communications Technology (ICOIACT), 866-871.

Sha, M., Zhang, T., Lan, Y., Zhou, X., Qin, T., Yu, D., & Chen, K. (2016). Scheduling Optimization of Yard Cranes with Minimal Energy Consumption at Container Terminal. Computer & Industrial Engineering, 1-26. doi:http://dx.doi.org/10.1016/j.cie.2016.03.022

Simwell. (2020, November 22). Why choose Arena. Diambil kembali dari SIMWELL CONSULTING & TECHNOLOGIES INC.: https://www.simwell.ca/en/arena-simulation/products/

Sundari, A. S., Surjandari, I., & Rachman, A. (2017). OPTIMISASI BIAYA OPERASI PENGALOKASIAN TRUK-SEWA ANGKUTAN OLAHAN MINYAK KELAPA SAWIT. Jurnal Sistem Industri, 11, 59-68.

Trust, E. L. (2021, April 7). Run Chart. Diambil kembali dari Quality Improvement: https://qi.elft.nhs.uk/resource/run-charts/

Wirjodirjo, B., Budianto, A. G., Pujawan, I. N., & Maflahah, I. (2020). Container Yard Planning Layout Model Considering Demand and Lost Sale Container. Association for Computing Machinery, 314-318. doi:10.1145/3396743.3396753

Yazdi, P. G., Azizi, A., & Hashemipour, M. (2018). An Empirical Investigation of the Relationship between Overall Equipment Efficiency (OEE) and Manufacturing Sustainability in Industry 4.0 with Time Study Approach. Sustainability, 1-28. doi:10.3390/su10093031

Zhou, C., Lee, B. K., & Li, H. (2020). Integrated optimization on yard crane scheduling and vehicle positioning at container yards. Transportation Research Part E, 1-20. doi:10.1016/j.tre.2020.101966

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