UNIVERSITAS INDONESIA

STACKING ACTIVITY MODELING IN TANJUNG PRIOK CONTAINER TERMINAL USING DISCRETE EVENT SIMULATION

UNDERGRADUATE THESIS

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1906317732

FACULTY OF ENGINEERING

DEPARTMENT OF INDUSTRIAL ENGINEERING

DEPOK

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Submitted as a requirement to receive the Engineering Degree

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STATEMENT OF ORGINALITY SHEET

This undergraduate thesis is the result of my own work, and I have stated all the sources both cited and referred to correctly

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APPROVAL PAGE

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PREFACE

In the name of Allah S.W.T., the Most Gracious and the Most Merciful, the author praise and thank for His blessings as the author has finally had the opportunity to complete this research with the title “Stacking Activity Modeling in Tanjung Priok Container Terminal Using Discrete Event Simulation”. The purpose of this writing is to fulfill one of the requirements to obtain a bachelor degree in Industrial Engineering, Faculty of Engineering, Universitas Indonesia.

The author is fully aware of the significance of other parties' participation and moral support in this topic, since it would be quite impossible for the author to conduct this research without their assistance. As a result, the author wishes to thank everyone who has contributed to this research in their own distinctive way.God Almighty Allah S.W.T. as the source of strength, patience, repentance, and all the blessings that have enabled the author to go through the full length of university, especially in facing obstacles in working on this thesis.

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10. Najmi Nurul Febrifiani who continuously supports, accompanies, and assists in the author's daily activity with full compassion.

Last but not least, the author would like to apologize for any flaws that this study is bound to have. The author hopes that this research will have an impact on and benefit the reader. May Allah bless us all.

Depok, December 21, 2022

Best regards,

Irfan Rolanda Adfikaputra

STATEMENT PAGE OF FINAL PROJECT PUBLICATION APPROVAL FOR ACADEMIC INTEREST

As a part of the academic community at Universitas Indonesia, I am the undersigned:

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Faculty	: Engineering
Type of Work	: Undergraduate Thesis

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ABSTRACT

Name : Irfan Rolanda Adfikaputra

Study Program : Industrial Engineering

Title : Stacking Activity Modeling in Tanjung Priok Container Terminal Using Discrete Event Simulation

Counselor : Dr. Armand Omar Moeis, S.T., M.Sc.

Tanjung Priok Port and international trade are two things that cannot be separated. However, the performance of the Tanjung Priok Container Terminal is currently not optimal even though Tanjung Priok is the main port lever in Indonesia in terms of exports to foreign countries. As a result, increasing the productivity of container ports in serving container traffic flows is essential. In order to improve container terminal productivity, this study will create a model and simulation of container stacking in the stacking yard (stacking area). A proper stacking procedure (stacking rules) will limit the amount of reshuffling, which is a waste in container operations. The study's findings are discrete event simulation-based models that may be used to evaluate container stacking options based on container terminal productivity. As a result, it is planned to provide an understanding of the relationship between productivity and container stacking procedures in stacking yards.

Keywords:

Discrete Event Simulation, stacking rules, stacking yard, reshuffling, port productivity, container terminal, modeling

ABSTRAK

Nama : Irfan Rolanda Adfikaputra

Program Studi : Teknik Industri

Judul : *Stacking Activity Modeling in Tanjung Priok Container Terminal Using Discrete Event Simulation*

Pembimbing : Dr. Armand Omar Moeis, S.T., M.Sc.

Pelabuhan Tanjung Priok dan perdagangan internasional adalah dua hal yang tidak bisa dipisahkan. Namun, performa Terminal Peti Kemas Tanjung Priok saat ini belum optimal padahal Tanjung Priok merupakan tuas utama pelabuhan di Indonesia dalam hal ekspor ke mancanegara. Akibatnya, peningkatan produktivitas pelabuhan peti kemas dalam melayani arus lalu lintas peti kemas menjadi sangat penting. Untuk meningkatkan produktivitas terminal peti kemas, studi ini akan membuat model dan simulasi penumpukan peti kemas di lapangan penumpukan (stacking area). Prosedur penumpukan yang tepat (aturan susun) akan membatasi jumlah perombakan, yang merupakan pemborosan dalam pengoperasian peti kemas. Temuan studi ini adalah model berbasis simulasi peristiwa diskrit yang dapat digunakan untuk mengevaluasi opsi penumpukan peti kemas berdasarkan produktivitas terminal peti kemas. Akibatnya, direncanakan untuk memberikan pemahaman tentang hubungan antara produktivitas dan prosedur penumpukan peti kemas di lapangan penumpukan.

Kata kunci:

Discrete Event Simulation, Stacking rules, stacking yard, reshuffling, produktivitas pelabuhan, terminal peti kemas, pemodelan

TABLE OF CONTENT

CHAPTER I

INTRODUCTION

1.1. Background

International commerce promotes economic freedom, which can be used to boost a country's prosperity. Furthermore, economic freedom might motivate all manufacturers to improve product quality in order to compete in the global market. Foreign commerce plays a direct and indirect role in economic development by increasing foreign exchange revenues, transferring capital and technology from outside, and developing new domestic industries or industrialisation (Muchtar, 2001). Because it is a source of foreign exchange for the country's income, the movement of export-import goods between countries promotes economic growth. In 2021, Indonesia's imports will total USD 196,190.0 million (up 38.58 percent), with oil and gas imports being USD 25,529.1 million and non-oil and gas imports totaling USD 170,660.9 million. Tanjung Priok Port is the largest unloading point for imported products, accounting for 38.63 percent of the total (USD 75,786.3 million). Indonesia's export value would reach US$231,609.5 million in 2021, up 41.92 percent from 2020. (BPS, 2022). The expansion of supporting infrastructure, such as ports, container terminals, and road infrastructure connecting to ports, must be capable of accommodating the increase in commercial activity. This is because Indonesian ports handle the vast majority of world trade.

Tanjung Priok port is the epicenter of Indonesian export trade. This is corroborated by Export Data by BPS Port of Loading for 2021, which shows that Tanjung Priok handles the majority of Indonesia's exports. Tanjung Priok accounts for 44.39 million tons (27%) of Indonesia's net export weight of 163.12 million tons in 2021. Tanjung Priok has a total export value of USD 55.7 billion (24%) of the total value possessed by the country, which is USD 231.6 billion (BPS, 2022). Tanjung Priok, on the other hand, has a less competitive performance when compared to Asian ports. Yangshan, on the other hand, is ranked first in East Asia in terms of overall efficiency, analysis on port efficiency (CPPI indicator), with an index score of 183.5. The CPPI 2021 employs two methodological approaches: an administrative, or technical, approach, a pragmatic methodology based on expert knowledge and judgment, and a statistical approach based on factor analysis. The reasoning behind using two methodologies was to ensure that the ranking of container port performance represents actual port performance as precisely as possible. In the same study, the CPPI rated Indonesia 37th out of 66 analyzed ports in Asia, with a score of 28.2. (World Bank, 2021). Tanjung Priok is ranked 124 out of 370 ports in the World Bank database, according to the Container Port Performance Index (World Bank, 2021). It was demoted (-58) from the 2020H1 ranking. The **Figure 1.1** below shows a comparison of Indonesia's ranking.

Port Name	Rank	Index Points	Total Calls	<1500	1501-5000	5001-8500	8501-13500	>13500	2020H1	Change
TANJUNG PRIOK	124	28.2	775	122	169	80			66	-58

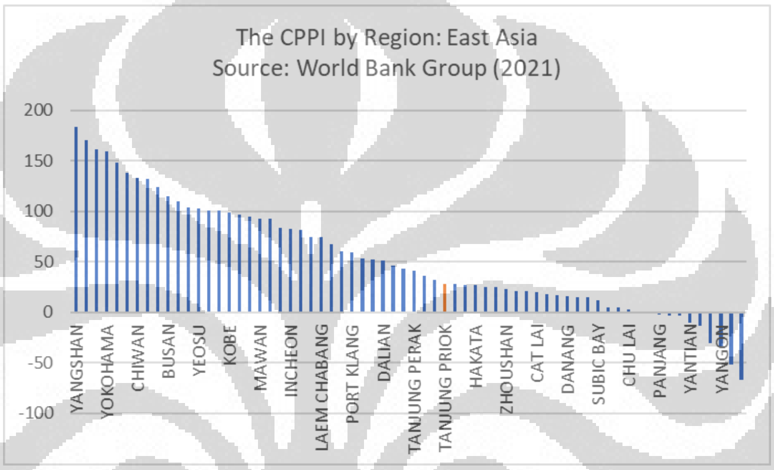


Figure 1.1 The CPPI by Region: East Asia (2021)

Source: World Bank (2021)

According to Hui (2019), data envelopment analysis (DEA) was used to analyze total port efficiency over infrastructure provision. The port efficiency index appears to have a linear relationship with infrastructure provision. According to the graph, Indonesia has less infrastructure and efficiency than other countries. The relationship is shown in **Figure 1.2.**

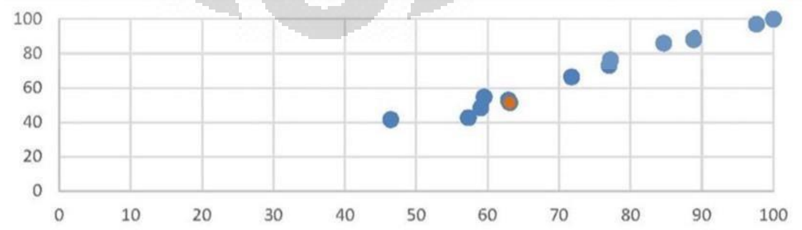


Figure 1.2 Relationship between infrastructure and overall efficiency comparison of Asian countries (2019)

Source: Hui (2019)

According to Hadi, GM PT Pelindo, the realization of dwelling time reached additional 3.11 days in June 2022 due to delays in ship arrivals from other international ports experiencing ship schedule disruptions. As a result, the export container to be loaded accumulates in the CY for an extended period of time (Puspa, 2022). Tanjung Priok's stacking time has a direct impact on the Dwelling Time. Dwelling time is estimated from the moment a container is loaded and unloaded from the ship until the time the container leaves the port via the main pier (Anita & Asmadewa, 2017). In the moment, the level of dwell time at Indonesian ports is extremely high. In Indonesia, the typical length of stay is 5 to 7 days. This time is very long when compared to Hong Kong's 2 day stay, Singapore's 1.5 day stay, Laem Chabang in Thailand's 5 day stay, Australia's 3 day stay, and Port Klang in Malaysia's 4 day stay (Rafi & Purwanto, 2016). The comparison of dwelling time is shown in Figure 1.3.

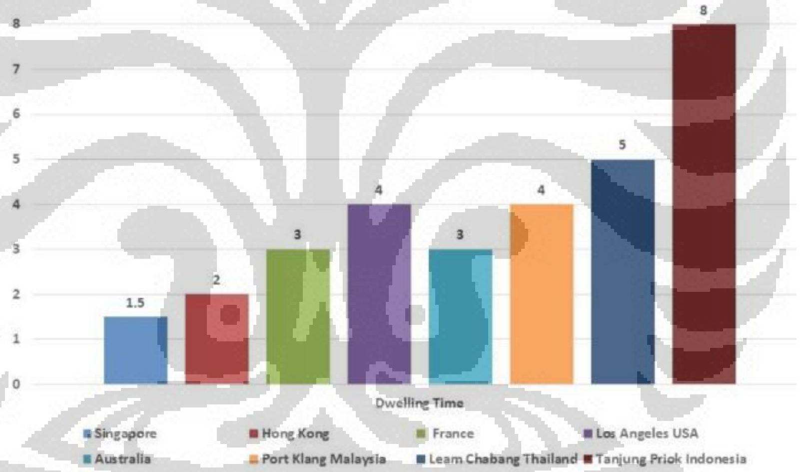


Figure 1.3 Comparison of dwelling time of several countries (2016)

Source: Rafi & Purwanto (2016)

Several factors, including the landfill's capacity, the loading/unloading facilities employed by each terminal operator, the amount of density of container loading and unloading handled, and so on, can have a significant impact on the length of dwell time. The high level of port loading and unloading in Indonesia has an impact on the country's economic sector (Gultom, 2017). Domestic industries geared to exporting to other countries will face productivity challenges. Stowage planning, wharf allocation, crane optimization, transportation optimization, and container stacking are all factors that influence container terminal productivity.

Low reshuffling affects port terminal productivity rise (Stahlbock and Voβ, 2008) and makes the port's country position better in the maritime logistics globe. The accumulation of containers in the stacking yard is one of the elements influencing the speed of ship loading and unloading activities.

As a result, this research is valuable in comparing the strategies utilized by container terminals in stacking containers in the stacking yard area. The stacking yard approach has the following goals: efficient use of stacking yards, minimizing time for container movement to and from ships, and minimizing reshuffling. According to the prior explanation, the problem statement for this research is low rate efficiency in container stacking operations (affects reshuffling), which has a negative influence on port terminal productivity. Then, using a discrete event simulation approach, this study intends to test three different container stacking rules in container stacking activities.

1.2. Problem Formulation

The author anticipates that by following industrial engineering best practices, the Discrete Event Simulation will significantly rise given the context of the report that has been detailed. The key issue facing this port is: "How to model and determine the Stacking Activity in Tanjung Priok Container Terminal Using Discrete Event Simulation?"

1.3. Problem Relationship Diagram

The author developed a bottom-up problem relationship diagram, as shown in Figure 1.4, to provide a clear representation of the problem flow of this research, beginning with the backdrop of this research and ending with the aim statement.

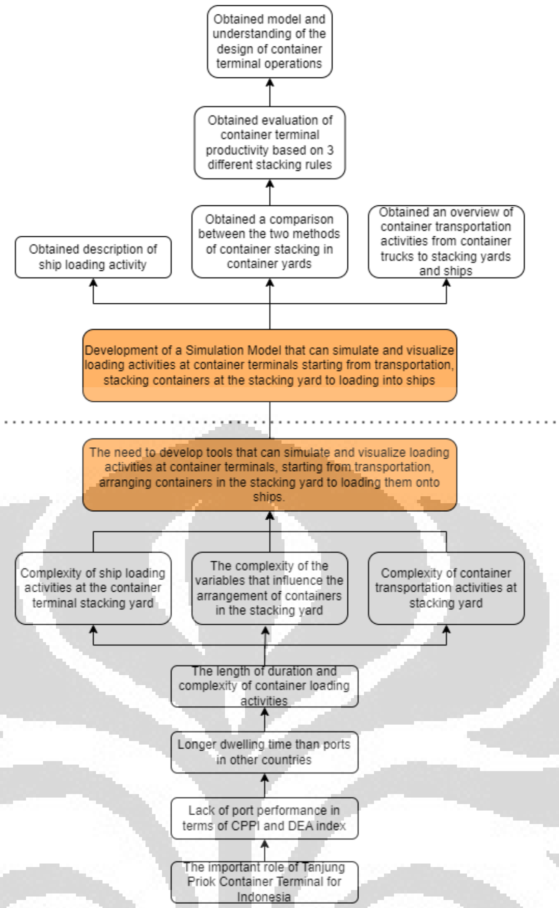


Figure 1.4 Problem Relationship Diagram

1.4. Research Objective

Based on the previously described research problem, the goal of this research is to develop a discrete-event simulation-based model of container terminal operations centered on container stacking activities in the stacking area. This research will also aim to learn about the design and operation of container terminals and determine the best stacking rules based on the least reshuffling from simulation.

1.5. Limitation of Research

In conducting the research, several problem limitations are needed to direct this research in accordance with what is expected. The research limitations include the following:

1. The research was conducted at Tanjung Priok Container Terminal located in the Tanjung Priok Port area of North Jakarta.
2. The container unit used is Twenty-feet Equivalent Units (TEU).
3. Simulation describes the flow of export containers to loading activities into ships.

4. The method used for comparison is category stacking based on destination and category stacking based on vessel.
5. Utilizing their historical data and interviews, the research was carried out within the JICT and NPCT1 PT Pelindo.
6. The outcome of this study did not take into account financial calculations and was limited to offering ideas, solutions, and assessments of the state of the equipment.

1.6. Research Methodology

This research will be conducted step by step starting from the early stage of the research until the closing stage of the research as shown in **Figure 1.5.** Initial Research Stage

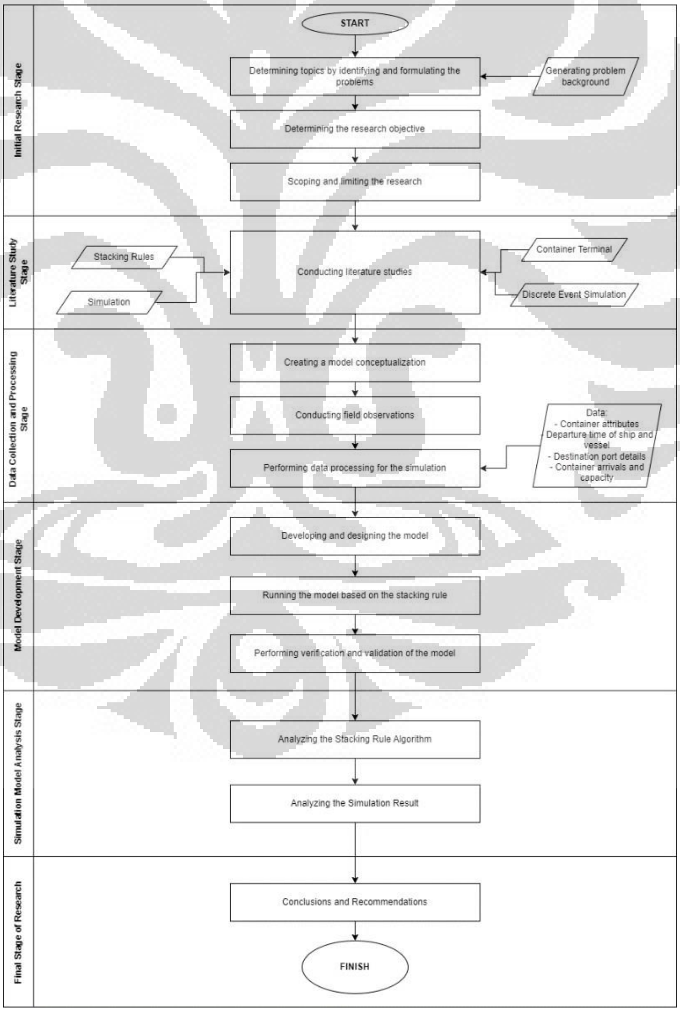


Figure 1.5 Research Methodology flow Diagram

There are five stages of this research such as:

1. Initial Research Stage

   Through conversations with supervisors, research topics were gathered, including those related to discrete event simulation of container loading and unloading operations. The parameters of the research problem are also established at this stage. in order for this research to be better focused, directed, and capable of producing the desired results

2. Literature Study Stage

   The theoretical underpinnings that serve as the framework for the rules governing this research will be described in this phase. The theory of simulation, the theory of discrete event simulation, the theory of stacking rules, and the philosophy of the design and operation of container terminals serve as the theoretical foundation.

3. Data Collection and Processing Stage

   At this stage, the procedure of gathering and analyzing the necessary data for this study is carried out. The process of collecting and processing this data begins with the problem being structured to provide an overview of the data required for the simulation model. Direct observation was used to obtain data at the Tanjung Priok Container Terminal. The collected data includes the average processing time at the container terminal, ship and container arrival schedules, and other information pertinent to the study. Following this phase is data processing as input to the simulation model.

4. Model Development Stage

   Creating a framework for model flow using a flowchart. This diagram depicts the activity flow that was modeled for this investigation. This framework is beneficial for providing an early understanding of the model's variables. The process then continued with the building of computer models utilizing plant simulation software. The framework created in the preceding flowchart serves as the basis for the model development. Verification and validation are the final steps to ensure that the model functions as intended and accurately mimics real-world.

5. Simulation Model Analysis Stage
   The next stage is to assess the simulation models findings once the model has been developed and the previously specified methods have been added
6. Final Stage of Research
   Comparing the stacking rules of stacking containers, the outcomes and conclusions of the model simulation are explained at this stage.

1.7. Writing Systematic

Introduction, literature review, data collection and processing, results and analysis, and conclusion make up the five chapters that make up this research:

1. The first chapter of this paper will discuss the research's introduction, including its context, problem formulation, problem relationship diagram, research objectives, research scope, research methodology, and writing procedures.
2. The second chapter is a review of the relevant literature that explains the fundamental theories utilized in this study. In addition, this chapter will provide an outline of the research's methodology
3. The third chapter is devoted to a discussion of the data, detailing the research's data gathering and data processing. The author will watch a worker in the manufacturing industry who will provide the data.
4. The fourth chapter discusses the analysis derived from the data processing performed in chapter three. After collecting the data, it will be processed to produce an analysis based on the data. This chapter will draw a direct correlation between the primary research problem, the literature review, and the data itself.
5. The undergraduate thesis closes with a conclusion and recommendation in the fifth chapter. This chapter will evaluate if the research objective has been met, along with a recommendation regarding the research's purpose and the people involved. This chapter also provides the possibility to do further research on this subject.

CHAPTER II
LITERATURE REVIEW

This chapter will explain about the fundamental theories that are used in this research which later can support the making of this research. Furthermore, this chapter will give an overview of the methodology of this research.

2.1. Container Terminals

The discussion of the container can be listed into the subtopics listed below.

2.1.1. Definition of Container Terminals

The majority of global trade is conducted across the ocean. As much as 90% of global trade flows use the sea route as a distribution channel for goods and rely on ships for transportation, according to statistical statistics (Rachel Henwood, 2006). The sea route was chosen as the primary form of international trade due to its lower costs and greater volume. The majority of maritime commerce utilizes containers as a shipping medium. 52% of global seaborne trade utilizes containers. Containers are utilized due to their multiple benefits, which include enhancing the efficiency of cargo handling, enhancing the security of goods, decreasing the risk of damage, and boosting the speed of cargo transportation (Gharehgozli, 2012).

Terminals for containers are ports where containers change modes of transportation (Stahlbock & VoS, 2008). This facility connects maritime and terrestrial traffic. The flow of goods commerce by sea employs the mode of maritime transport. The container terminal will facilitate the exchange of containers between the marine route and the land route. Trucks and railroads will be used to transport land-based cargo.

2.1.2. Container Area

The container terminal is separated into four primary sectors, each with its own role (Meisel, 2009). The four areas are as follows:

1. Quay Area: the ship rests and the loading and unloading activities of containers from and to the ship.
2. Transport Area: container transportation area inside the container terminal.

3. Yard Area: containers are piled up before changing to the next mode of transportation.
4. Truck and train area: place where containers are moved from and to trucks or trains.

The following **Figure 2.1.** shows the concept of a container terminal which is divided into four main areas.

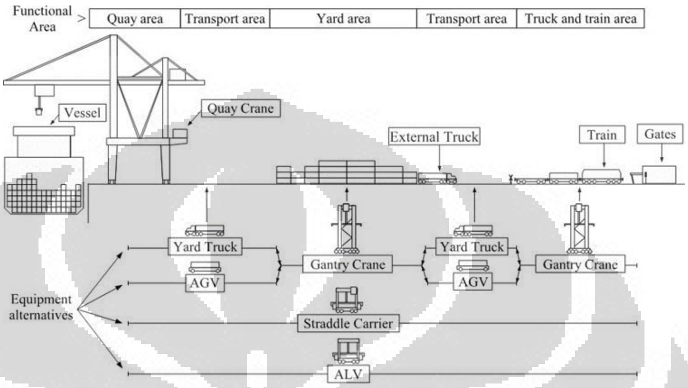


Figure 2.1 Four main areas of container terminal

Source: Meisel (2009)

2.2. Container

The discussion of the container can be listed into the subtopics listed below.

2.2.1. Definition of Container

Containerization technology has a significant impact on the transportation of products. This technique improves the efficiency of high-value loads by 85 percent and decreases loading time and expenses by 35 percent. Since 1952, when the first container ships began operations in the United States and Denmark, numerous container-related designs, volumes, and technologies have emerged (Alderton, 2008).

The container is a reusable iron box in the shape of a cube that serves as a means of carrying products (Levinson, 2008). In the 1950s, Malcolm Mclean was the first to develop containerization, the delivery of commodities using containers. He delivered 58 containers of trucks that had been shipped from Newark to Houston. It is believed that this is the first time containers have been utilized to transport goods.

Containers provide standardization of goods packaging media and the ability to be carried by a variety of means of transportation, including trucks, trains, and ships (Theo Notteboom, 2008). Therefore, a facility that serves as a location for shifting containers between modes of transportation is required. This establishment is a container terminal.

2.2.2. Type of Container

Based on (CMA CGM, 2017), containers are divided into various types based on their size and function. Containers consist of various types, namely:

1. General Purpose Containers

The most frequently used type of container because it can be used to load almost all types of packaged dry goods such as boxes, cartons, bags, bales, pallets, drums, and others. This container is characterized by having a single door at the end and being closed on all sides.

These containers are available in a range of lengths and heights. These containers are typically 8.6 feet tall and 20 or 40 feet long. In addition, this sort of container, known as a high cube, can be as tall as 9.6 feet and as long as 40 or 45 feet.

2. Reefer Containers

This type of container is equipped with a temperature control component with the aim of adjusting the temperature in the container according to the existing load. This type of container is used to send cargo that cannot be stored for a long time (perishable goods) and requires a special temperature in order to maintain the condition of the cargo. These containers are the same height as other types of containers and are either 20 feet or 40 feet long.

3. Open Top Containers

This type of container is very similar to general purpose containers except that it has a flexible roof that can be opened and moved to accommodate heavy and large loads that can only be moved by using a crane or rolling bridge. This type of container is 20 feet or 40 feet long.

4. Flat Track Containers

This type of container has no side walls and a roof but has walls at each end of the container that can be moved. This type is used for loads that are heavy, large, and have a height and or width that exceeds the container walls. The end walls can be moved to accommodate loads that exceed the length of the container. The floors are designed to withstand very heavy loads. These containers are 20 feet or 40 feet long.

5. Tank Containers

This type of container consists of a tank and a container frame. These containers are used to send liquid cargo either harmless or dangerous. This container is equipped with components to fill and empty the tank, and has a safety system to prevent liquid from spilling from the container. This type of container is only 20 feet long.

2.3. Container Terminal Operations

According to Li, Wu, and Goh (2015), there are three categories of containers at container ports based on their destination: export containers, import containers, and transshipment containers.

Primary movers such as trucks or railways transport export containers to the container terminal. Export containers arrive from the hinterland, which is the area around the terminal. Before the container enters the terminal, it will be inspected and the necessary documentation for the export process will be processed. The container will be carried to the field area by the primary mover once all processes at the terminal entrance gate have been completed. Containers will be carried from the primary mover to the storage facility in the field area utilizing a yard crane. The containers will be temporarily housed in this area until the ship arrives. When the ship arrives at the pier, the container will be transferred from the temporary storage facility to the primary mover, which will transport it to the dock. When the containers arrive at the dock, they will be transferred from the primary mover to the ship using a quay crane. The description of the flow of the operating process at the container terminal is in **Figure 2.2.**

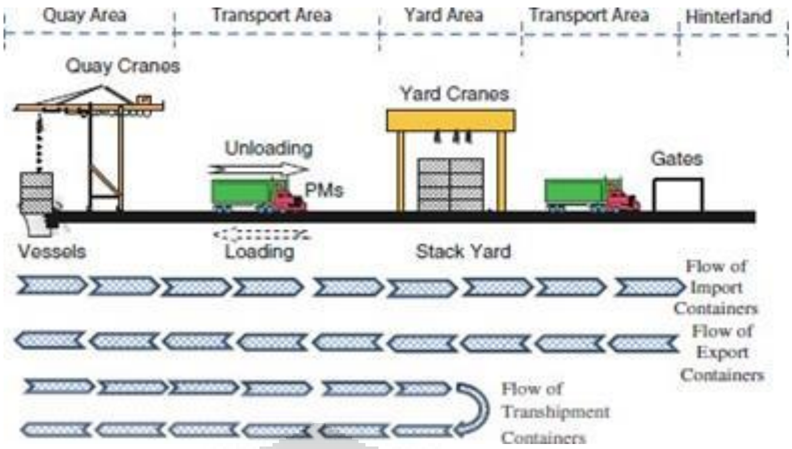


Figure 2.2 Flow of the operating process at the container

Source: Li, Wu, and Goh (2015)

The import containers are delivered to the container terminal by incoming ships. Import containers are unloaded from ships and loaded onto trucks using dock cranes. The primary mover will transport the container to the field area, where it will be transferred from the primary mover to a temporary storage location using a yard crane. Furthermore, the imported containers will be unloaded onto the primary mover using a yard crane before being transported to their final destination in the hinterland.

Transshipment containers arrive at the container terminal by ship and are returned by another ship. When a ship carrying transshipment containers arrives, the containers will be unloaded using a quay crane and loaded into the primary mover, which will then transport them to the field area. Yard cranes will be used to temporarily store transshipment containers in the field area. When the planned ship arrives at the terminal, the container will be emptied from the field area and carried to the primary mover via a yard crane. Furthermore, the container will be unloaded and loaded into the target ship utilizing a quay crane. The ship then departs the terminal for the next port.

The container terminal's working area is separated into four sections: the wharf area, the transfer area, the field area, and the hinterland. The transportation of export containers from the hinterland to the container terminal and import containers from the container terminal to the hinterland is the operational procedure in the hinterland. External trains or trucks are used in this transfer, which is trucks owned by parties other than the container port operator (Li, Wu, & Goh, 2015).

2.4. Container Stacking

2.4.1. Definition of Container Stacking

Container stacking is the act of stacking containers in a yard area. Stacking containers is one of the benefits of containers that tries to maximize land usage efficiency in container storage (Alderton, 2011). This, however, has other implications in the activity of emptying containers from the stacking yard area. The container to be taken must be on the top row during the container unloading process. If this does not occur, a reshuffling operation must be performed to unload the container arrangement and allow the desired container to be taken for unloading. Reshuffling is the process of deconstructing the container arrangement in the stacking yard. The reshuffling process is inefficient since it has an impact on the longer container handling process (Borgman, Asperen, & Dekker, 2011)

One of the keys to container terminal productivity is this action in container stacking (Stahlbock & VoS, 2008). Container stacking is quite important in terms of container loading time aboard the ship. Good container stacking will reduce the amount of reshuffling during the loading of containers into the ship. The fewer reshuffling that occurs, the faster the loading procedure into the ship. In the end, it will shorten a ship's docking time.

Improving a container terminal's service through increasing efficiency in container stacking is the best option because it requires no more resources (Meisel, 2009). Changing the way of stacking containers allows for changes.

2.4.2. Container Stacking Objectives

The following goals are achieved by stacking containers in an effective and efficient manner: efficiency of the stacking yard area, reduction of transportation time, and avoidance of reshuffles. The usage of land in container storage will be influenced by effective and efficient container stacking. Containers that are organized will utilize less land. Due to a lack of space to accommodate the number of containers, container arrangements in container ports with limited space might be very high. Singapore and Hong Kong ports are two examples. However, large container stacking has additional effect on the increased chance of reshuffling due to very high container stacks (Borgman, Asperen, & Dekker, 2011).

One of the purposes of proper container stacking is to save transit time. Containers with export destinations will be placed closer to ships if they are stacked properly (Borgman, Asperen, & Dekker, 2011). As a result, it does not require a lengthy transport time when transferred to the ship. It is also expected that the container arrangement is not too high because the higher it is, the longer the loading period of the containers aboard the ship would be.

The primary function of effective and efficient container stacking is to eliminate non-productive reshuffling operations in container ports. As a result, the major goal of effective and efficient container stacking is to reduce the number of reshuffling actions when emptying containers from the stacking yard.

However, achieving these three goals when stacking containers in the stacking yard area is nearly impossible. Because each of the above goals has ramifications for other goals (Dekker, Voogd, & Asperen, 2006). Reduce the height of container stacking, for example, to meet the goal of reducing reshuffling. However, because this strategy will take up a lot of area, it will result in inefficient use of land for container storage. So, in order to meet these three objectives ideally, modifications must be made.

2.5. Methods for Container Stacking

Container stacking at the container terminal can be done in a variety of ways and approaches. These approaches are tailored to their unique stacking container goals. Container stacking methods are broadly classified into two types: category stacking and residence time stacking. Category stacking is a way of stacking containers based on their similarities in categories. These categories can be based on weight, destination, or container type (Dekker, Voogd, & Asperen, 2006). Meanwhile, residence time stacking is a time-based approach that is a container property (Borgman, Asperen, & Dekker, 2011). In most cases, the time attribute is the ship's departure time.

The goal of this study was to compare two approaches based on category stacking classification. A comparison will be done between the container category stacking method and the container category stacking method based on the ship that will convey.

2.5.1. Category Stacking Based on Vessel

This container stacking approach involves stacking containers in the stacking area based on the qualities of the ship contained within the container. Each container has a characteristic that serves as the container's identity. The name of the ship that will convey the container is one of the identities contained in each container. Each container with the same ship attribute will be sorted in the same pile in the same order as the container with the same ship attribute. If the allocation for containers with the same ship attribute is no longer available, this will not apply. As a result, the container must be positioned in a different pile with the shortest stack height.

In general, the steps in assembling containers based on this stacking method are as follows. First, newly arrived containers are lifted using a Rubber-Tyred Gantry Crane (RTGC). Then the container is placed on top of the container that has the same ship attributes. The maximum stack height is six stacks. Second, if no container is found belonging to the same ship category, then the container is placed on another stack with the lowest stack height.

2.5.2. Category Stacking Based on Destination

This container stacking method arranges containers according to their category. The container's purpose is the category employed in this investigation. Each container has a final destination known as the Port of Destination (POD). So, using this strategy, the containers are ordered according on their POD. Containers that have just arrived at the stacking yard will be stacked on top of containers with the same POD.

The processes for building containers using this technology are as follows in general. The newly delivered containers are first lifted with a

Rubber-Tyred Gantry Crane (RTGC). The container is then placed on top of the container with the same POD. Six stacks are the maximum stack height. Second, if no container with the same POD type is identified, the container is moved to another pile with the lowest stack height.

2.6. Reshuffling

Reshuffling is an action that is considered as container terminal operating waste. One technique to assess the effectiveness of container terminal performance is to examine the reshuffles parameter. The percentage of reshuffles compared to the entire activity of moving containers in the stacking yard area is used to calculate reshuffles. Each rearrangement will have an effect on any subsequent reshuffles. As a result, this measure becomes one of the most essential indications in determining a container terminal's performance efficiency.

2.7. Discrete Event Simulation

Mes (2017) claims that simulation may be used to study physical phenomena, business processes, pedestrian and traffic movement, as well as manufacturing and logistical activities. There are primarily two types of simulation: time-oriented simulation (continuous or time-step simulation) and Discrete-event simulation. Time is continuous in the actual world. For example, observing a part go down a conveyor system will reveal no time jumps. Because the time it takes the component to traverse the system is continuous, the curve for the distance travelled is a straight line. A discrete event simulation (DES) software, on the other hand, only considers those moments in time (events) that are important to the simulation's overall outcome. The characteristic of DES is shown in **Figure 2.3.**

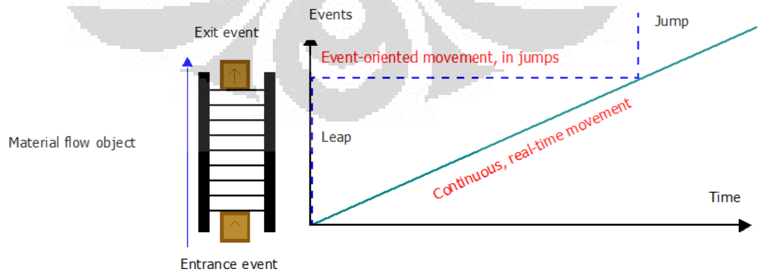


Figure 2.3 Characteristic of Discrete Event Simulation

Source: Siemens (2019)

Such occurrences might include a component entering, departing, or moving on to another machine. The simulation is unconcerned about any moves that occur between those occurrences. DES is used in Plant Simulation. Performance is a significant benefit of DES over time-oriented simulation (continuous or time-step simulation). Because the software may simply bypass any non-interesting points in time, it is feasible to replicate years of industrial activity in just minutes. According to Siemens (2019), the process during DES is especially handy when simulating numerous configurations of the same system and doing multiple replications for each configuration. Plant Simulation has built-in functionality for just the purpose of DES claims Siemens.

The discrete-event simulation is a simulation that is time-based. The variability of a model is directly related to time-based discrete-based models. Variability can occur in an entity's arrival time, processing time, and ability. Variability in a model is beneficial for simulating uncertainty in real-world systems. As a result, variability is a key aspect of discrete-based simulation. Variability is accommodated in a computer system using random numbers (Robinson, 2014).

CHAPTER III

DATA COLLECTION AND PROCESSING

3.1. Object of Research

This chapter will go over the procedures and data processing methods used in this investigation. The data was collected at New Priok Container Terminal and Jakarta International Container Terminal. The data collected is in the form of container terminal specifications such as layout, capacity, and existing container terminal facilities. Other information includes the volume of container traffic and the ships that will transport the containers. This data collection is tailored to the demands of the ongoing research.

During the data processing processes, data is processed as input data in the model to be produced. The input consists of truck and container arrival data, as well as container attributes. The data is then processed to establish the layout allocation of the containers in the stacking yard. The final step is data processing in the form of designing a container terminal operation model.

Model creation begins with designing the model's first design and outlining the model's objectives. Then, proceed with the design of the fundamental model, the model's restrictions, and the model's verification and validation methods. The final step is to create alternative models that may be used to compare existing situations. The stages of creating this model are supposed to serve as the foundation for the model analysis procedure at a later stage. As well as being valuable in drawing conclusions at the end of this investigation.

3.2. Data Collection

3.2.1. Layout Details and Capacity

TYPE	LADEN	REEFER	DG	MT
GROUND SLOT	5400	198	80	184

Figure 3.1 Layout Details of NPCT1

Source: NPCT1 (2022)

The chart above demonstrates that the majority of container terminal area is used for stacking yards. A stacking yard is a location where containers are temporarily stored before being transferred to the next method of transportation, which could be trucks or ships. Container layouts are classified according to their container type. NPCT1 has a quay length of 850 m that can serve 2 mother vessels and 1 local feeder vessel at the same time. The terminal provides 198 reefer ground slots which in total can serve about 990 reefer containers; this is the largest among competitors in the same region. There are 3 main docks for the ship, 3 main stacking areas, and 4 streets that will be the based layout of the simulation. The NPCT1 terminal facilities included 32ha area, 1.5m capacity (TEUs), 16m max depth, 8 quay cranes, 24 yard cranes (RTG), also 44 prime movers.

3.2.2. Arrival Time of Vessel

	datetime 1	object 2
string	Delivery Time	MU
1	2022/04/16 01:00:00.0000	.MUs.VesselExport_242
2	2022/04/16 06:00:00.0000	.MUs.VesselExport_242
3	2022/04/16 09:00:00.0000	.MUs.VesselExport_242
4	2022/04/17 05:00:00.0000	.MUs.VesselExport_242
5	2022/04/17 06:00:00.0000	.MUs.VesselExport_242
6	2022/04/17 23:00:00.0000	.MUs.VesselExport_242
7	2022/04/18 01:00:00.0000	.MUs.VesselExport_242
8	2022/04/18 06:00:00.0000	.MUs.VesselExport_242
9	2022/04/18 06:00:00.0000	.MUs.VesselExport_242
10	2022/04/19 01:00:00.0000	.MUs.VesselExport_242
11	2022/04/19 06:00:00.0000	.MUs.VesselExport_242
12	2022/04/19 15:00:00.0000	.MUs.VesselExport_242
13	2022/04/20 01:00:00.0000	.MUs.VesselExport_242
14	2022/04/20 06:00:00.0000	.MUs.VesselExport_242
15	2022/04/20 09:00:00.0000	.MUs.VesselExport_242
16	2022/04/20 17:00:00.0000	.MUs.VesselExport_242
17	2022/04/20 18:00:00.0000	.MUs.VesselExport_242
18	2022/04/21 15:00:00.0000	.MUs.VesselExport_242
19	2022/04/21 16:00:00.0000	.MUs.VesselExport_242
20	2022/04/21 22:00:00.0000	.MUs.VesselExport_242
21	2022/04/21 22:00:00.0000	.MUs.VesselExport_242
22	2022/04/22 10:00:00.0000	.MUs.VesselExport_242

Figure 3.2 Table of Arrival Time of the Vessels

The Arrival time of the Vessel displays the date and time of each vessel's arrival at the port.

3.2.3. Destination of Vessel

	string 1	string 2	string 3	datetime 4
string	Number	Destination	VesselName	ArrivalTime
1	1	Japan	Vessel1	2022/04/16 06:00:00.0000
2	2	USA	Vessel11	2022/04/16 09:00:00.0000
3	3	China	Vessel18	2022/04/16 01:00:00.0000
4	4	NZ	Vessel1	2022/04/16 06:00:00.0000
5	5	Malaysia	Vessel11	2022/04/16 09:00:00.0000
6	6	Singapore	Vessel18	2022/04/16 01:00:00.0000
7	7	Filipina	Vessel1	2022/04/16 06:00:00.0000
8	8	Taiwan	Vessel18	2022/04/16 01:00:00.0000
9	9	UAE	Vessel1	2022/04/16 06:00:00.0000
10	10	Filipina	Vessel11	2022/04/16 09:00:00.0000
11	11	Singapore	Vessel18	2022/04/16 01:00:00.0000
12	12	Iran	Vessel1	2022/04/16 06:00:00.0000
13	13	Iran	Vessel11	2022/04/16 09:00:00.0000
14	14	USA	Vessel1	2022/04/16 06:00:00.0000
15	15	Taiwan	Vessel1	2022/04/16 06:00:00.0000
16	16	Japan	Vessel1	2022/04/16 06:00:00.0000
17	17	Vietnam	Vessel1	2022/04/16 06:00:00.0000
18	18	China	Vessel18	2022/04/16 01:00:00.0000
19	19	China	Vessel1	2022/04/16 06:00:00.0000
20	20	Singapore	Vessel1	2022/04/16 06:00:00.0000
21	21	Japan	Vessel1	2022/04/16 06:00:00.0000
22	22	China	Vessel1	2022/04/16 06:00:00.0000

Figure 3.3 Table of Destination of the Vessels

The datasheet depicts the variation of each vessel's arrival time and destination as simulated by the model.

3.2.4. Attributes of Vessel

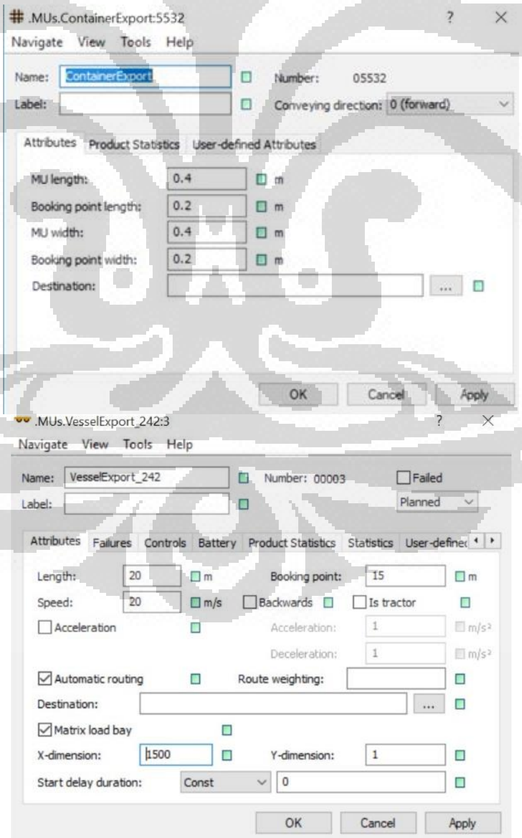


Figure 3.4 Input Attributes of the Vessels

The base length, speed, and length of each vessel simulated in the model are displayed in the Attributes of Vessel section. The capacity datasheet portrays Vessel variation.

3.3. Data Processing

After all of the data from the New Priok Container Terminal 1 has been acquired, the next step is to process it. NPCT1's role in this case is to serve as a learning model for researching the container terminal system. As a result, the acquired data will be further processed to meet the requirements of the model to be created.

Data processing is carried out in order to generate input for the model. The following data processing steps are taken to generate input for the model: Data on container characteristics and the arrival of container trucks Ship arrivals at the wharf data, Data on container allocation in the stacking yard, ship capacity, and containers moved.

Data processing is carried out in tandem with the establishment of model boundaries, which are a simplification of a model as a representation of reality. The model's limitations are as follows: the model describes the flow of export containers to ships; the model describes three piers in the north with a stacking yard position perpendicular to the wharf position; the model describes three export blocks in the stacking yard area; each block is facilitated with one gantry crane that will serve the container stacking process; and the model describes three export blocks in the stacking yard area.

3.3.1. User-defined Attributes

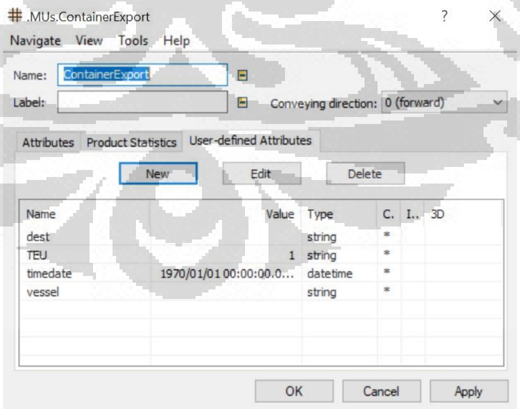


Figure 3.5 User-defined attributes

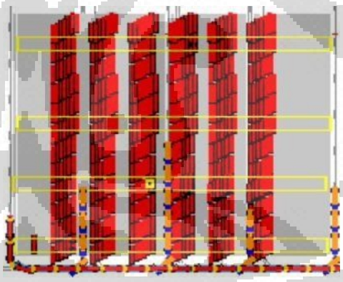
Each container in this model has a destination attribute as well as the name of the ship that will transport the container. The unexpected nature of container arrivals at ports is one of the obstacles in preparing for container stacking. As a result, the properties in this model's container are similarly randomized with a random uniform. The model's containers have the following properties:

1. vessel: a feature of the ship that will transport the container.
2. dest: the container's final destination
3. time: the arrival time of the ship transporting the containers

The Plant Simulation feature now allows researchers to provide properties for each container object in your model. These characteristics are known as user-defined traits. This feature allows users to assign specific properties to each item. The **Figure 3.5.** shows the display of user-defined properties.

3.3.2. Stacking Yard Layout and Capacity

This container terminal model models a total of 3 blocks of stacking yards which function as temporary container storage before being transferred to the next mode of transportation. The stacking yard block in this model is an export block as a storage area for containers before being transferred to the ship. In this model each block is a stacking yard.



Row	6 TEUs
Bay	24 TEUs
Tier	6 TEUs

Figure 3.6 Model of Stacking Block Area with Containers

Each container block has roads to the left and right of the road as transfer points between trucks and staking yards. The road on the left is where the flow of containers enters the stacking yard block. On the left side of the road, external trucks transport containers to the transfer point. After that, the gantry crane will transport the containers from the top of the truck to the stacking yard.

While the road on the right is the road for the head truck which will transport the containers to the wharf. To then be transported to the ship. At the end of the stacking yard there is a transfer point as the point for moving containers onto the head truck).

3.4. Model Development

The model was created using the Tecnomatix Plant Simulation program 9.0. The following objects are used by the author in the model created with Tecnomatix Plant Simulation 9.0:

1. Event Controller: an entity used to start, halt, continue, and control the simulation's duration. This simulation was conducted for 14 days, with four days for initialization and ten days for simulation.
2. Entity: a container model. The container modeled is a standard 40-foot container. ContainerExport is the name of the entity.
3. Transporter: an active object that can contain entities and transport them to another entity. The transporter is used to depict ships, internal trucks, exterior trucks, and trolleys on quay cranes in this model.
4. Source: an object that generates an entity before it enters the system. There are four source units in this model: one for producing ships, one for producing internal trucks, one for producing external trucks, and one for producing containers to be loaded onto external trucks. External truck arrival times are every two minutes.
5. Transfer Station: an object that loads, moves, and unloads entities from one object to another or vice versa. This setup employs a single transfer station to load containers onto trucks.
6. Track: a passive item that allows transporters to pass through. As a means of transportation for both ships and trucks, this model employs at least 70 track pieces that are interconnected throughout the model plan.

7. Portal Crane: Tecnomatix Plant Simulation 9.0 includes a portal crane object that is ideal for modeling container stacking regions. This model employs nine portal cranes labeled BlockA through BlockC.
8. Drain: an item that serves as a destination for mobile units when they have completed all processes on the system.
9. Frame: is the foundation for creating models, serving as a location for things to be placed and connected to one another.
10. Table File: This object stores data in the form of a table, which may subsequently be accessed by other objects. The table file is used in this model to hold data on ship arrivals and container placement in the portal crane.
11. Method: an object where the programming language as in Figure 3.6 is written to control the behavior of other objects. This model employs 60 methods, which include calculating object routes, loading and unloading containers from and onto ships, and container stacking in the stacking area.

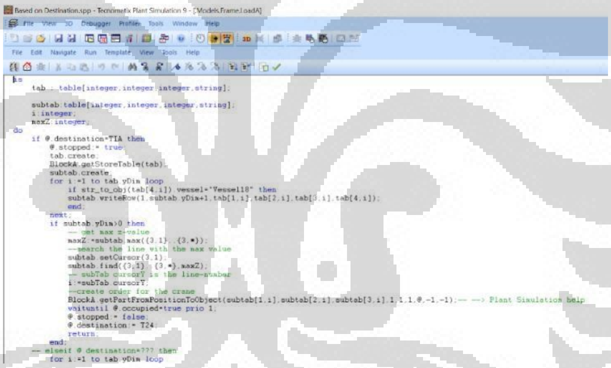


Figure 3.7 Additional Programming Languages in Plant Simulation

3.4.1. Model Conceptualization

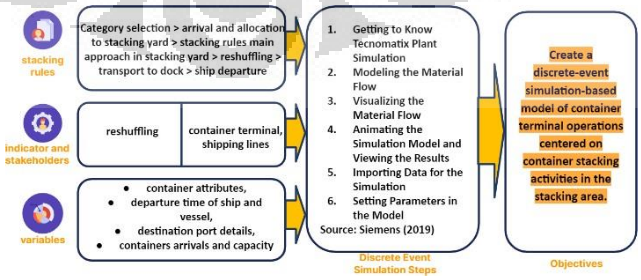


Figure 3.8 Conceptual Model

The inputs for this model are container arrivals and ship arrivals. The variables that affect the model from the outside are the attributes of the container, the arrival time of the container and the capacity of the stacking yard which will be the storage area for the container. In each container there is an attribute consisting of the name of the ship that will transport it and the destination of the container.

The model will be used as a medium for evaluating three stacking rules which consist of category stacking based on destination, category stacking based on vessel, and random stacking. Evaluation will be carried out with indicators of the number of reshuffles that occur during the process of unloading containers from the stacking yard and being transported to the wharf. Reshuffle has percentage units per all movements carried out by the gantrycrane.

The user of this model is a planner at a container terminal whose job is to plan the arrangement of containers in the stacking yard or commonly called the yard planner. Their job is very important because it affects the productivity of containers. Ultimately the stakeholders of this model are the container terminals and the shipping lines as the owners of the containers.

3.4.2. Base Model Development

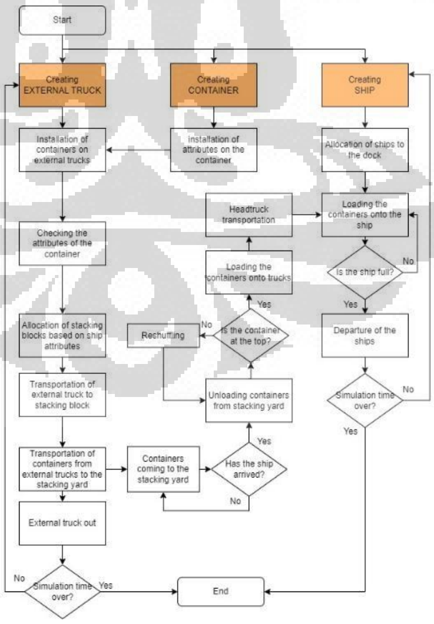


Figure 3.9 Base Flow Chart Model

The ship will arrive at the port according to a predetermined schedule. Each ship has a name and capacity attribute. The ship will dock at the port until all containers are filled with capacity. After the ship arrives at the port, the head truck will head to the stacking area to pick up the containers that are arranged in the stacking area. When it will be taken from the stacking area, containers that will be transported by ship must be ensured that they are on the top stack. If these conditions are not met, a reshuffling activity must be carried out to retrieve the container. Then the containers are loaded onto the head truck.

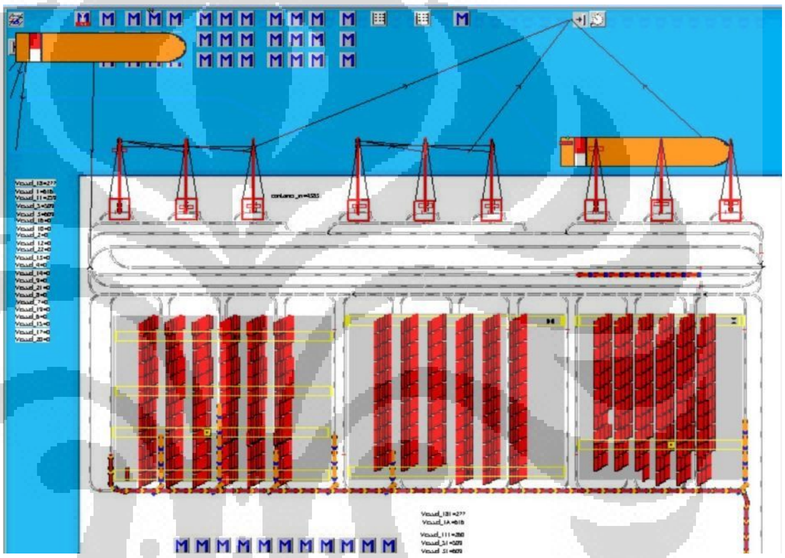


Figure 3.10 Model in Plant Simulation

One of the goals of establishing this model is to help users understand the architecture of operations at container ports. One approach is to create a model that is supported by visualization to help users comprehend the model. As a result, we require objects that may represent the current state of the container terminal. This model's objects are as follows:

1. Container

The primary component of this model is containers. In Plant Simulation, containers are represented as green rectangular objects that are MU.objects.

Figure 3.11 Container in Plant Simulation

2. Ship

The ship is a physical representation of the mode of transportation that will convey containers. The size of the ship in this model is independent of the ship's actual capacity. The model merely expresses capacity in numbers and does not represent it in form. VesselExport is the name given to the ship.

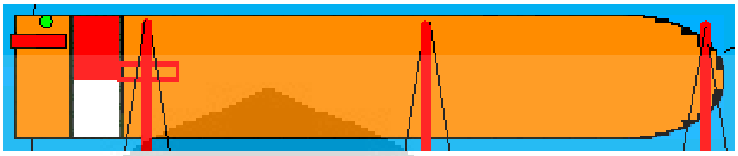


Figure 3.12 Ship in Plant Simulation

3. Head Truck

In the model, the truck object serves as the carrier. This model has two types of trucks: internal trucks and external trucks. External trucks transport containers into the port till they arrive at the stacking yard. Internal trucks transport containers from the stacking yard to the wharf. Each vehicle can only transport one cargo at a time.

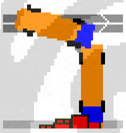


Figure 3.13 Head Truck in Plant Simulation

4. Gantry Cranes

A gantry crane is a tool used for container handling and stacking yards. This model has three gantry crane units, one in each block of the stacking area. This gantry crane has a motion rate of 50 moves per hour and can only lift one container each activity. **Figure 3.14** is an overhead shot of the gantry crane on the model.

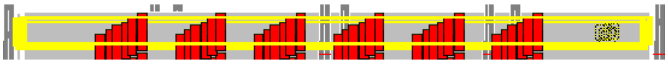


Figure 3.14 Gantry Cranes in Plant Simulation

5. Quay Cranes

A quay crane is a device used to transport containers to and from ships. Quay cranes are positioned on the wharf, with three units on each wharf for a total of eight units. Assuming that each operator has the same skill, the pace of each dock crane is the same, namely 24 moves per hour. The following is how the quay crane appears on the model:

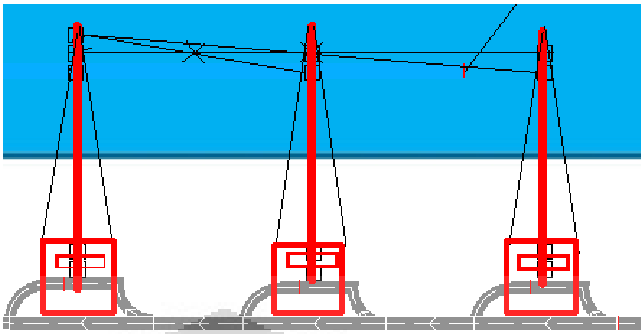


Figure 3.15 Quay Cranes in Plant Simulation

The simulation lasted 9 days. There is an initialization stage of the stacking area before the simulation is conducted to load the stacking area with containers. Because the simulation must be done in a steady-state stage with the stacking space already full of containers. The initiation phase lasted four days and twelve hours. The simulation will execute container actions for 13 days and 12 hours in total.

3.4.3. Category Stacking Based on Vessel

The first method modeled on this container terminal model is category stacking based on vessels. This method has the goal of stacking containers with the same ship attributes on the same pile. So that each container will be stacked in groups according to the ship that each will transport it. The attributes of the ship that will transport are useful when the process of unloading containers from the stacking area is carried out to be transported onto the ship. So that the container to be unloaded is not obstructed by piles of containers with different ships.

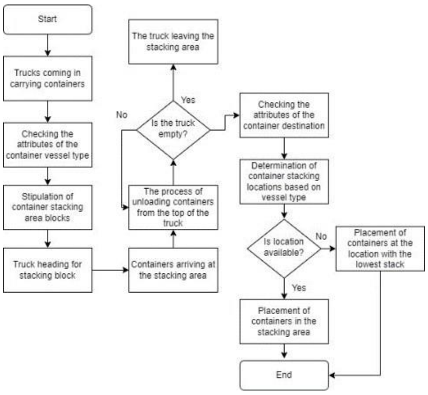


Figure 3.16 Flow Chart of Category Stacking Based on Vessel

3.4.4. Category Stacking Based on Destination

The next method used as a comparison in stacking containers in the stacking area is category stacking based on destination. This method is a method of stacking containers based on the categories in the containers. The category used as a reference is the purpose of each of these containers. Purpose is useful to serve as a reference because it is one of the considerations when carrying out stowage or stacking on board. The container with the farthest destination must enter the ship first because it will be at the bottom of the stack. The process of stacking containers using the category stacking method based on destination can be seen in the following flowchart.

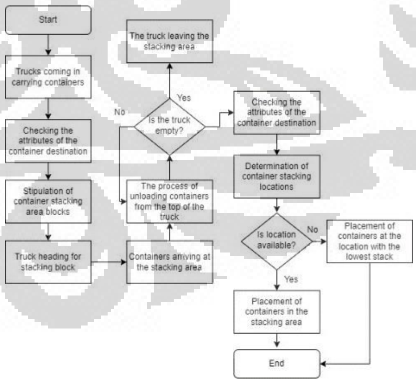


Figure 3.17 Flow Chart of Category Stacking Based on Destination

3.5. Verification and Validation

3.5.1. Verification

To guarantee that the model accurately depicts the actual scenario, the model is verified and validated. As a result, the model is plausible and may be believed (credible). The container terminal model is validated by watching the simulation run and checking that there are no flaws in the logic of the model in question.

The use of Plant Simulation 9.0 provides the ability to check for code and logic issues in the simulation while it is running. In addition, the show improper methods feature will display the location of mistakes and errors in the simulation model.

The model is then validated by verifying the present processes in the model with the model's conception. Verification begins by identifying the critical processes in the model and establishing whether they are operating in accordance with the model's conceptualization. The following table contains a list of processes and test results:

No	Activity	Result
1	Truck arrival	Success
2	Installation of container attributes	Success
3	Stacking block allocation	Success
4	Unloading of containers from trucks	Success
5	The process of stacking containers	Success
6	Ship arrival	Success
7	Departure of the ship	Success

Figure 3.18 Model Activity Verification

The data above illustrates that the verification procedure of testing the model's conceptualization was successful. The initial procedure, namely the truck's arrival, was successful after the truck came after a predetermined period. The procedure of assigning attributes to each arriving container is then completed successfully for each incoming container.

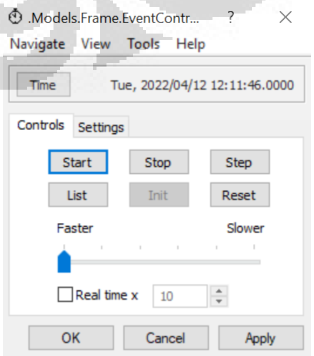


Figure 3.19 Time Controller Verification

The time controls display the simulation's exact time.

3.5.2. Validation

Validation is carried out by conducting tests based on weekly field performance data. The test is carried out by comparing the stacking area utilization in the model with the stacking area utilization performance data. The following is a comparison of the utilization of the stacking area in the model and the real situation data in NPCT1.

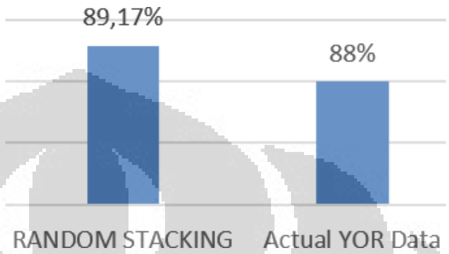


Figure 3.20 Yard Occupancy Validation

Based on NPCT1 data, the average utilization of the stacking area in NPCT1 is 88%. While the data generated from the model, the utilization ratio of the stacking area is 89.17%. The difference of 1.17% between the performance of the container terminal model and the container terminal in the real world is a small enough difference that it can be stated that the model is valid. Therefore, the validity of the model is 98.83%. The validity above 80% is really acceptable and greatly preferred according to acceptable range for Cronbach alpha test of reliability (Cortina, 1993).

CHAPTER IV

RESULTS AND ANALYSIS

Following the collection and processing of data in the previous chapter, the next stage is to assess the findings of the investigation. In the container stacking area, this chapter will compare the 3 approaches for stacking containers. The ultimate result is a description of container stacking processes in the stacking yard area. The end result of this chapter will provide a foundation for the following chapter, namely the chapter of findings and recommendations.

The analysis and outcomes of this study will be presented after an explanation of the factors employed as indicators in this investigation. Following that, it will be continued by examining the results of the models developed during the research. The fundamental model and model development with the stacking strategy approach were used as findings. After viewing the model's results, a comparison of various strategies in stacking containers in the stacking area will be made. The end result is an explanation of the comparative evaluation of the 3 stacking methods and their impact on container terminal productivity.

4.1. Parameter Analysis

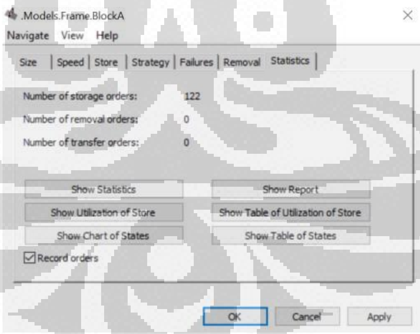


Figure 4.1 Simulation Orders Result in Plant Simulation

Parameter analysis was utilized to describe the aims of the research and the parameters used in this investigation. The goal of designing a container terminal model using a discrete-based modeling approach is to give a knowledge and evaluation of the performance of a container terminal based on a stacking strategy in the stacking area. The reshuffling process in the unloading process from the stacking area is the primary signal employed. Because the containers to be taken are blocked by other containers, this reshuffling is an action to unload heaps of containers. After the simulation is completed, Plant Simulation can generate the following data relating to the above indicators:

1. Number of Store Orders
   This statistic displays the number of crane movements made in the stacking area to stack containers. This data displays how many containers enter each stacking area block. Because each store order represents one container stacking action. The reshuffling procedure is unknown in the container stacking process, hence each number of store orders indicates one container stacking activity.
2. Number of Removal Orders
   The number of removal orders represents the number of crane movements made while removing containers from the stacking area. Only after the container has been successfully removed from the stacking area is the value calculated. As a result, the number of crane orders indicates the number of containers leaving each block's stacking area.
3. Number of Transfer Orders
   This data indicates how many containers were transported to other stacks while unloading containers from the stacking area. Every crane movement that does not go to the head truck to be carried to the dock is calculated. In other words, the number of transfer orders reflects the number of reshuffles caused by the stacking area demolition operation.

The simulation results in Plant Simulation are shown in **Figure 4.1**

4.2. Model Results

Next, the final results of the simulation will be presented. The simulation data results will be per stacking block. Each model has 3 stacking area blocks. The results that will be seen at this stage are the number of reshuffling events per stacking block and the total number of crane movements for the unloading process of the stacking area.

4.2.1. Category Stacking Based on Destination

BASED ON DESTINATION					
BLOK	MOVEMENT	OUT CONTAINER	RESHUFFLING	RESHUFFLING (%)	YOR
A	48	30	18	37,5	95
B	88	79	9	10,22727273	95
C	60	60	0	0	96,2
TOTAL	196	169	27	13,7755102	95,4

Figure 4.2 Reshuffling Table for Category Stacking Based on Destination

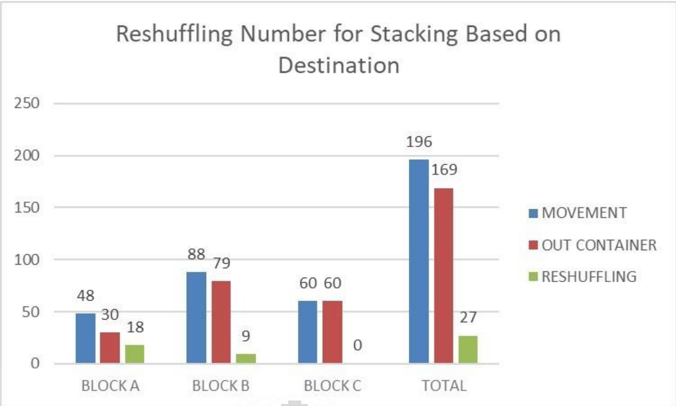


Figure 4.3 Reshuffling Graph for Category Stacking Based on Destination

The results of the Category Stacking Based on Destination model above show that reshuffling events only occur in 2 of the 3 stacking blocks. Reshuffling occurred by 37.5 percent in block A and 10.2 percent in block B. Meanwhile, in block C, no reshuffling occurred at all. The average total reshuffling in the Category Based on Destination model is 27 reshuffling out of 196 movements, which is 13.78 percent.

This little reshuffling activity suggests that emptying containers from the stacking area is an efficient activity. Almost every movement of the gantry crane is to transport containers from the stacking area to the stacking area.

Because not all containers with ship qualities can be assigned to distinct stacks, reshuffling happens. A stack must include many containers with ship properties. It's merely that containers with different ship qualities put on the same stack must ensure that the ships' schedules do not overlap. As a result, the probability of emptying the container pile after other containers have been brought to the ship grows. However, because container truck arrival is uncertain, numerous container trucks may arrive while the allotted container spots are still occupied by containers from other ships.

Because it has a low proportion of reshuffling, the model with the container stacking approach and category stacking based on destination performs quite well in the container stacking area. So that gantry cranes can be used to carry containers from the stacking area to the headtruck for onward transport to the wharf.

4.2.2. Category Stacking Based on Vessel

BASED ON VESSEL					
BLOK	MOVEMENT	OUT CONTAINER	RESHUFFLING	RESHUFFLING (%)	YOR
A	254	157	97	38,18897638	94,46
B	70	37	33	47,14285714	96,59
C	124	103	21	16,93548387	96,83
TOTAL	448	297	151	33,70535714	95,96

Figure 4.4 Reshuffling Table for Category Stacking Based on Vessel

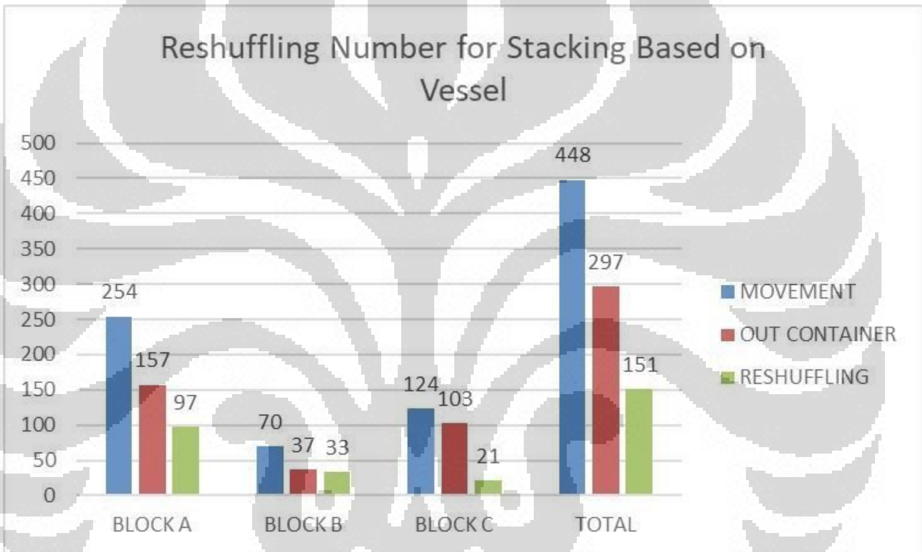


Figure 4.5 Reshuffling Graph for Category Stacking Based on Vessel

The results of the Category Stacking Based on Vessel model above show that reshuffling events occur in all stacking blocks. Reshuffling occurred at 38.18 percent in block A, 47.14 percent in block B, and 16.93 percent in block C. The total average reshuffling in the Category Based on Vessel model was 151 reshuffling out of 448 movements, which was 33.7 percent.

According to these findings, more than half of the gantry crane movements are for reshuffling operations caused by container stacking that is not in agreement with the operational design of the container terminal. This is a barrier to enhancing container terminal productivity. If the percentage of reshuffling is more than the percentage of the container departing itself, the unloading operation from the stacking area takes twice as long. Because every unloading process from the stacking area is constantly followed by reshuffling activities, which constitute a waste in container terminal operations.

The high percentage of reshuffling activity is due to an accumulation of containers that have not been changed in accordance with the order in which the ships arrive. Container unloading operations from the stacking area is timed to coincide with the ship's arrival at the port. Then, in the container stacking area, the order of unloading activities will be modified between the ship's name and the ship's name attribute in each container. In this strategy, containers are sorted on the same stack based on destination attributes. Containers, on the other hand, are not consistently mentioned on the ship's name attribute. As a result, there will be a lot of reshuffling during the emptying process. As a result, the container unloading order did not match the container layout order.

4.2.3. Random Stacking

RANDOM STACKING					
BLOK	MOVEMENT	OUT CONTAINER	RESHUFFLING	RESHUFFLING (%)	YOR
A	253	84	169	66,79841897	89,22
B	260	85	175	67,30769231	89,11
C	242	79	163	67,3553719	89,18
TOTAL	755	248	507	67,15231788	89,17

Figure 4.6 Reshuffling Table for Random Stacking

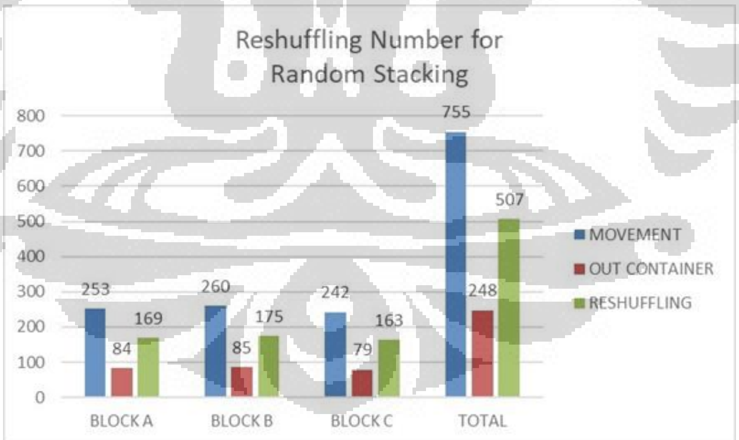


Figure 4.7 Reshuffling Graph for Random Stacking

The results of the Random Stacking model above show that reshuffling events occur in all stacking blocks. Reshuffling occurred at 66.79 percent in block

A, 67.3 percent in block B, and 67.35 percent in block C. The total average reshuffling in the Random Stacking model was 507 reshuffling out of 755 movements, which was 67.15 percent.

These results indicate that about half of the gantry crane activities are for reshuffling. This certainly affects the length of time for unloading containers from the stacking area. Even in several stacking blocks, reshuffling activities are more numerous than activities to move containers onto the head truck.

4.3. Comparison of Model Results

4.3.1. Reshuffling Rate

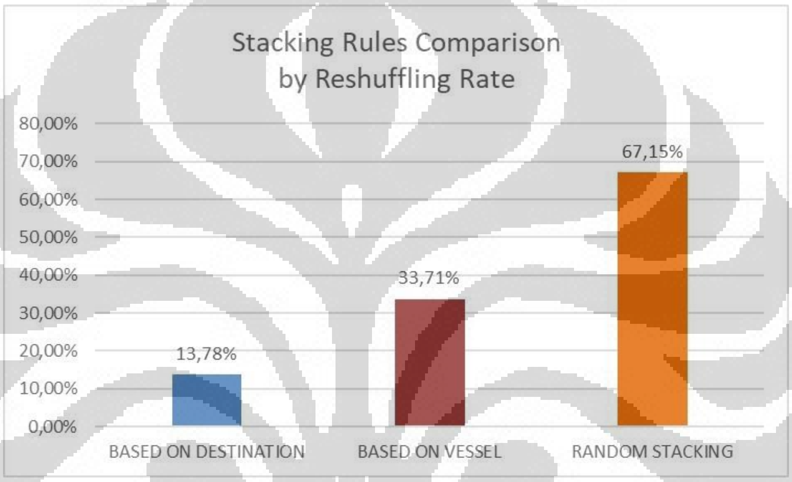


Figure 4.8 Reshuffling Rate Comparison Graph

The stacking rule Category Based on Destination has the lowest reshuffling rate (13,78%). The lower the reshuffling rate, the more efficient it is. Because reshuffling events reveal whether or not a container is stacked correctly in the stacking area, the percentage indication for these events is the primary indicator. The percentage of reshuffling on the three models is contrasted in the table below. The % value given here represents the model's overall stacking block reshuffle percentage.

4.3.2. Yard Occupancy Ratio

BASED ON DESTINATION	BASED ON VESSEL	RANDOM STACKING	Actual YOR Data
95,40%	95,96%	89,17%	88%

Figure 4.9 Yard Occupancy Ratio Comparison Table

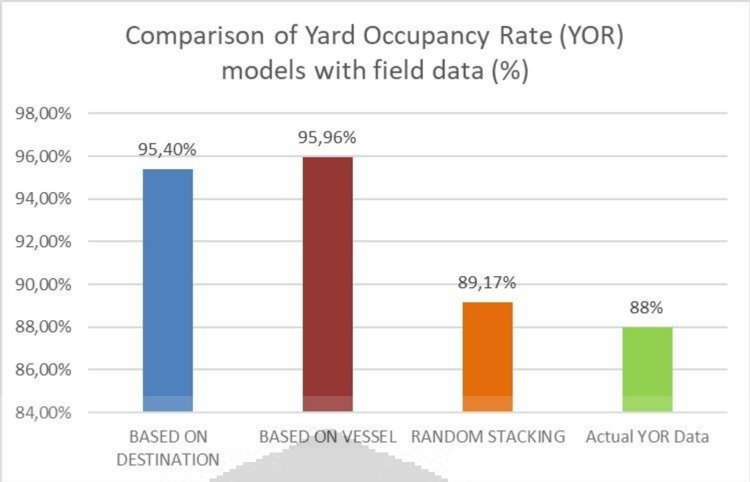


Figure 4.10 Yard Occupancy Ratio Comparison Graph

Yard Occupancy Ratio shows the performance data of stacking area utilization. In the Category Stacking model created in Plant Simulation, it can be seen that the area utilized in the model is larger than the real field YOR data.

4.4. Evaluation of Model Results

Depending on the model's final results in the preceding section, the three indicators used as a reference suggest that stacking containers based on ship characteristics delivers the best performance (Category Stacking Based on Destination). According to the three indications, the approach yields the least number, reflecting the efficiency of container unloading activities in the stacking area.

Essentially, the container unloading procedure will be tailored to the ship's arrival at the pier. Containers from ships that dock first will be unloaded first in the stacking area. As a result, it is critical to stack containers in groups based on the ship that will deliver them. So that containers from one ship do not mingle with containers from other ships. Finally, it will make unloading containers from the stacking area easier.

The model with the destination-based category stacking approach, on the other hand, does not stack containers in groups based on the ship that will convey them. Because stacking is solely determined by the container's function. Meanwhile, the containers are stacked randomly rather than clustered when seen through the ship's properties. Finally, there will be issues throughout the container unloading procedure. Because the containers will be picked up by the gantry crane in the sequence in which the ships arrive at the dock.

However, stacking approaches based on destination qualities are still relevant in the design of container terminal operations. In reality, aside from the arrival of ships anchored at the wharf, there is also a matter of planning for stacking on board at the container port (Stowage Planning). The destination of the container is the most essential component in stacking on board. Because the container with the most distant destination must be at the bottom of the stack. So that it does not obstruct the operation of loading and unloading containers at the next port.

As a result of an examination of the model architecture and container stacking simulation, it is possible to conclude that Category Stacking Based on Destination is the optimum strategy.

CHAPTER V
CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Based on research conducted by researchers by simulating container models over 9 days of simulation time beginning with 4 days of startup, the following findings may be concluded:

1. Researchers were successful in developing a discrete-event simulation-based container terminal model that represents the activity of loading and export containers from the time the container enters the container terminal to the time the container is transported on board.
2. The model was able to represent the process of stacking containers in the stacking area using three types of stacking methods: category stacking basedon destination, category stacking based on vessel, and random stacking.
3. The category Stacking Based on Destination approach produced the least reshuffling activity, resulting in the maximum efficiency in container stacking activities in the stacking area. Reshuffling accounts for just 13.78% of total crane movement.

According to research, the category stacking approach based on destination has the highest performance since it creates the least amount of reshuffling. Other metrics, such as the number of gantry crane movements and the percentage of gantry crane movements, similarly reveal low values. So, in this model for the stacking yard approach, category stacking based on destination is superior to category stacking based on vessel and random stacking.

However, in order to develop operational activities for stacking containers that are more true with real-world settings, stowage planning concerns (stacking of containers on ships) must be taken into account. This model does not take these factors into account. As a result, the destination-based category stacking strategy can still have a considerable influence on container port operating performance. When discharging containers from the stacking area, the activity of stacking containers on ships is taken into account.

5.2. Recommendation

To be produced, extensive research on the operation of each container terminal is required. Because the container terminal's activities and operations are highly complicated. As a result, the researcher has some recommendations for the future development of this research, which are as follows:

1. The use of Discrete Event Simulation software which is more up-to-date in terms of visualization in the future.
2. The next model development is expected to be able to use other methods that are more complex and have more variables as consideration for container stacking methods such as Allocation Methods, Ship Queues, and Crane Placement.
3. The development of the next model is expected to be able to incorporate other factors such as stowage planning and other factors for the complexity of container terminal operations. So that the model is able to more closely represent the container terminal in the real world.

REFERENCE

A. Rofiq, “Jakarta highway,” Journal of Business Research, vol. 2, no. 2, pp. 12-119, 2010.

A. Salim. (2016). The ptp container capacity is targeted to reach 11.5 million TEUs. [Online]. Available: http://www.antaranews.com/berita/584029/kapasitas-peti-kemas-pelabuhan-tanjung-priok-ditargetkan-115-juta-teus

Alderton, P. M. (Patrick M. (2008). Port Management and Operations. Igarss 2014. https://doi.org/10.1017/CBO9781107415324.004

Anita, S. L., & Asmadewa, I. (2017). Analisis Dwelling Time Impor Pada Pelabuhan Tanjung Priok Melalui Penerapan Theory of Constraints. Jurnal Perspektif Bea Dan Cukai, 1(1). https://doi.org/10.31092/jpbc.v1i1.125

Arvis, J. F., Ojala, L., Wiederer, C., Shepherd, B., Raj, A., Dairabayeva, K., & Kiiski, T. (2018). Connecting to compete 2018: trade logistics in the global economy-the logistics performance index and its indicators.

CLARISA, CLAUDIA ANDHARISTA (2021) PENANGANAN STACK PETIKEMAS DOMESTIK DI CONTAINER YARD TERMINAL BERLIAN OLEH PT. BERLIAN JASA TERMINAL INDONESIA (BJTI PORT) SURABAYA. KARYA TULIS.

CMA CGM. (2017). CMA CGM Containers.

Cortina, J. M. (1993). What is coefficient alpha? An examination of theory and applications. Journal of applied psychology, 78(1), 98.

Feng, Y., Song, D. P., & Li, D. (2022). Smart stacking for import containers using customer information at automated container terminals. European Journal of Operational Research, 301(2), 502-522.

Gultom, E. (2017). Pelabuhan Indonesia sebagai Penyumbang Devisa Negara dalam Perspektif Hukum Bisnis. Kanun : Jurnal Ilmu Hukum, 19(3), 419–444. https://doi.org/10.24815/kanun.v19i3.8593

Güven, C., & Eliiyi, D. T. (2014). Trip allocation and stacking policies at a container terminal. Transportation Research Procedia, 3, 565-573.

Hassan, R., & Gurning, R. O. S. (2020). Analysis of the container dwell time at container terminal by using simulation modelling. International Journal of Marine Engineering Innovation and Research, 5(1).

J. D. Sterman, (2000). Systems Thinking and Modeling for a Complex World. Https://doi.org/10.1108/13673270210417646

Legato, P., Mazza, R. M., & Trunfio, R. (2010). Simulation-based optimization for discharge/loading operations at a maritime container terminal. OR Spectrum, 32(3), 543–567. https://doi.org/10.1007/s00291-010-0207-2

Li, W., Wu, Y., & Goh, M. (2015). Planning and scheduling for maritime container yards: Supporting and facilitating the global supply network. Planning and Scheduling for Maritime Container Yards: Supporting and Facilitating the Global Supply Network, (Stromberg 2015), 1–110. https://doi.org/10.1007/978-3-319-17025-1

Mes, M. (2017). Simulation modelling using practical examples: a plant simulation tutorial.

Moeis, A., Chaulan, T.A.C., Zagloel, T.Y., Hidayatno, A., & Iman, M.R.N. (2018) Analysis of Container Terminal Yard Truck and Yard Allocation Operations

Moeis, A., Tantri, L.E., Zagloel, T.Y., Hidayatno, A., Mubarak, A. & Destyanto, A.R. (2019) Design of Berth Allocation Problem Visual Model: Case

Muchtar,2001. Penerapan Teori Dasar Ekonomi Internasional

Prakoso, A., Moeis, A. O., & Sayuti, K. (2017). Tanjung priok port development policy effect analysis to DKI jakarta economic growth with system dynamic approach. Int. J. Struct. Civil Eng. Res., 6(4).

PT Pelabuhan Indonesia II. (2015). IPC 2015 Annual Report.

Rafi, S., & Purwanto, B. (2016). Dwelling Time Management (Antara Harapan dan Kenyataan di Indonesia) Salahudin. Jurnal Manajemen Bisnis Transportasi Dan Logistik (JMBTL), 2(2), 220–228.

Rouli Samaria, R., Moeis, A. O., Sihombing, T. T. A. H., & Destyanto, A. R. (2021). The Development of Stowage Planning Model for General Cargo Ship and Cargo Barge Vessel. Jurnal Penelitian Transportasi Laut, 23(1), 9–18.

https://doi.org/10.25104/transla.v23i1.1700

Siemens Industry Software. (2019). Tecnomatix Plant Simulation Help. https://docs.plm.automation.siemens.com/

Stahlbock, R., & Voß, S. (2008). Operations research at container terminals: A literature update. OR Spectrum, 30(1), 1–52. https://doi.org/10.1007/s00291-007-0100-9

Strategies: Port of Tanjung Priok, Indonesia. Paper presented at the 3rd Belt & Road Conference, Saigon, Vietnam. p.28

Study Indonesian Port of Tanjung Priok. Paper presented at the 4th Belt & Road Conference, Bangkok, Thailand. p.56

T. E. Notteboom and J. P. Rodrigue, (2005). Port regionalization: towards a new phase in port development. Maritime Policy & Management, 32 (3), 297-313. [Online]. Available: Https://doi.org/10.1080/03088830500139885

TomTom Traffic Index. (2016). Jakarta Congestion TomTom. Retrieved January 1, 2017, from https://www.tomtom.com/en_gb/trafficindex/city/jakarta

World Bank. (2013). High logistics costs hamper Indonesia's economic