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ANALYSIS OF WAITING TIME AND OPERATIONAL EFFICIENCY OF LOADING AND UNLOADING AT THE NEW MAKASSAR CONTAINER TERMINAL USING DISCRETE HEADTRUCK SIMULATION

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Abstarct:This research aims to analyze waiting times and operational efficiency in the loading and unloading process at the New Makassar Container Terminal (Terminal 1) using the Headtruck (HT) discrete simulation model. The focus of this research is to identify the duration of waiting time for trucks and find solutions to reduce the queues that occur. The method used in this research is discrete simulation, where a simulation model is applied to map the truck queuing process at Stacking Yards I and K. The data used includes HT travel time, RTG (Rubber-Tyred Gantry) and RS (Reach Stacker) service times. , as well as the current operational conditions of the terminal. The findings from this research show that the average waiting time for trucks at Stacking Field I reached 84.03 minutes. By implementing the scenario of adding 1 Reach Stacker unit, the waiting time was successfully reduced to 2.69 minutes, which resulted in a reduction in fuel costs of IDR. 5.22 million per day. Apart from that, the HT handling capacity has also increased, with the Stacking Field I block capable of handling 32 HT per day, higher than the previous condition. These results indicate that additional equipment can increase terminal operational efficiency. The conclusion of this research is that the application of discrete simulation models in waiting time analysis can provide an effective solution to improve operational performance at the New Makassar Container Terminal. The addition of the Reach Stacker tool has been proven to reduce waiting time and fuel costs, as well as increasing HT handling capacity. This research also provides recommendations for further research using other simulation software and considering external factors that influence terminal operations.

Keywords: Waiting Time and Operational Efficiency of Loading and Unloading

INTRODUCTION

A container terminal is a port facility specifically designed to handle containers in loading and unloading activities [1]. This terminal functions as a logistics center that supports the efficient transportation of goods using a containerization system, where goods are packaged in standard containers to facilitate transportation, handling and storage [2]. Container terminals are usually equipped with infrastructure such as special docks, cranes for loading and unloading containers from ships [3], as well as temporary storage areas before goods are further distributed via land or sea transportation modes [4]. Organized processes at this terminal help speed up the flow of goods and reduce logistics costs [5].

Container terminals have a strategic role in the global supply chain [6]. Apart from being a loading and unloading center, this terminal is a connecting hub between modes of transportation, such as ships, trucks or trains. Each terminal is usually equipped with a technology-based management system to manage container movements effectively [7], including position tracking and delivery schedules [8], [9]. Modern container terminals also adopt efficiency and sustainability principles, such as the use of energy-saving equipment and automation systems to reduce carbon emissions [10]. In this way, container terminals not only support international trade, but also have a significant economic impact on the surrounding areas.

For example, the Singapore Container Terminal at PSA Port is one of the busiest terminals in the world. This terminal handles millions of TEUs (twenty-foot equivalent units) containers every year, making it a major distribution center for international trade in the Asia-Pacific region [11]. With advanced technology such as Automated Guided Vehicles (AGVs) and automatic cranes, this terminal is able to significantly increase loading and unloading efficiency [12]. Singapore also takes advantage of its strategic location as a crossroads of global trade routes, so that its container terminals become important hubs connecting more than 600 ports throughout the world. The success of the PSA Terminal reflects how modern management and technology integration can increase a country's logistics competitiveness.

Another example is the Tanjung Priok Container Terminal in Indonesia, which implemented a discrete simulation model to optimize headtruck operations in the loading and unloading process [13]. This terminal faces challenges such as long queues and high waiting times due to the high volume of containers [14]. By using discrete simulation, managers can analyze various headtruck movement scenarios, such as optimal route allocation, arrival time, and loading and unloading scheduling. One of the results is a reduction in headtruck idle time by up to 20% and an increase in overall terminal throughput. This approach helps terminals deal with growing trade and improve efficiency without the need for significant physical expansion.

The New Makassar Container Terminal (Terminal 1) as the main gateway for container flows in the Eastern Region of Indonesia is facing the challenge of overcrowding in line with the increasing volume of goods. Intensive loading and unloading activities often cause long queues, even spilling out of the port area, which disrupts the smooth distribution of logistics. To overcome this problem, the Makassar Port Branch continues to strive to improve services, including optimizing infrastructure, managing goods traffic, and implementing terminal management technology. These steps aim to minimize congestion, speed up the loading and unloading process time, and maintain the position of the New Makassar Container Terminal as a reliable logistics gateway in the region.

The research gap in this study lies in the lack of studies that specifically apply discrete simulation models to analyze and optimize headtruck flow in the loading and unloading process at the New Makassar Container Terminal (Terminal 1), even though challenges such as long queues and congestion are often the main problems at this terminal. . Previous research has focused more on increasing physical capacity or implementing general technologies without exploring the potential of discrete simulation as a predictive tool and data-driven solution. The novelty of this research is the application of discrete simulation to produce optimal scenarios that can reduce queue times significantly, making a real contribution to the operational efficiency of container terminals as the main logistics gateway in Eastern Indonesia.

METODOLOGY

This research is quantitative research that uses numerical data to describe the research process from collection to presentation of results. The focus of the research is to analyze the movement of containers at the New Makassar Container Terminal (Terminal 1). This research aims to provide an alternative to increasing the capacity of the stacking yard without expanding the area and measuring the effect of the number of loading and unloading equipment on terminal performance. This research uses Discrete Event Simulation (DES) via Arena Software to simulate terminal operational scenarios, with the aim of speeding up experiments, minimizing risks and costs, and evaluating system performance. Two types of models are applied in this research, namely physical (iconic) models which are small-scale representations of real systems to understand interactions and conduct experiments, and mathematical (logic) models which are based on quantitative structures to save time, costs and risks. Through this approach, research seeks to understand, improve, and increase the efficiency of the system as a whole.

Data collection techniques in this research include literature studies to provide an overview of problems such as queues at terminals and utility equipment, as well as primary and secondary data collection. Primary data includes service time at the gate and stacking yard, number of loading and unloading equipment, as well as truck arrival times and service at the dock, while secondary data includes the number of domestic truck arrivals, terminal layout and stacking yard. The data that has been collected is analyzed using Arena Software to simulate the Headtruck (HT) flow in the loading and unloading process. The data presentation includes a terminal equipment table showing the availability of 6 QCC, 18 RTG, 5 RS, and other equipment that supports terminal operations, as well as berth allocation information where the terminal has 3 main berths for containers (B1, B2, B3) with dock length reaches 750 meters. Apart from that, data is presented regarding blocks and field capacity, such as the number of blocks A to N with varying capacities, where block A is the block with the largest capacity, namely 5005 TEUs.

Data analysis in this research was carried out in several stages, starting with collecting references, which included literature related to previous research and current terminal conditions. Next, identification of existing conditions is carried out, which includes analysis of the duration of waiting time and the utility of the equipment used at the terminal. The collected data is then processed using simulation to evaluate queues and equipment performance, which will provide an overview of the terminal's operational efficiency. The next stage is preparing a scenario model, where scenario simulations are carried out to reduce waiting time by implementing a more efficient workflow. The resulting simulation results are expected to provide a more effective model, which can reduce waiting times and overall increase terminal operational efficiency.

RESULTS AND DISCUSSION

New Makassar Container Terminal (Terminal 1)

To find out the existing condition of the New Makassar Container Terminal (Terminal 1), the author conducted interviews and direct observations to obtain information related to business process flow, operational performance and available facilities. One of the important aspects found was the equipment and facilities that support container loading and unloading activities. This terminal has two main types of gates, namely Gate Receiving and Gate Delivery. Gate Receiving is used for the arrival of containers to be unloaded, while Gate Delivery is used for the delivery of containers that have been unloaded and are ready to be sent to their destination. These two gates have a very important role in managing the flow of goods and ensuring smooth operations at the terminal.

Figure 1. Gate Receiving dan Gate Delivery

At the New Makassar Container Terminal (Terminal 1), the Gate Receiving and Gate Delivery facilities have several gates that support smooth operations. At Gate Receiving, there are two entrance gates for Headtruck Receiving which are used to receive arriving containers into the terminal. Meanwhile, on the other side of the terminal, there is a Gate Out which is equipped with two exit gates, namely Headtruck Receiving which brings containers into the terminal and Headtruck Delivery which brings containers out of the terminal. This arrangement facilitates the flow of goods in and out, as well as ensuring the smooth loading and unloading activities at the New Makassar Container Terminal (Terminal 1).
In the process of loading and unloading activities at the New Makassar Container Terminal dock (Terminal 1), the tool used to move container cargo from the ship to the port terminal or vice versa is the Quay Container Crane (QCC). QCC is a tool specifically designed to lift and move containers from ship to land, or from land to ship, with a large capacity. The existence of a QCC is very important to speed up and simplify the loading and unloading process at the terminal, considering that this tool can handle large quantities of containers efficiently, as well as ensuring smooth operations at the dock.

Figure 2. Quay Container Crane (QCC)
In Figure 2, it can be seen that the New Makassar Container Terminal (Terminal 1) has 6 units of Quay Container Crane (QCC). The advantage of using a QCC compared to a Harbor Mobile Crane (HMC) lies in the faster service time in handling container loads, so that the loading and unloading process can take place more efficiently and more containers can be processed. At the New Makassar Container Terminal, the use of QCC is divided into three parts, where each berth uses 2 QCC units, which helps ensure smooth operations and increase productivity at the dock.
The New Makassar Container Terminal (Terminal 1) has several types of loading and unloading equipment which function to support container stacking activities in the field. The three main tools used for this activity are Rubber Tyred Gantry Crane (RTGC), Reach Stacker (RS), and Side Loader. The first tool is a Rubber

Tyred Gantry Crane (RTGC), which is used for the stacking process at the New Makassar Container Terminal yard. RTGC allows container stacks to reach a maximum height of 6 rows and 30 slots. This tool is very useful because it can easily pick up containers located in the middle of the stack, optimizing efficiency and simplifying operational processes. As in the example of terminals for overseas shipping (Ocean Going), the use of RTGC is also very common in other container terminals for more orderly and fast stacking. At the New Makassar Container Terminal itself, there are 18 RTGC units spread across various terminal blocks, both for Receiving and Delivery activities, which helps expedite the loading and unloading process.

Apart from RTGC, Reach Stacker (RS) is also used for container stacking activities in the New Makassar Container Terminal yard. Reach Stacker has better mobility than RTGC, which allows this tool to easily move as needed. However, even though it has advantages in terms of mobility, the Reach Stacker also has weaknesses, especially in terms of reach. Reach Stacker cannot directly reach containers located in the middle of the stack. Apart from that, this tool is more wasteful in fuel consumption compared to RTGC. The New Makassar Container Terminal has 5 Reach Stacker units which play a role in supporting stacking activities that require flexibility.

To support the process of moving containers between the stacking yard and the dock, the New Makassar Container Terminal (Terminal 1) uses an Internal Headtruck and Terminal Tractor. The Internal Headtruck has the main function of moving containers from the stacking yard to the dock or vice versa, and also transporting containers that have exceeded the maximum stack limit to Line 2 of the stacking yard. At the New Makassar Container Terminal, there are 4 Internal Headtruck units that operate when ships dock for loading and unloading. The loading and unloading process begins with the movement of the Headtruck which transports the containers to the right location at the dock. Apart from that, the Terminal Tractor is also used to support the movement of 28 containers, which functions to ensure the smooth flow of containers between the stacking yard and the dock during terminal operational activities.

The New Makassar Container Terminal (Terminal 1) has a fairly long dock area and has quite a lot of stacking yards. So for container services good and fast operations are needed. Where at the dock (cade) the QCC loading and unloading equipment is assisted. For loading and unloading equipment at pier 1, 2 QCCs are used, for loading and unloading equipment at pier 2, 2 QCCs are used, and for loading and unloading equipment at pier 3, 2 QCCs are used.

Table 1. Pier area

Pier	Berth (M')	Length Berth (M')	Length (M')	Area
Bulk	KNV	(0-220)	220	Domestic
CC 01 - CC 02	B1	(220-460)	240	Domestic
CC 03 - CC 04	B2	(460-710)	250	Domestic
CC 06 - CC 07	B3	(710-970)	260	Domestic
Special	EXT	(970-1000)	30	Domestic

Source: Terminal 1 Makassar, 2023

Table 1 shows the area of the pier at the New Makassar Container Terminal, which is divided into several piers with different lengths and areas. This pier includes various berths such as CC 01 - CC 02, CC 03 - CC 04, CC 06 - CC 07, and Special KNV, each of which has a length ranging from 220 to 1000 meters, depending on the pier and its function. Piers B1, B2 and B3 are used for domestic activities with a length of between 220 and 260 meters each, as well as different areas to support the loading and unloading process. This dock is also equipped with an EXT extension, which has a length from 0 to 1000 meters, with an area adapted to support domestic container operational needs. This table provides an overview of the distribution of space at the dock for various activities and types of ships operating at the terminal.

Domestic Container Headtruck Flow Conditions

Based on the results of direct observations and interviews, the business process at the New Makassar Container Terminal (Terminal 1) shows that there are queues, both inside the terminal and in front of the entrance gate. Queues in the terminal occur due to external HTs waiting their turn to be served by loading and unloading equipment such as RTG or RS. Meanwhile, queues at the terminal entrance gate occur when HT containers wait their turn to be served by the Receiving or Delivery Entry Gate. The business process flow at this terminal includes various stages, starting from the arrival of the HT at the gate, checking documents, to the process of loading and unloading containers.

The loading and unloading process itself consists of a series of stages involving various activities, such as ship and port preparation, notification of ship arrival, document inspection, physical inspection, loading and unloading of goods, stockpiling of goods, and delivery of goods. In each stage, the documents required are divided into three main groups, namely loading documents, unloading documents and in/out clearance documents. During the loading and unloading process at the port, various procedures must be followed, including stevedoring, cargodoring, and receiving/delivery, to ensure smooth distribution of goods between ports. This process requires quite a long time and involves good coordination between related parties to ensure that goods can move safely and on time.

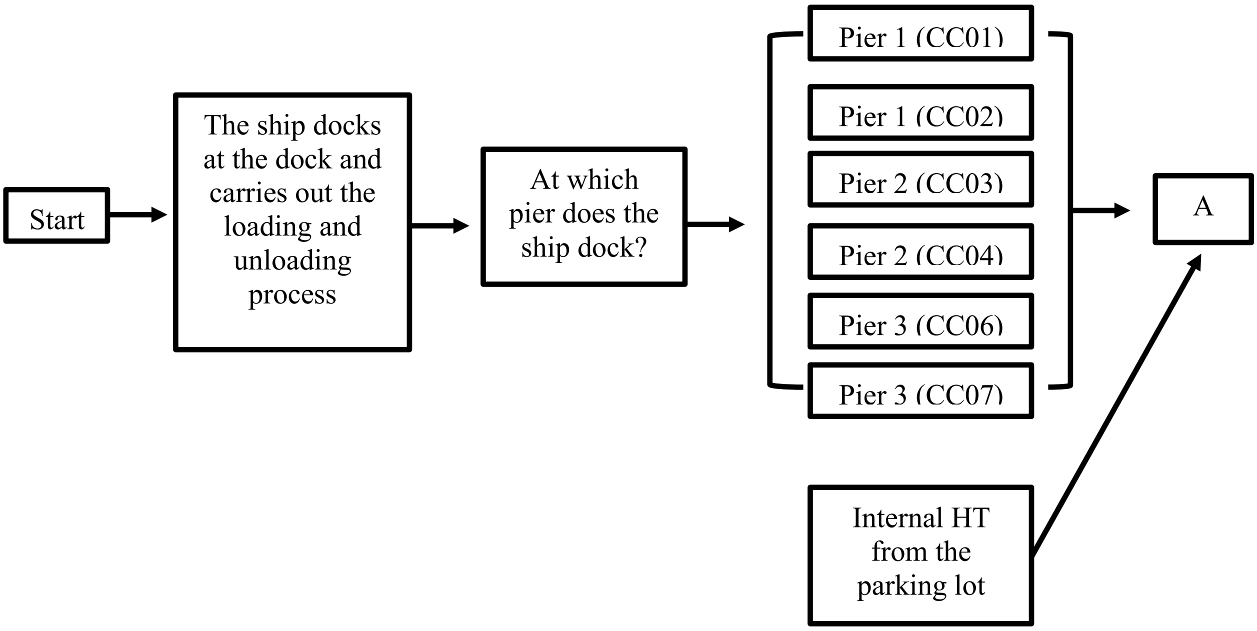

Figure 3. Unloading Activity Process

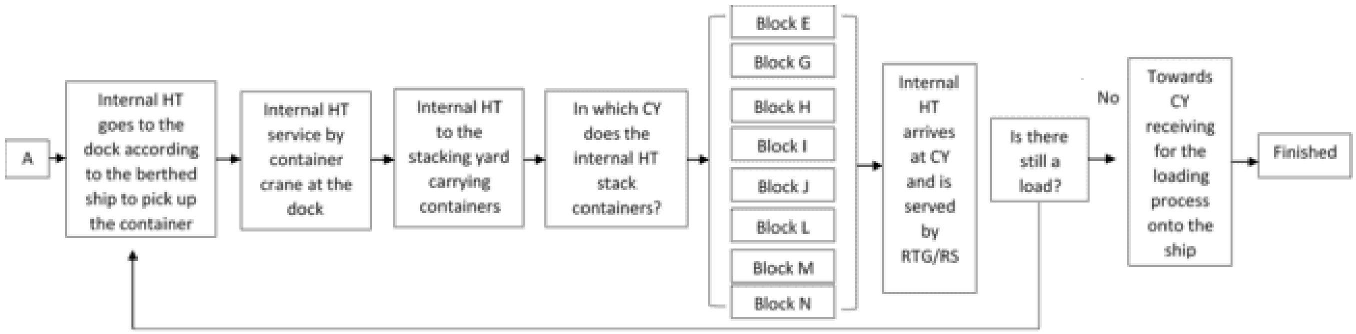

Figure 4. Unloading Activity Process

In figures 3 and 4, the unloading process begins when the ship docks at the pier, either at Piers B1, B2, or B3. After the ship docks, the unloading process begins using a Quay Container Crane (QCC). The containers that have been unloaded are then transported by internal Headtruck (HT) to the stacking yard, with the designated stacking yard destination, between Blocks A-N. Upon arrival at the stacking yard, containers are served by RTG or Reach Stacker (RS) to be stacked in accordance with applicable procedures. After the stacking process is complete, the internal HT returns to the dock until all containers unloaded from the ship have been removed. Furthermore, after the unloading activity is complete, the internal HT will go to the receiving yard to transport the containers back to the ship during the loading process.

The Delivery activity process begins with the release of the imported container, where the gate officer receives the Container Release Letter and carries out verification. If it is not suitable, the container is returned to the consignee; if appropriate, a gate-in transaction is carried out which is monitored by control. Field officers ensure the readiness of personnel and equipment, and inform control. The container lift-on process is carried out by the RTG operator, then updated to the system and monitored by control. Gate also checks the seals and physical condition of containers via CCTV monitors. After the inspection is complete, the container HT can leave to carry the container to the factory or cargo owner's destination. In addition, containers that have piled up at the LINI 1 yard for more than 3 days will be moved to the Line 2 TPS, in a process known as Moving Stacking Yards (PLP) or overbrengen. Containers can be moved to TPS Line 2 after a Goods Release Order (SPPB) document has been issued, and the procedure for releasing them at TPS Line 2 is the same as for releasing imported containers. After payment is completed at TPS Line 2, the container can be taken directly to the factory or cargo owner's destination.

The Delivery process begins with the arrival of the external delivery truck which goes to the Delivery Entrance Gate to check documents. After that, the external truck is directed to the stacking yard location that has been determined by the Gate Operator. Upon arrival at the stacking yard, the external HT is served by RTG or RS which moves the containers from the stacking yard onto the external HT trailer. After the transfer process is complete, the external delivery HT immediately goes to the exit gate carrying the container. At the exit gate, physical checks of containers and documents are carried out. If all documents and the physical condition of the container are appropriate, the container truck is allowed to leave the terminal.

The Receiving activity process begins with the arrival of the receiving external HT which goes to the Receiving Entrance Gate to check documents. After the documents have been checked, the external HT is directed to the stacking yard according to the location determined by the Gate Operator. Upon arrival at the stacking yard, the RTG or RS serves the external HT by moving containers from the external truck to the stacking yard. Once the transfer process is complete, the external truck receives the necessary services and immediately heads to the Exit Gate to exit the terminal.

In the Loading activity process, containers that have been transferred to the stacking yard receive services from the RTG or RS to be moved from the stacking yard to the internal HT. After the container is on the internal HT, this truck transports the container to the dock. At the dock, containers are transferred from the internal HT to the ship by the CC. This loading process continues until all containers have been transported, after which the internal HT returns to the stacking yard and parks in the designated place.

This process runs in an integrated manner with strict supervision. Each stage, such as checking the seal and physical condition of the container, is carried out using a monitoring system that utilizes CCTV and updating data in the system. The process of releasing containers also involves checking the seals and physical condition of the containers before they are released through the exit gate. If there are containers piled up for more than three days, then the Stacking Field Transfer (PLP) or overbrengen procedure is carried out in accordance with applicable regulations, followed by appropriate release procedures after the SPPB document is issued.

For external headtruck receiving data, it is very necessary to be able to see which day the most Ht activity occurs. Truck Turnaround Time is one of the performance indicators in receiving/delivery activities. Truck turnaround time shows how long it takes for a truck belonging to an external customer to complete the entire receiving/delivery process. Based on data processing, it is known that there are still a large number of truck turnaround times with high values that exceed the maximum applicable standards.

Tabel 2. External HT Data Receiving

Day to	HT exits Terminal
1	773
2	543
3	529
4	601
5	666
6	416
7	83
8	67
9	11
10	321
11	443
12	9
13	13
14	95
15	343
16	563
17	499
18	367
19	331
20	172
21	87
22	429
23	425
24	513
25	618
26	565
27	362
28	104
29	363
30	394

In Table 6, based on the Indonesian Trucking Entre[illegible] he waiting time for HT export or receiving at the New Makassar Container Terminal (Terminal 1). So it can be assumed that the normal waiting time for receiving and delivery is 25 minutes and 11 minutes

Replication of the Number of Trucks Exiting the Port Terminal (Units/Day)

After seeing that there are stacking yard blocks that have problems or experiencing obstacles in the process of loading and unloading containers, namely with an average waiting time of 84.03 minutes, it is necessary to carry out a scenario for stacking yard block I. Apart from piling yard block I there is piling yard block K , receiving gate and delivery gate which are included in the scenario division. Because the stacking yard block K (Receiving) is a comparison with the stacking yard block I (delivery) and the delivery gate is a comparison with the receiving gate. Below is a complete breakdown of the scenarios. After carrying out several experiments for scenarios in the field, the results obtained for scenarios 1 to 9 are as follows:

Scenario 1 (Current Conditions at the Receiving Gate)

In scenario 1, it starts when the HT enters the receiving gate and waits at the receiving gate

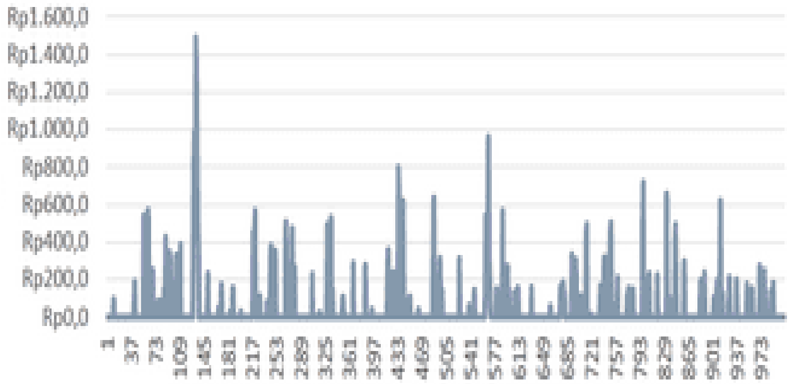

Figure 5. Current Conditions at the Receiving Gate
After obtaining the waiting time at the Receiving Gate, proceed with calculating the cost of Fuel Oil (BBM) waiting at the Receiving Gate. In graphic image 33 which shows fuel costs at Rp. 0 means there is no HT waiting. The fastest waiting time is 0 minutes, the longest time is 3.4 minutes, and the average waiting time is 0.11 minutes. The busiest time for trucks coming to the Receiving Gate is during the day, precisely from 14.00 to 14.30. The total fuel cost for trucks waiting at the Receiving Gate in the current condition scenario in the field is IDR. 48,152.4/day. The total cost is obtained from the number of HTs waiting at the Receiving Gate.
Scenario 2 (Current Conditions in Piling Field I)
In scenario 2, namely for the conditions in the stacking yard I and the conditions while waiting in the stacking yard I.

Figure 6. Current Conditions in Piling Field I
After obtaining the waiting time at the Penumpukan Field I block, proceed with calculating the cost of fuel oil (BBM) waiting at the Penumpukan Field I block. In graphic image 34 which shows the fuel cost at Rp. 0 means there is no HT waiting. The fastest waiting time was 0 minutes, the longest time was 158.69 minutes, and the average waiting time was 84.03 minutes. The busiest time for HTs to come to the Penumpukan Field I block is in the afternoon, to be precise, between 16.00 and 18.00. The total fuel cost for trucks waiting at the Stacking Field I in the current condition scenario in the field is IDR. 5.7 million/day. The total cost is obtained from the number of trucks waiting at the Stacking Field Block I.
Scenario 3 (Current Conditions in the K Piling Field)
In scenario 3, namely for the conditions in the K stacking yard and the conditions while waiting in the K stacking yard.

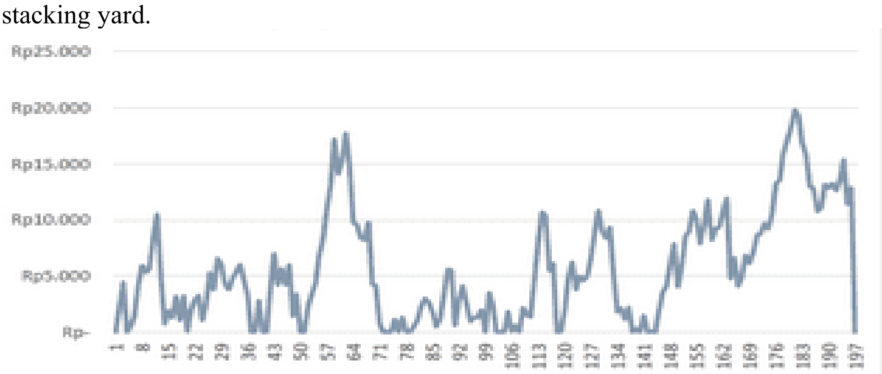

Figure 7. Current Conditions in the K Piling Field
Setelah didapatkan waktu tunggu pada blok Lapangan Penumpukan K, dilanjutkan dengan perhitungan biaya Bahan Bakar Minyak (BBM) yang menunggu di Blok Lapangan Penumpukan K. Pada gambar grafik 35 yang

menunjukan biaya BBM pada Rp. 0 berarti tidak terdapat HT yang menunggu. Waktu menunggu tercepat yaitu 0 menit, waktu terlama 46,1 menit, dan untuk rata-rata waktu tunggu selama 12,9 menit. Waktu paling ramai HT yang datang ke blok Lapangan Penumpukan K yaitu pada sore hari tepatnya pukul 14.00 hingga 16.00. Untuk total Biaya BBM HT yang menunggu di Lapangan Penumpukan K pada sKenario kondisi saat ini di lapangan sebesar Rp. 1 juta/hari. Total biaya tersebut didapatkan dari jumlah truk yang menunggu di Blok Lapangan Penumpukan K.

Scenario 4 (Current Conditions at the Delivery Gate)

In scenario 4, it starts when the HT enters the Delivery gate and waits at the Delivery gate.

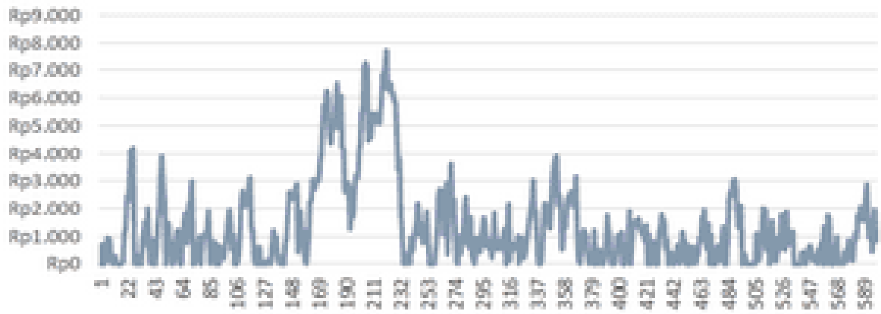

Figure 8. Current Conditions at the Delivery Gate

After obtaining the waiting time at the Delivery Gate, proceed with calculating the cost of Fuel Oil (BBM) waiting at the Delivery Gate. In graphic image 36 which shows fuel costs at Rp. 0 means there is no HT waiting. The fastest waiting time was 0 minutes, the longest time was 17.9 minutes, and the average waiting time was 3.1 minutes. The busiest time for HT to come to the Delivery Gate is during the day, precisely from 14.00 to 15.00. The total cost of HT fuel waiting at the delivery gate in the current condition scenario in the field is IDR. 804,736/day. The total cost is obtained from the number of HTs waiting at the Delivery Gate.

Scenario 5 (Conditions of adding 1 RTG unit in Stacking Field I)

In scenario 5, namely the addition of 1 RTG unit to stacking field I.

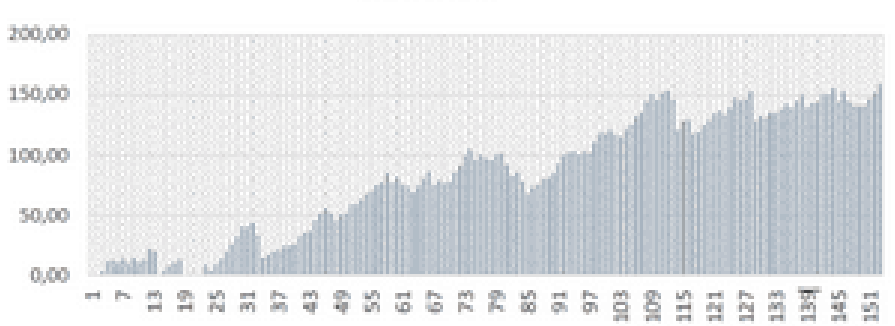

Figure 9. Conditions of adding 1 RTG unit in Stacking Field I

With the addition of 1 unit of RTG equipment, the average HT waiting duration is 84.03 minutes. This has no effect on the current condition time.

Scenario 6 (Conditions of adding 1 hospital unit in Piling Field I)

In scenario 6, namely the addition of 1 unit of hospital equipment in the stacking yard I.

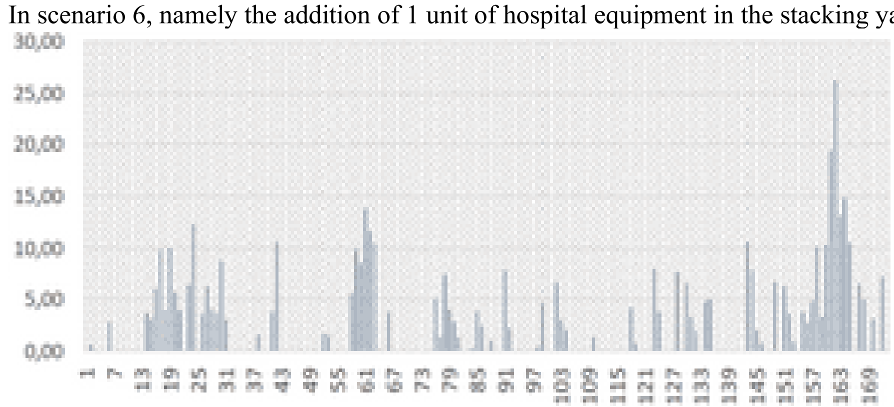

Figure 10. Conditions of adding 1 hospital unit in Piling Field I

With the addition of 1 unit of hospital equipment, the average waiting duration for Ht is 2.69 minutes. The average HT waiting in scenario 2 is the same as scenario 5. The average truck waiting in scenario 2 is different from scenario 6. Therefore, the best scenario is scenario 6. This is very significantly different from the current waiting time. Of the two scenarios that have been carried out, the tool chosen is the Reach Stacker (RS). With an average HT duration of 2.69 minutes after adding 1 unit of RS equipment, with a scenario of 6 blocks of stacking field I can handle 32 HT HTs, more than the current conditions.

Scenario 7 (Conditions of adding 1 hospital unit in Stacking Field K).

In scenario 7, namely the addition of 1 unit of RS equipment to the K stacking field.

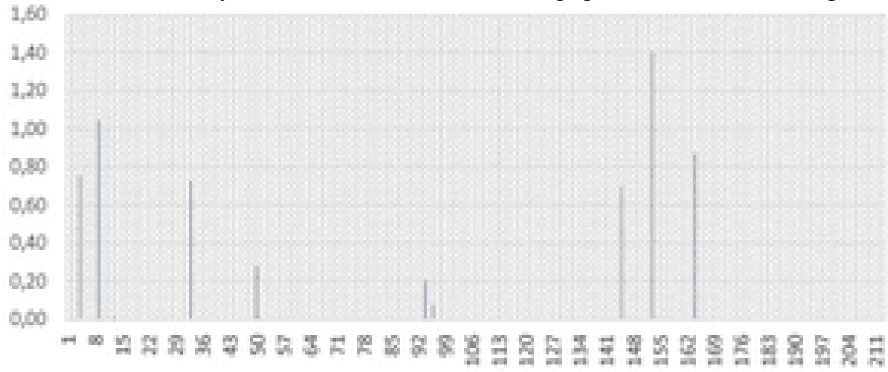

Figure 11. Conditions of adding 1 hospital unit in Stacking Field K

With the addition of 1 unit of hospital equipment, the average HT waiting duration is 0.03 minutes. This is significantly different from the current waiting time. more than in the current situation. With the average HT duration after adding 1 unit of RS equipment, with a scenario of 7 blocks the K stacking yard can handle 431 HT trucks, more than under current conditions.

Scenario 8 (Condition of adding 1 unit of Receiving Gate)

In scenario 8, there is the addition of 1 Receiving gate unit.

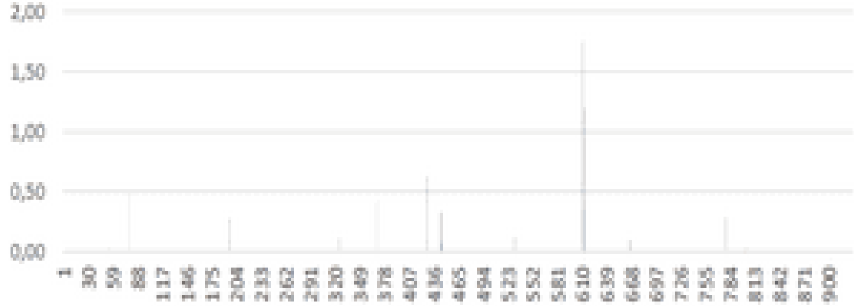

Figure 12. Condition of adding 1 unit of Receiving Gate

After 1 unit of gate counters was added, there were differences from the current conditions. The average waiting time at the Receiving Gate is 0.01 minutes. Waiting time reduction reached 90.9%. By reducing utility the tool can reduce waiting time by 0.1 minutes. With an average HT duration of 0.01 minutes after adding 1 unit of Receiving Entry Gate counter, scenario 8 can handle 2 HTs, more than the current condition..

Scenario 9 (Conditions of adding 1 unit of Delivery Gate)

In scenario 9, there is the addition of 1 Delivery gate unit.

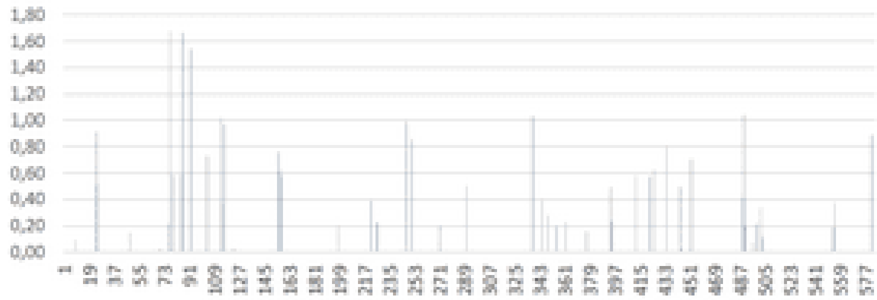

Figure 13. Conditions of adding 1 unit of Delivery Gate

After 1 unit of gate counters was added, there were differences from the current conditions. The average waiting time at the Delivery Gate is 0.05 minutes. Waiting time reduction reached 98.4%. By reducing utility the tool can reduce waiting time to 3.09 minutes. With an average HT duration of 0.05 minutes after adding 1 unit of Delivery Entry Gate counter, scenario 9 can handle 63 HTs, more than the current condition.

Based on the results of the scenarios carried out, the addition of one unit of equipment in each block of the stacking yard and gate shows a significant impact on truck waiting time (HT) and fuel oil (BBM) costs incurred. In scenario 6, the addition of one unit of Reach Stacker (RS) equipment in Stacking Field I succeeded in reducing truck waiting time drastically, with an average waiting time of only 2.69 minutes, lower than the current condition which reached 84.03 minutes . This scenario shows the potential for higher operational efficiency, where Stacking Field I can handle more trucks, namely 32 trucks per unit of time. Apart from that, the addition of units at the Receiving and Delivery gates (scores 8 and 9) also provides significant results in terms of reducing waiting times. The addition of one unit at the Receiving Gate reduces waiting time to only 0.01 minutes, which reduces waiting time by 90.9%, while the addition at Delivery Gate reduces waiting time to 0.05 minutes, with a reduction reaching 98.4%. This shows that adding units in this area can significantly increase truck handling capacity, thereby reducing operational costs and increasing overall efficiency of loading and unloading times.

Calculation of fuel costs at Piling Field I shows that scenario 2, which only uses two RTG equipment, results in fuel costs of IDR 25.13 million per day. On the other hand, in scenario 6, with the addition of one Reach Stacker (RS) unit and two RTG equipment, the total fuel costs decrease to IDR 13.18 million per day. This shows savings of IDR 11.94 million per day. The addition of the Reach Stacker tool contributes significantly to reducing waiting time and fuel costs, although the tool's utility is still within safe limits. Therefore, even though the level of tool utility in both scenarios is still within reasonable limits, the addition of one Reach Stacker unit in scenario 6 is still necessary to increase operational efficiency. The resulting reduction in waiting time not only reduces fuel costs, but also improves the performance and effectiveness of processes at the New Makassar container terminal (Terminal 1), which will support the smooth flow of containers and reduce overall operational costs.

Calculation of fuel costs at the K Piling Field shows that scenario 3, with one RTG device, results in fuel costs of IDR 25.40 million per day. Meanwhile, in scenario 7, with the addition of one Reach Stacker (RS) unit, the total fuel costs are reduced to IDR 14.1 million per day. This savings in fuel costs of Rp. 11.2 million per day shows that the addition of RS equipment not only increases operational efficiency but also reduces expenditure on fuel. This cost calculation is used to compare fuel costs incurred in the Delivery and Receiving Stacking Field blocks, in order to evaluate the effectiveness of resource management at the container terminal.

After analyzing the impact of waiting time on fuel costs and equipment utilities, the next step is to carry out a cost benefit analysis to assess the feasibility of procuring an additional 1 unit of Reach Stacker. The focus of this cost benefit analysis was carried out on the Stacking Field I block, because this block shows the most severe waiting times, which can have a significant impact on operational efficiency. In this case, the procurement of Reach Stacker equipment is expected to reduce waiting time, increase equipment utility, and optimize the use of existing resources at the container terminal.

Calculation of capital costs for procuring a Reach Stacker shows the total cost of purchasing equipment is IDR 5,068,346,347. This cost includes the procurement of Reach Stacker equipment needed to increase efficiency in Stacking Field I. Meanwhile, in calculating operational costs, a number of other expenses are also considered, such as operator salaries, equipment maintenance costs, and fuel consumption. The total operational costs calculated reached IDR 1,224,122,045 per year. With this analysis, it can be understood how much expenditure is needed for additional operational equipment at the terminal.

On the other hand, the calculation of the benefits resulting from the procurement of the Reach Stacker tool shows quite significant figures. From an operational perspective, the benefits obtained from container handling, lift on/lift off, and terminal entry tickets are estimated to reach IDR 2,752,100,000 per year. These benefits include time savings and increased productivity in the container service process, which can have a direct impact on terminal revenues. Apart from that, other benefits that cannot be measured directly in monetary terms, such as increasing the efficiency of equipment performance and stability of equipment movement, also have a positive impact on terminal operations.

Overall, the cost benefit analysis shows that procuring a Reach Stacker can provide greater benefits than the costs incurred. Although there are significant initial costs for equipment procurement and annual operational costs, the benefits derived from increased efficiency and reduced waiting times, as well as increased terminal productivity, provide significant benefits. Therefore, it is feasible to procure Reach Stacker equipment at Stacking Field I in order to improve operational performance and reduce costs arising from long waiting times.

This analysis shows that increasing the capacity and operational efficiency of port terminals can be achieved through the addition of equipment such as the Reach Stacker (RS). The significant reduction in waiting time in the scenario with the addition of hospitals in Stacking Fields I and K reflects the principles of operations management theory which emphasizes the importance of reducing bottlenecks in the system to increase efficiency. According to production and operations systems theory, reducing waiting times and increasing truck handling capacity directly reduces operational costs, including fuel costs, which is one of the main components in cost management in port terminals [15].

Supply chain management theory is also relevant in this context, where efficiency in every stage, from receipt of goods to delivery, is very important to create a smooth flow of goods and reduce total costs [16]. The addition of effective RS units reduces waiting times at critical points such as Stacking Field I, which functions as the main link in the loading and unloading process. By increasing efficiency at these critical points, terminals can operate faster and reduce costs associated with delays or inefficiencies in the logistics process.

CONCLUSION

The application of a discrete system simulation model provides a clear picture of the impact of waiting time on terminal operations. This research shows that under current conditions, Piling Field I experiences the longest waiting time, with an average waiting time reaching 84.03 minutes. However, by implementing the best scenario, namely the addition of 1 Reach Stacker unit, waiting time can be reduced to only 2.69 minutes. In addition, a reduction in fuel costs of IDR. 5.22 million per day and increasing the HT handling capacity to 32 units per day in the Stacking Field block I are significant positive results. This shows that additional equipment can increase operational efficiency and reduce costs related to fuel consumption and speed up the loading and unloading process.

As next steps, there are several suggestions for future research that could enrich this study. One of them is the use of other simulation software such as Anylogic which can provide more accurate results in managing truck queues and other operational processes at the terminal. In addition, agent-based methods (Agent-Based Models) can be an attractive alternative for describing interactions between actors in more complex systems. Future research can also take into account external factors such as ship arrival schedules and external HT arrivals, which can influence the speed of service at the terminal. Thus, the application of more sophisticated simulation models and consideration of external variables can further optimize the performance of the New Makassar Container Terminal.

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