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Optimizing Distribution Time Performance: Simulation-based Study of Loading and Unloading Operations at New Priok Container Terminal 1, Jakarta, using System Layout Planning Method and Anylogic Software

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Containers have become a primary choice for shipping logistics and cargo in global trade. According to statistical data, more than 90% of international shipments are transported via sea. As a maritime country with two-thirds of its territory consisting of water, Indonesia naturally leverages this mode of transport due to its various advantages. One of the efforts to harness sea transportation is providing international-standard container terminals to facilitate smooth trading activities in Indonesia, particularly in Jakarta, the busiest trade and cargo shipping center.

Despite being the 23rd busiest country in port activities worldwide, Indonesia ranks only 51st out of 160 countries in the international ports' Logistic Performance Index (LPI). One of the contributing factors to the decline in Jakarta's port ranking is the timeliness in the loading and unloading processes for import and export activities.

The author has designed a simulation to address the optimization challenges in the loading and unloading operations at the New Priok Container Terminal in Jakarta. This simulation aims to optimize the layout using the System Layout Planning (SLP) method and analyze it using AnyLogic software. The goal is to improve timeliness, enhance the LPI rating, and foster trust in the services provided at Jakarta's ports. Ultimately, the recommended layout presented in this thesis can be utilized to construct NPCT 2 and 3, currently under development, to implement the SLP method.

Keywords: Containers, Loading and unloading, Anylogic, System Layout Planning (SLP), New Priok Container Terminal (NPCT)

INTRODUCTION

Indonesia holds a significant international position, particularly in the economic and military realms(Amar, 2019). Its strategic location is a gateway for economic development, providing extensive access to global markets. Consequently, logistics processes in Indonesia, especially those related to waterway shipping, play a crucial role in facilitating domestic and international trade routes.

Currently, the loading and unloading operations at Tanjung Priok Terminal lack an optimized system, resulting in a lower ranking in the Logistic Performance Index (LPI)(The World Bank, 2023) compared to smaller Southeast Asian countries such as Singapore, Malaysia, Thailand, and Vietnam. Recognizing the need for improvement, the researcher aims to conduct an analysis using

AnyLogic simulation to explore the potential for maximizing the existing terminals in Indonesia.

The study focuses on the vital aspects of loading and unloading, which are integral to System Layout Planning. The objective is to enhance productivity, reduce costs, and minimize the required time by utilizing resources efficiently. Applying the System Layout Planning method in simulating loading and unloading activities revolves around designing and improving material handling systems, including optimizing loading and unloading systems and layouts. Software tools(Verawati et al., 2022), such as AnyLogic, play a crucial role in the transportation industry, allowing for detailed modeling, analysis, and optimization of logistics systems(Kumar & Naga Malleswari, 2022).

AnyLogic, a versatile computer system for program creation and simulations, enables users to combine multiple techniques to develop simulations. This complexity and flexibility make AnyLogic suitable for various manufacturing processes and allow the interrelated nature of System Layout Planning(Karpov, 2004) and loading and unloading simulations. Through the utilization of AnyLogic software, detailed modeling, analysis, and optimization of logistics systems can be conducted, thus improving the efficiency of logistics operations.

In this paper, the researcher aims to leverage AnyLogic simulation to analyze and maximize the potential of existing terminals in Indonesia.

LITERATURE REVIEW

In this study, a literature review is needed to gain an in-depth understanding of a strong foundation of knowledge in two major topics: System Layout Planning

and Logistics System Simulation. With a literature review, the author can study various strategies in System Layout Planning, such as modeling techniques, optimization algorithms, and analytical methods to plan efficient layouts in production or operational environments, which will then be simulated in AnyLogic software to optimize existing layouts.

System Layout Planning

Systematic Layout Planning is an organized way to conduct layout planning. It consists of a framework of phases, a pattern of procedures, and a set of conventions for identifying, rating, and visualizing the elements and areas involved in planning a layout (Muther & Hales, 2015).

System Layout Planning has 4 phases (Muther & Hales, 2015). Phase I is Location, this location determines the location of the area to be laid out. Phase II is General Overall Layout.

Phase II: General Overall Layout establishes the basic arrangement and size of major areas in the layout. Phase III is Detailed Layout Plans specify the precise placement of machinery and equipment through electronic or physical drawings. And phase IV is Installation involves planning, seeking approval, and executing the physical moves required for implementing the layout, including calculating associated costs.

In addition, system layout planning also has a pattern. The system layout planning pattern is an approach that has structure and is systematic for stretching, optimizing efficiency, productivity, and security(Mokhtar, S. S. M., Yusof, S. M., & Yusoff, 2021). This pattern is made of three basic factors, namely: Relationship, Space, and Adjustment.

In system layout planning, there is a way to unlock layout problems. Two important

points for unlocking this layout problem are Product or material and Quantity or volume. For a more detailed (Muther & Hales, 2015), explain it as P, Q, R, S, T. Explanation of this P, Q, R, S, T are:

1. P – Product: Include goods, raw materials, finished goods, and service items.

2. Q – Quantity: refers to the number of goods or services produced or used

3. R – Routing: defines the process, sequence of operations, and equipment.

4. S – Supporting: includes maintenance, machine repair, and facilities.

5. T – Time: include when the operational schedule of the planned layout.

Relationship Chart in System Layout Planning are activities that have a relationship with one another and the best way to integrate supporting services with the operating or producing departments and of planning the arrangement of office or service areas having little or no flow of

materials and to make it easier to do by using flow and activity relationship diagram (FARD). FARD can be done through color coding and shaping code.

The Basic Steps for Discrete Event Simulation

The basic steps for discrete event simulation are to describe the problem and identify the simulation system to be worked on, develop a contextual model, run the simulation, build the simulation, collect input data, and then generate the result from the simulation.

A discrete system is one in which the state variable(s) change only at a discrete set of points in time. It isn't easy to use mathematical equation to show the mathematical model of a discrete system, and the model(Ping, 2018) is as follow:

$$M = (T, U, X, Y, \Omega, \lambda)$$

Among them: T – times basis; U – input variables; X – state variable; Y – output variable; Ω – state transition function, and λ – state space.

There are many basic steps for discrete event simulation to explain problems and identify simulations. Queuing systems and inventory systems are examples given in this paper.

A queuing system is a collection of resources that customers use to complete some services and consist of a waiting line and a service facility, and customers arrive randomly and are served according to predefined rules(Fujimoto, 2018; Mitra, 2018). The queuing system can be described using the number of temporary entities, arrival mode, system capacity, and Queueing rules (Ping, 2018)
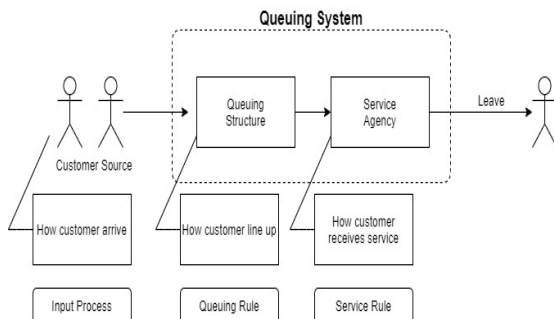

Figure 1 Describe the meaning of the Queuing system.

The inventory system is a common class of discrete event systems and is highly representative. In the inventory system, customer demand and orders (stock replenishment) continue changing inventories dynamically.
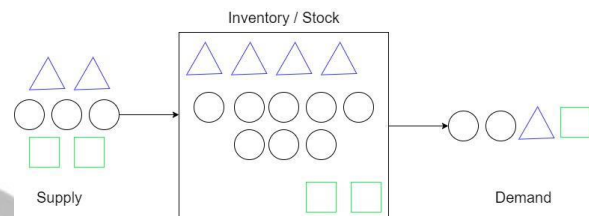

Figure 2 Inventory System Model

The basic parts constitute the Inventory system:

1. Supply mode refers to quantity, time, and characteristics of supply.

2. Demand mode refers to the quantity, frequency, and time the customer requires for the goods to go out.

3. Cost price refers to the price to pay when inventory is short or surplus.

RESEARCH METHODOLOGY

The analysis of the loading and unloading using the SLP Method and AnyLogic software simulation, the area used for this case study is New Priok Container Terminal, Tanjung Priok. This research aims to study the perspective to find solutions, improve, and make loading and unloading in New Priok Container Terminal efficient. This study has been done by analyzing data from IPC (Indonesia Terminal Corporation), a government agency that oversees all Terminals throughout Indonesia. Data were analyzed by using queuing and inventory system calculation and made analysis using AnyLogic Software simulation.
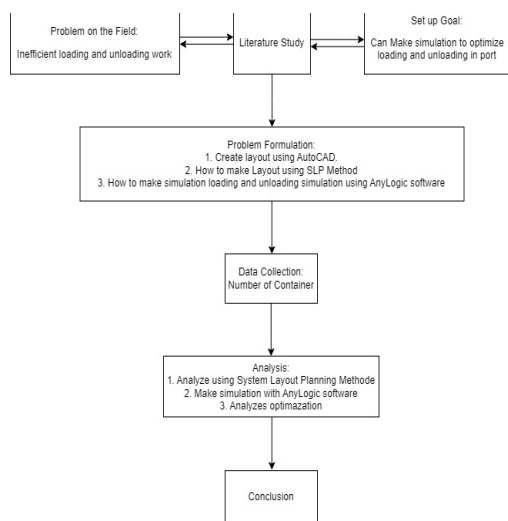

Figure 3 Research Methodology

ANALYSIS

Terminal Port Information

Port or terminal information includes the name, location, infrastructure, and available equipment. The following is the Terminal/Port Information owned by New Priok Container Terminal 1, Jakarta (New Priok Container Terminal 1, n.d.-b)

Table 1 Termina Information

Information		Unit
Berth Length	850	m
Max Draft	-16	m
Hectare per Quay Crane	4	
Capacity	1.5	mio TEU
Facility Space	32	hectare

Layout Sketch NPCT1 using AutoCAD

Making layout sketches on the Layout

Planning System using AutoCAD Software in this research is to facilitate accurate and effective layout design. AutoCAD can also visualize drawings clearly and easily understood so that it is possible to determine the right equipment and furniture to maximize the use of space(Ayers, D., Maynes, T., & Schneider, 2007; Rao & & N. M. V. R. Prasad, 2014).
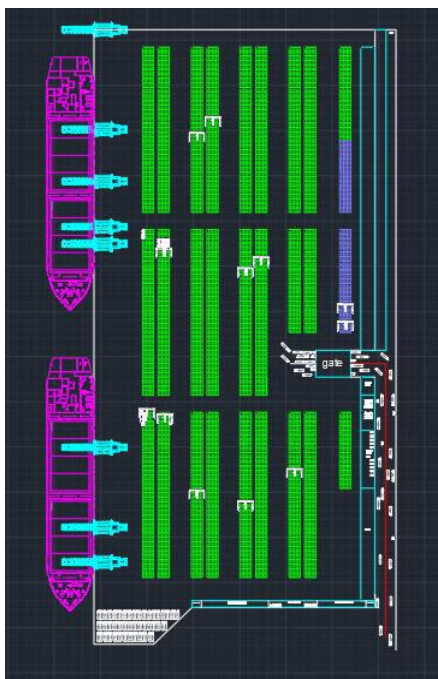

Figure 4 Original Layout Sketch Using

AutoCAD.

Loading and Unloading activities at New

Priok Container Terminal, Jakarta, and

breakdown determine P-Q-R-S-T requirements.

Table 2 Product and Quantity at NPCT1

Product (P)	Quantity (Q)
Container Yard Ground slot	5400
Reefer Ground Slot (5-tier capable)	196
DG Ground Slot	80

The following is the container quantity at New Priok Container Terminal 1 based on surveys and IPC - Indonesia Port Corporation 2021 information.

Table 3 Actual Data Each Day from IPC

2021

Product (P)	Quantity (Q)
Loading Box	336
Discharge Box	234
Transshipment Loading Box	2
Transshipment Discharge Box	2

Routing at New Priok Container Terminal 1, Jakarta, can be divided into two processes (New Priok Container Terminal 1, n.d.-a) Import and Export Operations.
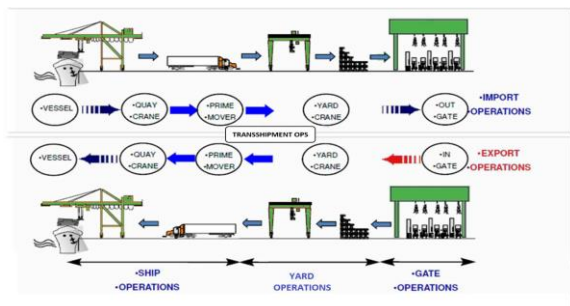

Figure 5 Import and Export Operation at

NPCT

Supporting Services are the utilities, auxiliaries, and related activities or functions that must be provided in the area to be laid out so that it will function effectively.

Table 4 Equipment at NPCT 1

Information	Quantity (Q)
Quay Cranes	8
Twin-lift Capable Crane	8
e-RTG	24
Prime Mover	44

Time involves when products will be produced, or the planned layout will operate. Activities at NPCT1 are 24 hours a day for seven days or 24/7, which means the activities at NPCt never stop and will be an increase in major holidays in Indonesia, such as Eid (Muslim Holiday), Christmas, New Year, and Chinese New Year.

The following is the number of incoming and outgoing vehicles at NPCT 1 based on surveys and information from JICA (Japan International Cooperation Agency, 2019)

Table 5Number of Vehicles In and Out at

NPCT1

Time	Vehicle In	Vehicle Out
06. 00 – 10. 00	451	290
10. 00 – 16. 00	549	405

16.00 – 20.00	351	175
20.00 – 06.00	215	270
TOTAL VEHICLE	**1,566**	**1,140**

4. Prime Mover

5. Bert/Vessel/Quay Yard

Loading and Unloading activities at New Priok Container Terminal, Jakarta, and breaking down The Relationship Chart

The division of names in the system layout planning process can make the process smoother and more efficient, saving time and reducing errors (Muther & Hales, 2015)

Table 6 Area or Department Name

Area Name
1. Gate and Office
2. Discharge Container Area
3. Loading Container Area

After knowing the area name, we can then find out about the explanation of the activities in NPCT1, namely:

1. Import Activities

   4 → 5: Prime mover goes to the Berth area and moves the container from Vessel to Container Yard for doing Discharge (prime mover movement counting as container discharger quantity);

   5 → 2: Container from the vessel using Prime Mover goes to Discharge Container Area (Data Discharge Container). Total Discharge Box Container each Day + Total Discharge Box TS each day = 234+2 = 236

   2→4: Prime mover comeback to Prime mover area after doing offloading (prime mover movement

counting as container discharge quantity)

2 → 1: Vehicle truck carries the container outside the area port (Data Vehicle out)

2. Export Activities

1 → 3: A truck vehicle with a container comes and heads toward the Loading Area (Data Vehicle in)

4 → 3: Prime mover goes to Loading container area for doing mounting (prime mover movement counting as container loading quantity)

3 → 5: Prime mover move from Loading container area and brings the container from Container Yard to the Berth area/vessel (container quantity counting as Loading). Total Loading Box Container each Day + Total Loading Box TS each day = 336+2 = 338

5 → 4 : Prime mover comeback to Prime mover area after doing Loading (prime mover movement counting as

container loading quantity)

Table 7 Form for the Activity Relationship Chart

| From/To	1	2	3	4	5
1	█	0	1566	0	0
2	1140	█	0	236	0
3	0	0	█	0	338
4	0	0	338	█	236
5	0	236	0	338	█

From the Activity Relationship Chart, we know the highest score is 1566. For the activity relationship chart change, we need to divide by 4 to obtain four ranges of material flow values.

$$Range = \frac{High\ score}{4} = \frac{1566}{4} = 391.5$$

Table 8 Range from Table Activity Relationship Chart

	Range
A	1174.5 - 1566
E	783 – 1174.5
I	391.5 - 783
O	1-391.5
U	0

3 ↔ 5	O	Ordinary	Blue	/
4 ↔ 5	I	Important	Green	//
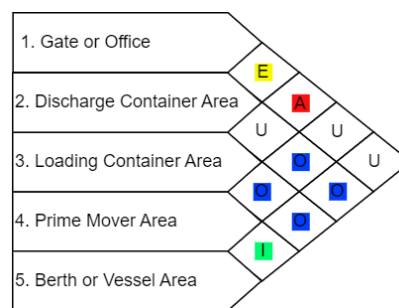
Flow and Activity Relationship diagrams can explain diagramming with the symbol, colors, and shapes.

Figure 6 Activity Relationship Chart with color

Table 9 Coding for Activity Relationship Chart

Activity Relationship chart with line

From /to	Range	Closeness Rating	Color Code	Number of Lines
1 ↔ 2	E	Especially Important	Yellow	///
1 ↔ 3	A	Absolutely Necessary	Red	////
1 ↔ 4	U	Unimportant	Uncolored	
1 ↔ 5	U	Unimportant	Uncolored	
2 ↔ 3	U	Unimportant	Uncolored	
2 ↔ 4	O	Ordinary	Blue	/
2 ↔ 5	O	Ordinary	Blue	/
3 ↔ 4	O	Ordinary	Blue	/
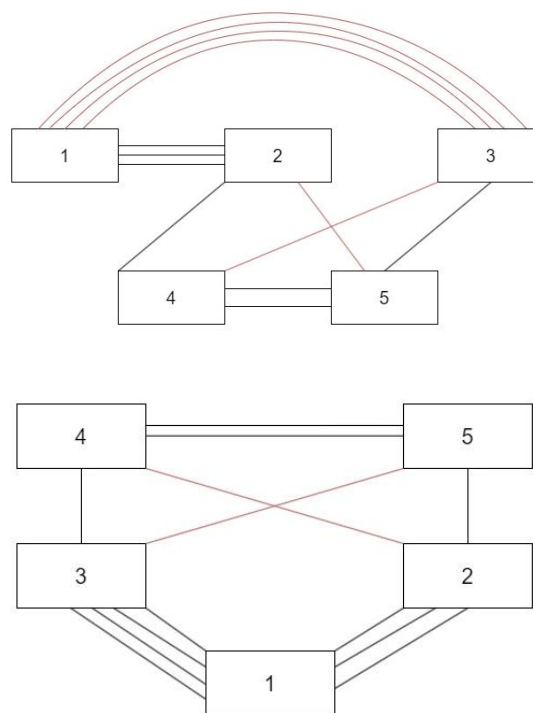
Figure 7Activity Relationship Chart with the

line before SLP analysis

In layout designs, non-adjacent loads may result in delays, inefficient movement, or non-optimal use of resources. If there are activities that have high attachment or dependence, but there are significant non-adjacent loads, then this can affect and hinder work and cause excess time and costs. As an alternative to optimal layout planning, directly related activities can be placed close together and do not cross each other with other activities so that work will run smoothly and coordination or communication between departments becomes easier. This can increase productivity in terms of time and the efficient use of resources.
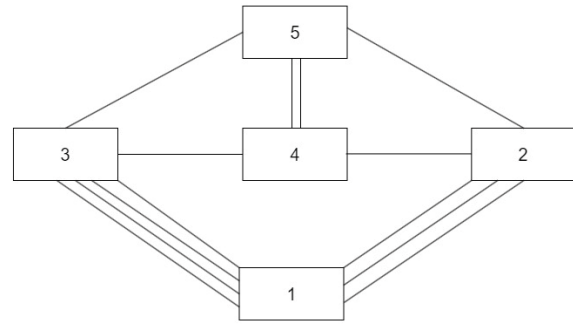
Figure 8 Activity Relationship Chart with

line after SLP analysis

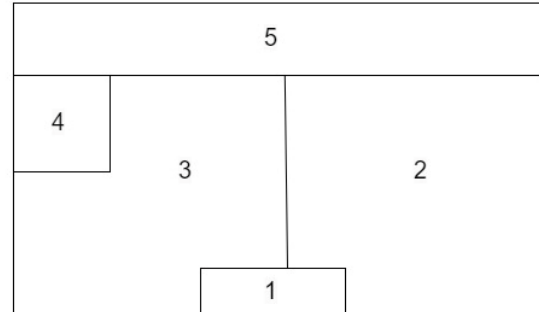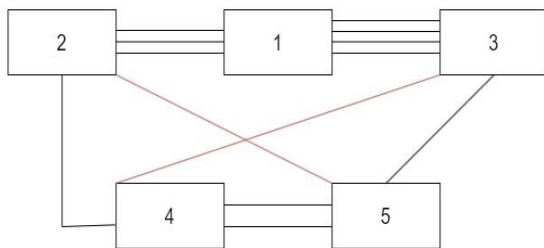Activity Relationship Chart with Shape/

Develop Layout

Figure 9 Layout Before Planning

In system layout planning, the term "Develop Layout" refers to designing and creating an efficient arrangement that involves determining and optimizing the configuration of various components to support the

effectiveness of activities(Industrial Engineering and Manufacturing, 2022). The purpose of the Develop layout in the layout planning system is to improve overall system performance to optimize production. After doing the analysis, the Layout developed in this study can be seen in Figure 10. Here we change the layout of the Prime Mover area to be in the middle according to the analysis.
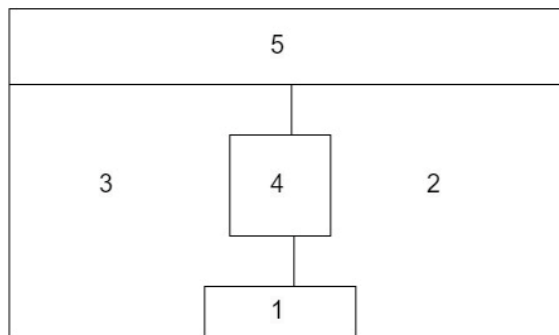
simulation approach for various industries, such as logistics and manufacturing(Anakuzina, L., Gracheva, T., & Silaeva, 2017). This thesis uses AnyLogic Software version AnyLogic 8.8.3 Personal Learning Edition.
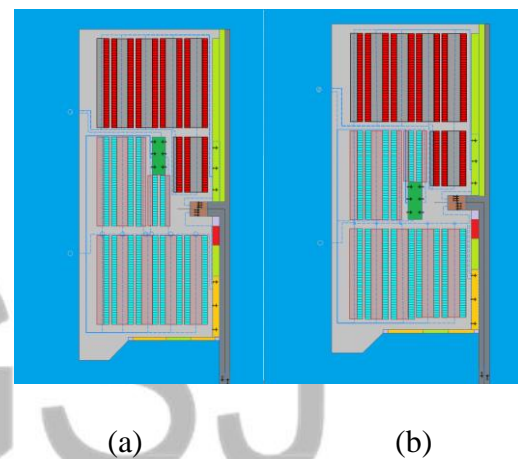

(a)   (b)

Figure 11 Layout model (a) 1 and (b) 2 after

SLP analysis

Figure 10 Develop Layout After Planning

AnyLogic Simulation

AnyLogic Software in simulation has many advantages for analyzing very complex systems. AnyLogic provides a flexible modeling

A flowchart created in AnyLogic is by the Queueing system described in Chapter 2 previously to present this queuing system. The flowchart in the simulation will have a queuing structure and service agency. For the queuing structure, Export and Import trucks will wait in line while waiting for the Gate

Area (Service Area) queue.

Figure 12 Queueing System Flowchart

The simulation results show that there is no queue that occurs in the Gate Area, both in the original layout and the layout that has been made.

Table 10 Waiting timetable for Export and Import trucks

Name	Waiting Time
TruckExport	0.134
TruckImport	0.133

This table implements the simulation results that successfully overcome the queuing problem at the gate area so that there is no significant buildup of export and import trucks that have to wait to leave or enter from the terminal area.

In addition to the queuing system, this simulation also includes an inventory system aiming to optimize loading and unloading activities that occur in the terminal area.
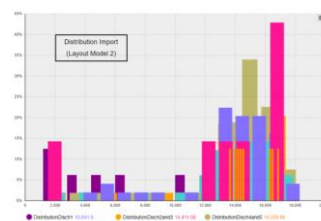

Figure 13 Inventory System Flowchart

The histogram of the analysis results from AnyLogic shows that the time distribution for loading and unloading activities on the original layout has the highest peak in the longest period. This indicates that several parts or processes take longer to complete the activities.
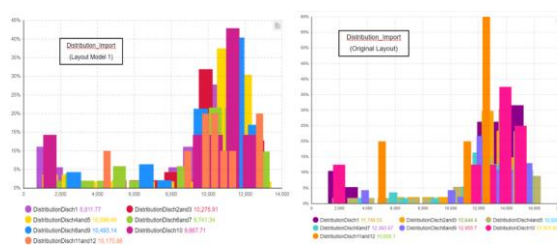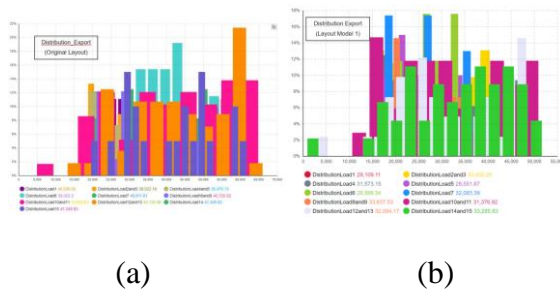

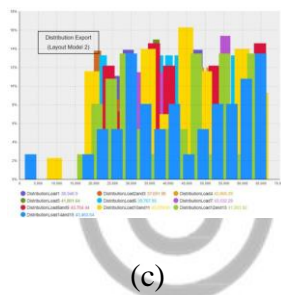(a)   (b)

(c)

Figure 14 Distribution Time Import for (a)

Original Layout (b) Layout Model 1 (c) Layout

Model 2

(a)   (b)

(c)

Figure 15 Distribution Time Export for (a)

Original Layout (b) Layout Model 1 (c) Layout

Model 2

CONCLUSION

(a)   (b)

From the data above, it can be seen that there has been a decrease in distribution time for both export and import activities from the original layout to the Model 1 Layout:

For Import Data, $Percentage = \frac{(12,206.41-9,893.91)}{12,206.41} x\ 100\%$

$\approx 18.95\%$

For Export Data, $Percentage = \frac{(40,360.68-31,139.56)}{40,360.68} x\ 100\%$

$\approx 22.84\%$

From the calculation Import, distribution time decrease of 18.95 % and distribution time for Export a remarkable decrease up to 22.48% for model 1. Based on data from calculation and histogram graphs, it can be concluded that the analysis results on layout model 1 produced through the layout planning system have proven successful and have a more effective and efficient time than
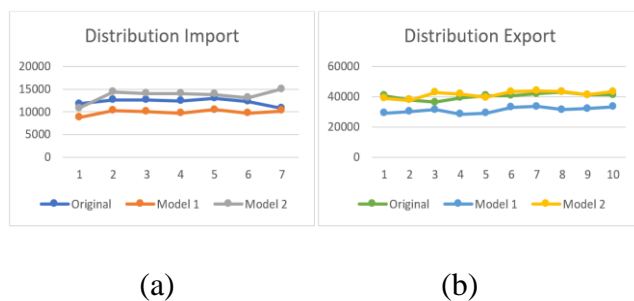
the original layout. Information from the results of this analysis can become a solid basis for better decision-making in planning and optimizing layouts in the future.

Simulations are only one aspect of container terminal port management. In addition to optimizing loading and unloading through layout, it is also necessary to maintain infrastructure, use the latest information systems, and adopt the latest technology. Thus, New Priok Container Terminal 1 will become an efficient, reliable, and innovative logistics center capable of taking advantage of opportunities in the rapidly growing and growing international trade. In addition, periodic evaluation and monitoring will assist in identifying new trends and patterns so that the port can further develop.

This research is also inseparable from the limitations of researchers in making simulations less complex and only using a few variables.

Researchers hope that future research can use many variables to make the desired results more accurate, increase terminal capacity, and contribute to economic growth.

There is construction of New Priok Container Terminals 2 and 3 for the next stage. We hope this research will be useful for layout design using the System Layout Planning method and optimization testing using AnyLogic software researcher.

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