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Cover Page Footnote

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ANALYSIS OF COST AND TIME EFFICIENCY IN CONTAINER DISTRIBUTION BETWEEN CONTAINER TRUCK AND FREIGHT TRAIN FROM INDUSTRIAL AREA TO PORT

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ABSTRACT

Jakarta International Container Terminal (JICT) in Tanjung Priok Port, which serves export and import containers, can serve up to 5500 TEUs daily. However, no more than 1% of the total containers are transported by freight trains, meaning that 99% of container distribution from industrial areas is carried by trailer trucks. This condition causes a long queue at the container terminal entrance, resulting in delays in the services as well. Currently, Tanjung Priok Port is connected to rail transportation from Cikarang dry port with the frequency of twice a day with 30 flatcars (FC) for each trip. The capacity of one series of freight trains from Cikarang dry port to Tanjung Priok Port can reach 30 Feus or 60 Teus. However, the container distribution using freight trains is still less optimal because of the double handling at the JICT emplacement which is located outside JICT and the use of trailer trucks to move the containers from the area to JICT. The cost of transporting export and import containers always increases year by year because of the slow transportation due to inefficiency of the container depot location in Tanjung Priok area. In this research, the method used to determine the efficiency of container transportation is divided into three scenarios. The first scenario is when the container is fully transported by truck from the industrial area. The second scenario is when the container is transported by train and handled twice while entering JICT. Finally, the third scenario is when the JICT emplacement is located inside the JICT area, changing the business process of containers coming in and out, needing no stacking in the JICT container yard, relocating the container depot placement, consolidating containers, and automating equipment at JICT to reduce the cost and time of containers for export and import. After analyzing the costs and time of the three scenarios, it was found that the third scenario could reduce travel costs and shorten container time when exporting and importing. The 3rd scenario can reduce the cost by almost 50% from the 1st and 2nd scenarios due to container consolidation.

Keywords: *Efficiency; Business process; Freight train; Dry port; Container; Container terminal*

INTRODUCTION

Tanjung Priok Port in DKI Jakarta serves not only as a port for passenger transportation but also as the centre of distribution for export-import with various container terminals. There are seven container terminals at this port, two of which are PT. Jakarta International Container Terminal and Koja Container Terminal. Tanjung Priok Port is also integrated with rail freight transportation; however, currently only around 1% of the goods incoming and outflow use trains, while the rest use trucks.

Road congestion around Tanjung Priok Port increases due to high truck volumes, causing longer service time at the container terminal. Inefficient distribution is also influenced by the large number of stakeholders, from transportation, warehouse, and packaging, causing an increase in product prices. Air pollution occurs due to the exhaust emissions from container trucks, while emissions per unit container by trains are actually more efficient.

According to UNCTAD, Indonesia is included in the top 20 global ports; nevertheless, the Logistics Performance Index 2023 from the World Bank shows a decrease in Indonesia's ranking from 46 to 63. Some factors that influence port performance are loading and unloading speed, utility of terminal facilities and infrastructure, service consistency, digitalization, and environmental sustainability. This stacking of trucks at the port gate-in often occurs because most container deliveries are carried out at the same time, which is in the evening. This container truck queues in the port area result in extra service time at the container terminal.

The government has actually provided dry ports with infrastructure and services that make things easier for exporters and importers, aiming to reduce the burden on port area roads and spread out the arrival of container trucks so that they do not arrive at the same time. Therefore, it is necessary to study the mode change from container trucks to freight trains so that the double-double track lines that have been built and are being built by the government can be maximally utilized.

The researcher intends to find out the business process, the best mode for transporting goods from the hinterland to the container terminal, and the impact on the flow of inbound and outbound containers if the mode is changed from trucks to freight trains. The result can serve as an input for the relevant agencies to maximize the use of trains for transporting goods to and from the port.

METHODS

This research uses two approaches, namely descriptive qualitative and quantitative analysis. The method is divided into six stages, from data collection to data processing. In the analysis, the primary data obtained is rearranged to attain the efficiency of container travel from the industrial area to the container terminal.

The data used for this research is based on the results of interviews and direct observations at the research objects, which are the Jakarta International Container Terminal (JICT), JICT emplacement, and Cikarang Inland Port (CIP). The data results are then analysed by creating a business flow for the container travel process from the industrial area to the JICT and vice versa.

DATA COLLECTION

In this research, primary and secondary data is used. Primary data of container handling time was obtained from direct observations at the research location and interviews with sources from PT. JICT, PT. Kalog, and PT. CIP, which are involved in the existing business process in the three places. Secondary data is obtained from relevant journals; this includes fuel costs, containers entering JICT, type of heavy equipment, TRT (truck round time), existing heavy equipment specifications, and ACT heavy equipment specifications.

After reviewing previous literature and conducting a meta-analysis, the variables that can reduce costs, time and vehicle emissions can be found. In this research, the variables used are dependent variables (cost, time, and emissions from both modes of transportation) and independent variables (crane, cargo train, truck, dry port, container yard, business process).

Table 1 Literature on container transport efficiency

VARIABLE	RESEARCHER
Cost	(de Jong et al., 2016); (Bozuwa et al., 2009); (Izadi et al., 2020); (Kordnejad, 2014) ; (Castrellon et al., 2023) ; (Sáez-Carramolino et al., 2019) ; (Zhang et al., 2019); (Yan et al., 2020); (Schulte et al., 2017) ; (Roy & de Koster, 2018).
Time	(de Jong et al., 2016); (Kordnejad, 2014); (Irawan et al., 2020); (Liu et al., 2004) ; (Sáez-Carramolino et al., 2019); (Zhang et al., 2019); (Yan et al., 2020); (Roy & de Koster, 2018).
Emission	(Kordnejad, 2014) ; (Castrellon et al., 2023); (Liu et al., 2004) ; (He et al., 2015; Yang & Chang, 2013) ; (Yang & Chang, 2013); (Sáez-Carramolino et al., 2019) ; (Schulte et al., 2017) ; (Liu et al., 2004)
Crane	(Liu et al., 2004) ; (He et al., 2015) ; (Yang & Chang, 2013); (Roy & de Koster, 2018);
Cargo train	(Castrellon et al., 2023) ; (Sáez-Carramolino et al., 2019; Yan et al., 2020); (Yan et al., 2020) ; (Frisch et al., 2023)
Container truck	(Castrellon et al., 2023; Irawan et al., 2020) ; (Schulte et al., 2017) ; (Zhang et al., 2019) ; .
Dry Port	(Anwar Septiana et al., n.d.); (Castrellon et al., 2023).
Contanier Yard	(Liu et al., 2004) ; (He et al., 2015); (de Jong et al., 2016); (Liu et al., 2004)
Automatic Container Port	(Xu et al., 2023); (He et al., 2015); (Luo, 2019)
Reengineer Probis	(Luo, 2019)

In general, container terminals have three types of handling equipment, namely Quay Crane (QC), Internal Truck (IT), and Yard Crane (YC). The layout of the container terminal is divided into two areas, which are the quayside and the yard side. At the quayside, QC is used for loading and unloading containers to and from the ship. The yard side area is divided into several blocks, and YC is used to move containers between trucks and stacks of containers. The vehicle to connect the quayside and yard side areas is called the internal truck (IT). ITs transport containers from ship to yard side and vice versa. The productivity of an IT in an hour is 26 mph (moves per hour) on average, while the demand for container trucks that come at the same time in the evening causes external queues of the trucks that will import or export. Therefore, to minimize costs, time, vehicle emission, the initial condition of the business process needs to be studied.

The primary and secondary data obtained is then analysed to determine the time, costs, and emissions produced, with Cikarang industrial area as the starting point and JICT as the end point. In this research, three scenarios are created. The first scenario is the existing condition where shipping containers use only trailer trucks; the second scenario is where containers are carried by freight trains and trailer trucks, and the third scenario, which is the optimum scenario, is where containers are only transported by freight trains to the JICT container terminal.

The current business processes at JICT includes delivering, receiving, discharging, and loading as seen in the figures below.

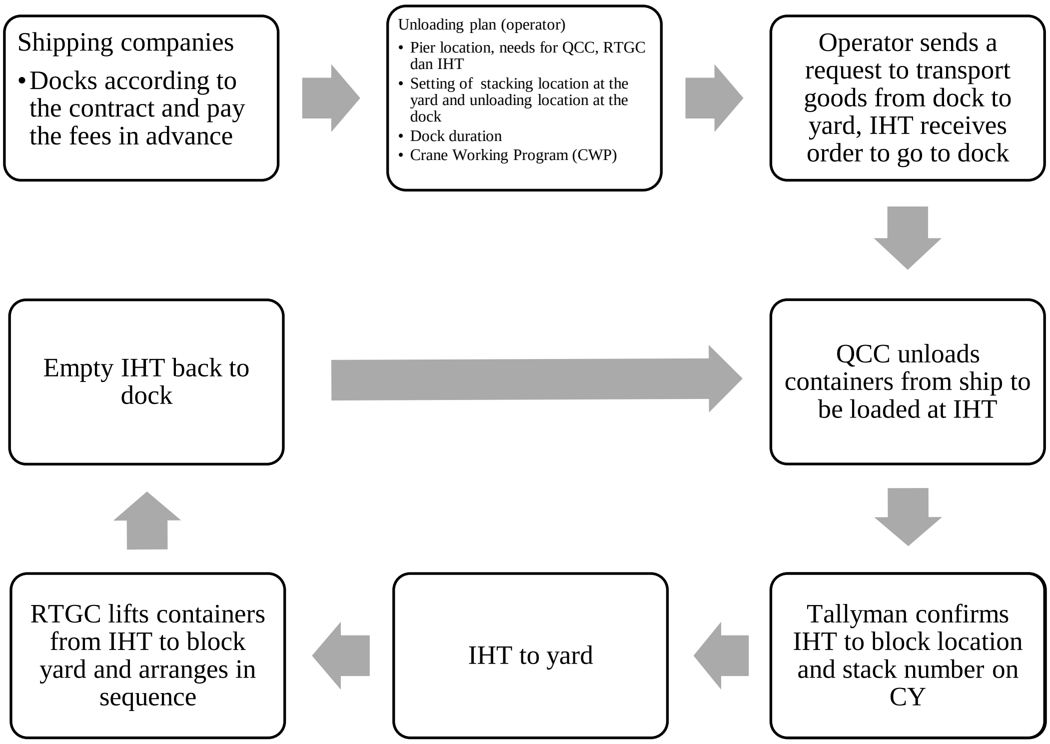


Figure 1 Discharging

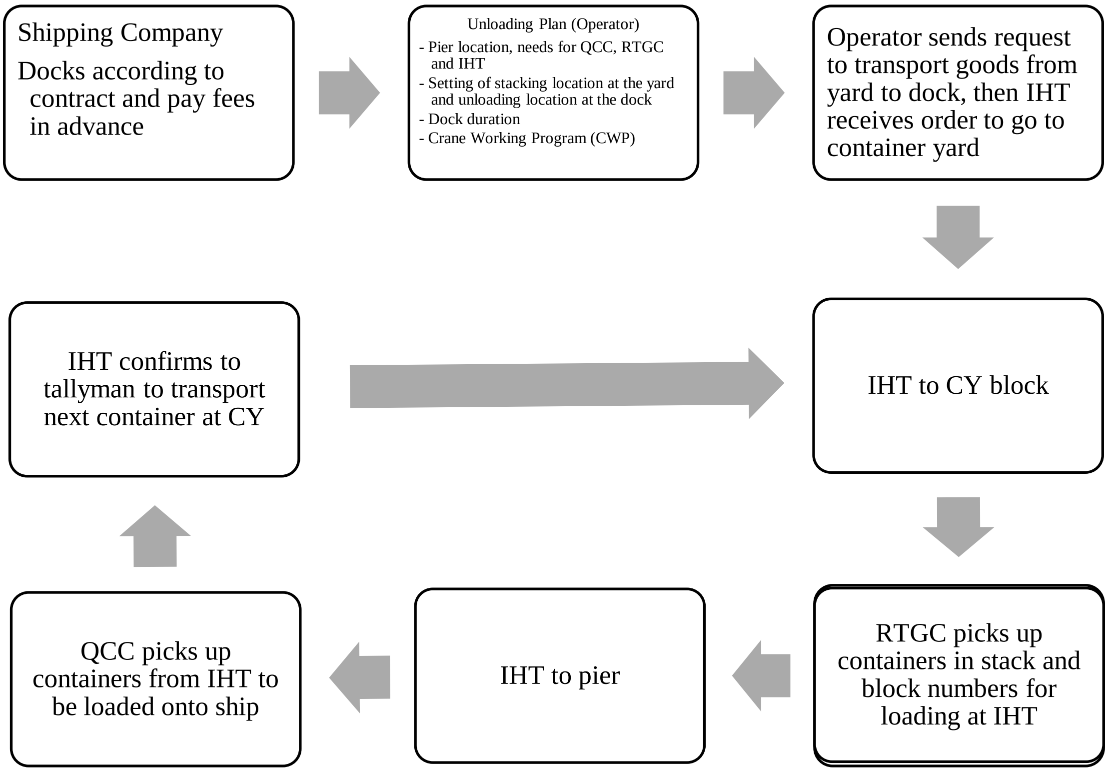


Figure 2 Loading

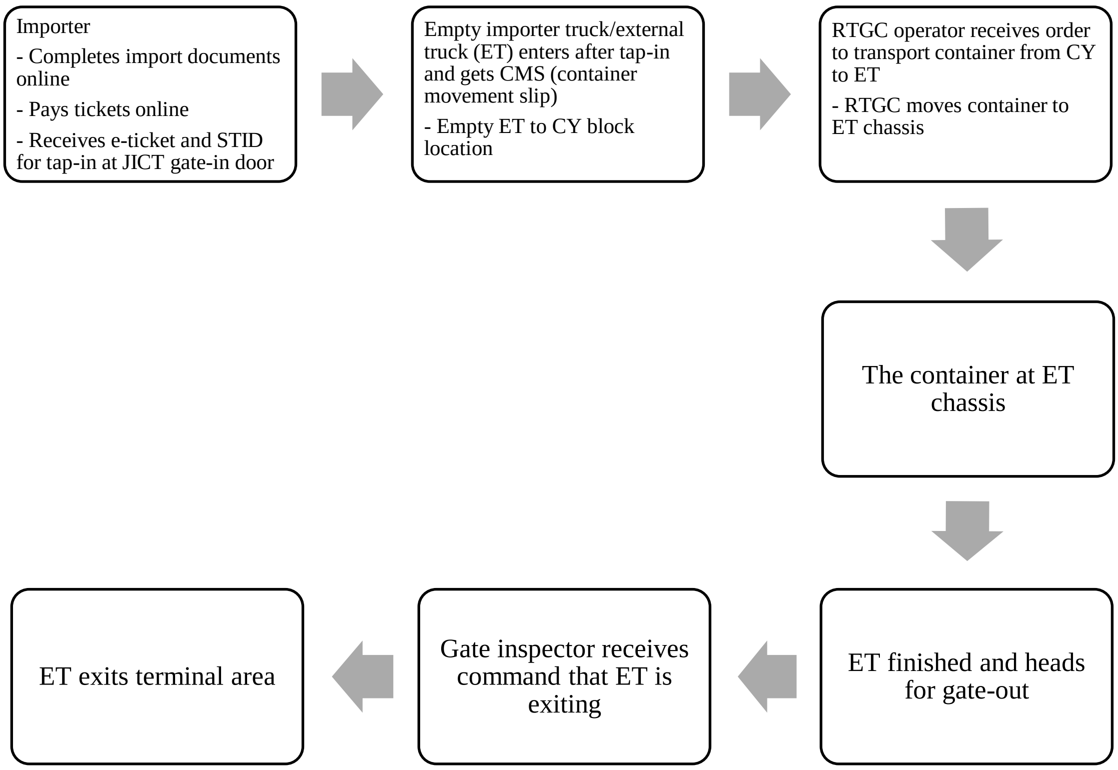


Figure 1 Delivering

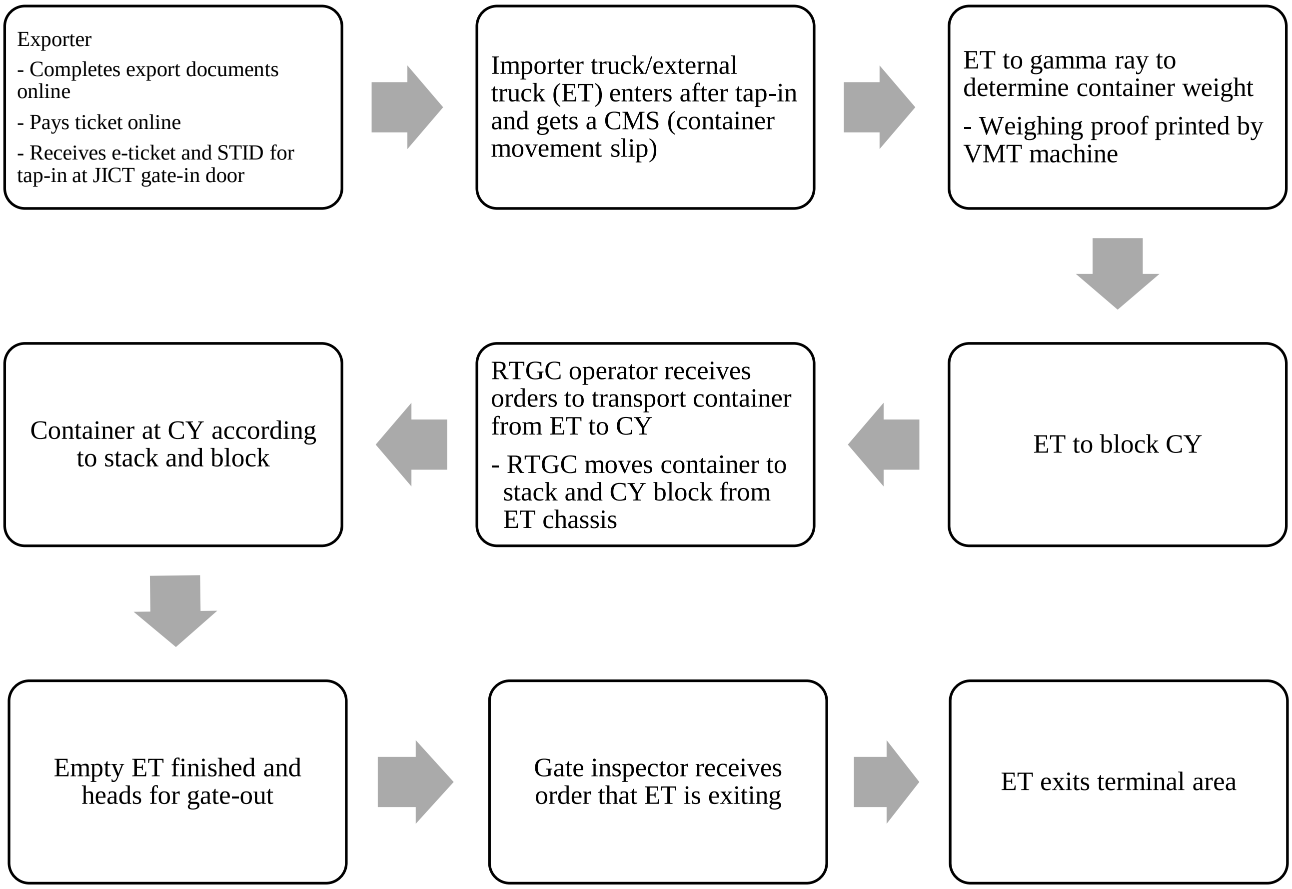


Figure 2 Receiving

In condition 1, the emissions produced from export activities are the emissions within JICT area and from JICT to the industrial area and to the depot. Emissions in JICT area are produced by heavy equipment and vehicles operating in JICT, such as RTGCs, reach stackers, side loaders, forklifts, and internal head trucks.

Emission level = activity data (km) x emission factor (gr/km)

CO (gr/km)	HC (gr/km)	NOx (gr/km)	PM10 (gr/km)	CO2 (gr/km)	SO2 (gr/km)
8,4	1,8	17,7	1,4	3172	0,83

Figure 3 Trailer truck emission factor 5

RESULTS AND DISCUSSION

1. General Description of Research Objects

Tanjung Priok Port is an international port that has separated transportation facilities for passenger and goods. Container terminals in this area, including the Jakarta International Container Terminal (JICT), have the function of handling the flow of goods in and out of Indonesia and export-import activities. JICT uses booking system via the GBOSS application to arrange container trucks, but there are often long queues due to inaccurate arrival times.

The JICT area has been integrated with the freight train route to the Cikarang dry port, although its use is still less than optimal. Optimizing this facility is expected to reduce queues of container trucks at the JICT entrance. Dry port Cikarang, or Cikarang Inland Port (CIP), has custom facilities and uses the MyCDP application for the container booking and tracking system. However, it is used more for imports than for exports.

Other than JICT and CIP, PT. Kalog - as a provider of container train services - also plays a role in optimizing container transportation. PT. Kalog provides two trips a day between JICT and CIP, with the target of transporting 2200 containers per month. Each train set can carry two container TEUs.

1.1. Existing equipment and vehicles

To support operational activities at JICT, CIP and both emplacements, equipment and vehicles are needed so that business processes can be maximized for customer service. The equipment at JICT is more complex than at CIP because there are more containers to handle at JICT. The equipment is divided into two sections, in the yard and at the dock. To connect the two places, an internal head truck (IHT) is used.

1.2. Time for receiving, delivering, and IHT movement in the JICT area

Receiving and delivering are services received by external trucks when picking up or grounding containers, while IHT movement is its movement within the JICT terminal area (from CY to the pier and vice versa).

1.3. RTGC and QC time and speed

RTGC (rubber tire gantry crane) is a crane that is placed in the container yard area of the container terminal. RTGC components are divided into three parts, namely hoist, trolley, and gantry. These three components determine the speed of the crane in handling and stacking containers. The movement synchronization of the three components determines the productivity of the crane. The crane operates in three dimensions, which are horizontal, vertical, and longitudinal.

- Horizontal movement, the movement that happens when the trolley moves over a stack of containers so that the crane can move back and forth to obtain the position needed for stacking or handling containers.
- Vertical movement, the movement which is carried out by a hoist hung on a trolley and functions to raise or lower containers.
- Longitudinal movement, the movement which happens when the gantry is working. This component moves along rails or crane tracks so that the crane can cross several rows to pass through container blocks in the container yard.

To find out when the container moves from CY to IHT, the surveyor calculates the time starting from when the hoist clamp is installed on the container body until when the container is installed on the IHT chassis. It is vice versa for the process from IHT to CY.

Quay Crane (QC) is a crane placed at the pier and used for handling containers to and from ships to or from IHT. Just like RTGC, QC components consists of trolley, hoist, and gantry. However, the difference between the two cranes is the on-land movement. RTGC can move across blocks in CY, while QC longitudinal movement is very limited because the rails embedded in the pier allow only a few tens of meters of movement.

Calculating the transfer of containers from the ship to the IHT or vice versa starts from the time the spreader is attached to the container on the ship until when the container can be placed correctly on the IHT, and vice versa.

1.4. Fuel Consumption

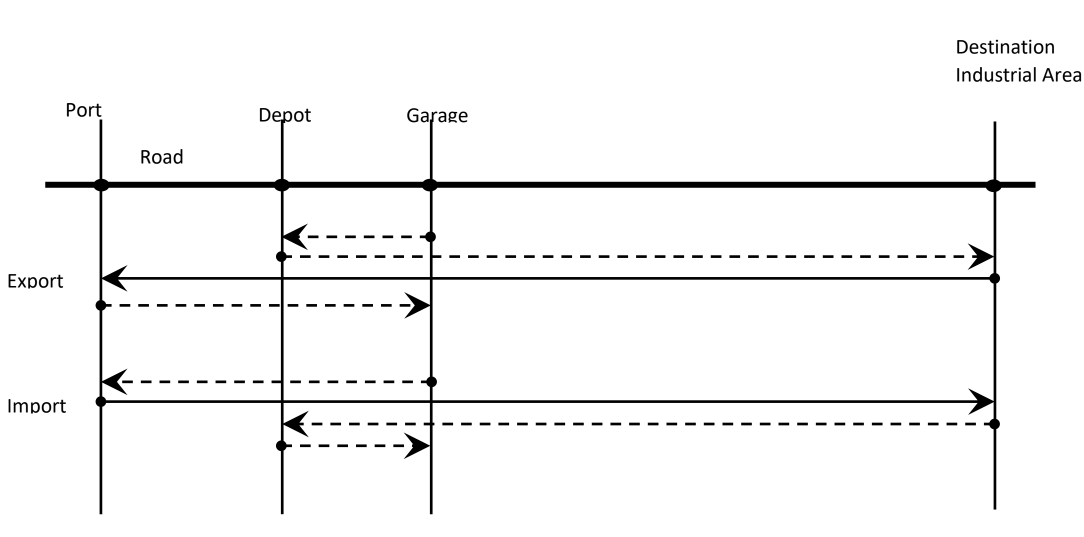
Fuel consumption at JICT is used for the operation of RTGC, IHT, Reach Stacker, Side Loader (SL) and Forklift operations, while electrical power is used for the operation of QCC.

2. Existing Business Processes

To compare the cost, time, and emission efficiency of container transportation from industrial areas to container terminals, three scenarios were created. The first scenario is the existing condition, in which a trailer truck is used to transport containers from the industrial directly to JICT container terminal. The second scenario is where a freight train is used from Cikarang dry port to JICT emplacement and then continued by a trailer truck to enter JICT. The third scenario is where full freight train is used from the industrial area to the CIP dry port before continuing to JICT.

3. Physical Transportation from Beginning to End

Even though the delivery process seems faster, the use of trucks for container distribution depends on road conditions. If the road condition is at its peak, the container delivery time from the depot to the industrial area to container terminal will definitely be longer. In scenario 1 where the container moves only with a trailer truck, the movement pattern is as shown below.



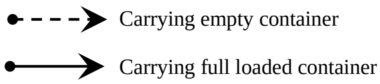


Figure 4 Illustration of container truck movement from industrial area to port

Each import or export activity requires four transfers, resulting in congested traffic flow in the port area. If it is an import activity, after the container enters the JICT gate, the container receives a service at JICT, and then it returns to the depot or to the industrial area.

4. Equipment and Vehicle Time Calculation in JICT in Scenario 1

The existing scenario is the first scenario, where the equipment used at JICT is still the existing equipment. RTGC, IHT, and QCC are more widely used to handle containers. This condition is shown in figure 2.1 for discharging, figure 2.2 for loading, figure 2.3 for delivering, and 2.4 for receiving.

Table 1 Average of JICT service time in existing scenario

T dock to CY (minutes)	1,121
Truck Round Time (TRT) IHT (minutes)	28,8092
IHT to CY (minutes)	1,967
CY to ET (minutes)	2,121
TRT ET (minutes)	106,0258

5. Travel Time Calculation in JICT and CIP in Scenario 2

In scenario 2, there are equipment and vehicle additions from scenario 1. The additions include travel time from JICT to JICT emplacement, handling at JICT emplacement, travel between JICT and CIP emplacement, and handling at CIP.

Table 3 Morning time duration for containers to travel from depot to industrial area

Location	Time duration (minutes)
South Tangerang	110
Cilegon	160
Tangerang reg.	110
Serang reg.	150
Sumedang reg.	170
Sukabumi reg.	160
Subang reg.	190
Purwakarta reg.	140
Cikarang reg.	80
Karawang reg.	110
Bogor reg.	80
Bekasi reg.	80
North Jakarta	60
East Jakarta	45

Table 4 Morning time duration for container trucks to travel from industrial area to JICT

Location	Time duration (minutes)
South Tangerang	110
Cilegon	210
Tangerang reg.	140
Serang reg.	160
Sumedang reg.	170
Sukabumi reg.	160
Subang reg.	140
Purwakarta reg.	120
Cikarang reg.	70
Karawang reg.	120
Bogor reg.	90
Bekasi reg.	60
North Jakarta	40
East Jakarta	40

6. Time Duration in Scenario 1

The duration from start to finish in scenario 1 is calculated from the flow of activities as below:

Total duration = trip to JICT + handling at JICT + JICT trip to industrial area + trip from industrial area to container depot.

- Trip to JICT: about three days custom application, booking a JICT ticket, and physical travel from the garage to JICT,
- Handling at JICT: time from a container leaves the ship's hold until arriving at the container yard to be picked up by an external truck,
- JICT trip to industrial areas and unloading containers,
- Trip from industrial area to container depot.

Table 5 Travel duration from industrial area to depot and to JICT

Tabel industrial area to depot

Location	Time duration (minutes)
South Tangerang	110
Cilegon	160
Tangerang reg.	110
Serang reg.	150
Sumedang reg.	170
Sukabumi reg.	160
Subang reg.	190
Purwakarta reg.	140
Cikarang reg.	80
Karawang reg.	110
Bogor reg.	80
Bekasi reg.	80

Tabel industrial area to JICT

Location	Time duration (minutes)
South Tangerang	110
Cilegon	210
Tangerang reg.	140
Serang reg.	160
Sumedang reg.	170
Sukabumi reg.	160
Subang reg.	140
Purwakarta reg.	120
Cikarang reg.	70
Karawang reg.	120
Bogor reg.	90
Bekasi reg.	60

North Jakarta	60
East Jakarta	45

North Jakarta	40
East Jakarta	40

Table 6 Total time required for containers in scenario 1

No	Location	Time at JICT (minutes)	Unloading time (minutes)	Depor – industrial area trip time (minutes)	JICT – industrial area trip time (minutes)	Total waktu (minutes)
1.	South Tangerang	140,044	120	110	110	480,044
2.	Cilegon	140,044	120	160	210	630,044
3.	Tangerang reg.	140,044	120	110	140	510,044
4.	Serang reg.	140,044	120	150	160	570,044
5.	Sumedang reg.	140,044	120	170	170	600,044
6.	Sukabumi reg.	140,044	120	160	160	580,044
7.	Subang reg.	140,044	120	190	140	590,044
8.	Purwakarta reg.	140,044	120	140	120	520,044
9.	Cikarang reg.	140,044	120	80	70	410,044
10.	Karawang reg.	140,044	120	110	120	490,044
11.	Bogor reg.	140,044	120	80	90	430,044
12.	Bekasi reg.	140,044	120	80	60	400,044
13.	North Jakarta	140,044	120	60	40	360,044
14.	East Jakarta	140,044	120	45	40	345,044

7. Time Duration in Scenario 2

The total time required in scenario 2 is calculated from when the time the container is being unloaded from the ship, leaving JICT gate to JICT emplacement, heading to CIP emplacement using a freight train, handling the goods arriving at CIP, until transferring from JICT emplacement to CIP emplacement.

Total time = handling at JICT + freight train trip + handling at CIP + trip to industrial area + trip to container depot.

- Handling at JICT and travel to JICT emplacement,
- Handling at JICT emplacement and train trip to CIP,
- Handling at CIP,
- Traveling from CIP to the industrial area by the truck owner, and then unloading the container,
- Traveling from industrial area to container depot.

Table 7 Total time required in scenario 2

No	Location	Time at CIP (minutes)	Trip to JICT emplacement (minutes)	FC to CIP emplacement (minutes)	CIP Emplacement to ET (minutes)	t freight train (minutes)	Unloading time (minutes)	Depor – industrial area trip time (minutes)	CIP - industrial area trip time (minutes)	Total time (minutes)
1.	South Tangerang	140,044	15	1,5	1,5	120	120	110	103	611,044
2.	Cilegon	140,044	15	1,5	1,5	120	120	160	167	785,044

No	Location	Time at CIP (minutes)	Trip to JICT emplacement (minutes)	FC to CIP emplacement (minutes)	CIP Emplacement to ET (minutes)	t freight train (minutes)	Unloading time (minutes)	Depor – industrial area trip time (minutes)	CIP - industrial area trip time (minutes)	Total time (minutes)
3.	Tangerang reg.	140,044	15	1,5	1,5	120	120	110	126	694,044
4.	Serang reg.	140,044	15	1,5	1,5	120	120	150	153	761,044
5.	Sumedang reg.	140,044	15	1,5	1,5	120	120	170	134	762,044
6.	Sukabumi reg.	140,044	15	1,5	1,5	120	120	160	213	831,044
7.	Subang reg.	140,044	15	1,5	1,5	120	120	190	76	724,044
8.	Purwakarta reg.	140,044	15	1,5	1,5	120	120	140	60	658,044
9.	Cikarang reg.	140,044	15	1,5	1,5	120	120	80	15	553,044
10.	Karawang reg.	140,044	15	1,5	1,5	120	120	110	64	632,044
11.	Bogor reg.	140,044	15	1,5	1,5	120	120	80	94	632,044
12.	Bekasi reg.	140,044	15	1,5	1,5	120	120	80	43	581,044
13.	North Jakarta	140,044	15	1,5	1,5	120	120	60	60	578,044
14.	East Jakarta	140,044	15	1,5	1,5	120	120	45	64	567,044

8. Emissions in Scenario 1

Emissions produced in scenario 1 export activities are the emissions within JICT area and from JICT to industrial area to depot. The emissions in the JICT area are produced by heavy equipment and vehicles operating in JICT, such as RTGCs, reach stackers, side loaders, forklifts, and internal head trucks.

Emission level = activity data (litre.km) x emission factor (gr/km)

The costs incurred due to vehicle emissions are obtained from the emission load value of each vehicle and the increasing vehicle volume that causes congestion (Rizky, 2022).

Table 8 Emissions into costs conversion

Pollutant types	Cost per ton ($)	Cost per ton (Rp)
CO	205	3.280.000
HC	44	704.000
NO_X	934	14.944.000
PM_{10}	3,17	50.720
CO_2	205	3.280.000
SO_2	1000	16.000.000

(source: Rizky, 2022)

Table 9 Emission levels in JICT area

Equipment type	N	FUEL	AD	LF	EF						Emission (gr/km)					
					CO	HC	NO_X	PM_{10}	CO_2	SO_2	CO	CO	HC	PM_{10}	CO_2	SO_2
RTGC	1,82	0,3425	0,43	8,4	1,8	17,7	1,4	3172	0,83	135,079	28,945	284,631	22,513	51008,367	13,347	1,82
IHT	0,93	0,3425	0,39	8,4	1,8	17,7	1,4	3172	0,83	119,989	25,712	252,834	19,998	45310,17	11,856	0,93

Equipment type	N	FUEL	AD	LF	EF						Emission (gr/km)					
					CO	HC	NO_X	PM_{10}	CO_2	SO_2	CO	CO	HC	PM_{10}	CO_2	SO_2
Forklift	0,008	0,3425	0,3	8,4	1,8	17,7	1,4	3172	0,83	0,066	0,014	0,138	0,011	24,76	0,006	0,008
RC	0,026	0,3425	0,59	8,4	1,8	17,7	1,4	3172	0,83	0,176	0,038	0,372	0,029	66,655	0,017	0,026
SL	0,025	0,3425	0,39	8,4	1,8	17,7	1,4	3172	0,83	0,168	0,036	0,355	0,028	63,54	0,0166	0,025

Table 10 Emission levels from JICT to industrial areas

Location	KM	EF						Emission (gr/km)					
		CO	HC	NO_X	PM_{10}	CO_2	SO_2	CO	HC	NO_X	PM_{10}	CO_2	SO_2
South Tangerang	62,22	8,4	1,8	17,7	1,4	3172	0,83	522,648	111,996	1101,29	87,108	197362	51,6426
Cilegon	136,66	8,4	1,8	17,7	1,4	3172	0,83	1147,94	245,988	2418,88	191,324	433486	113,428
Tangerang reg.	66,66	8,4	1,8	17,7	1,4	3172	0,83	559,944	119,988	1179,88	93,324	211446	55,3278
Serang reg.	86,66	8,4	1,8	17,7	1,4	3172	0,83	727,944	155,988	1533,88	121,324	274886	71,9278
Sumedang reg.	177,76	8,4	1,8	17,7	1,4	3172	0,83	1493,18	319,968	3146,35	248,864	563855	147,541
Sukabumi reg.	118,88	8,4	1,8	17,7	1,4	3172	0,83	998,592	213,984	2104,18	166,432	377087	98,6704
Subang reg.	152,22	8,4	1,8	17,7	1,4	3172	0,83	1278,65	273,996	2694,29	213,108	482842	126,343
Purwakarta reg.	94,44	8,4	1,8	17,7	1,4	3172	0,83	793,296	169,992	1671,59	132,216	299564	78,3852
Cikarang reg.	52,22	8,4	1,8	17,7	1,4	3172	0,83	438,648	93,996	924,294	73,108	165642	43,3426
Karawang reg.	78,88	8,4	1,8	17,7	1,4	3172	0,83	662,592	141,984	1396,18	110,432	250207	65,4704
Bogor reg.	57,76	8,4	1,8	17,7	1,4	3172	0,83	485,184	103,968	1022,35	80,864	183215	47,9408
Bekasi reg.	47,76	8,4	1,8	17,7	1,4	3172	0,83	401,184	85,968	845,352	66,864	151495	39,6408
North Jakarta	21,1	8,4	1,8	17,7	1,4	3172	0,83	177,24	37,98	373,47	29,54	66929,2	17,513
East Jakarta	18,88	8,4	1,8	17,7	1,4	3172	0,83	158,592	33,984	334,176	26,432	59887,4	15,6704

Table 2 Emission costs in scenario 1

Location	Emission Cost (Rp)						Total emission cost (Rp)
	CO	HC	NO_X	PM_{10}	CO_2	SO_2	
South Tangerang	1.714,3	78,8	16.457,7	4,4	647.347,4	826,3	666.428,9
Cilegon	3.765,2	173,2	36.147,7	9,7	1.421.834,1	1.814,8	1.463.744,8
Tangerang reg.	1.836,6	84,5	17.632,1	4,7	693.542,9	885,2	713.986,1
Serang reg.	2.387,7	109,8	22.922,3	6,2	901.626,1	1.150,8	928.202,9
Sumedang reg.	4.897,6	225,3	47.019,1	12,6	1.849.444,4	2.360,7	1.903.959,6
Sukabumi reg.	3.275,4	150,6	31.444,9	8,4	1.236.845,4	1.578,7	1.273.303,4
Subang reg.	4.194,0	192,9	40.263,5	10,8	1.583.721,8	2.021,5	1.630.404,4
Purwakarta reg.	2.602,0	119,7	24.980,2	6,7	982.569,9	1.254,2	1.011.532,7
Cikarang reg.	1.438,8	66,2	13.812,6	3,7	543.305,8	693,5	559.320,5
Karawang reg.	2.173,3	100,0	20.864,5	5,6	820.679,0	1.047,5	844.869,9
Bogor reg.	1.591,4	73,2	15.278,0	4,1	600.945,2	767,1	618.658,9
Bekasi reg.	1.315,9	60,5	12.632,9	3,4	496.903,6	634,3	511.550,6
North Jakarta	581,3	26,7	5.581,1	1,5	219.527,8	280,2	225.998,7
East Jakarta	520,2	23,9	4.993,9	1,3	196.430,7	250,7	202.220,8

9. Emissions in Scenario 2

Scenario 2 is the movement of a container to the JICT container terminal from the dry port by freight train, and then continued by trucks to enter JICT. It is started from when the container is unloaded from the ship, and then temporarily stored at JICT before being transported by freight train to CIP.
In general, the diesel fuel consumption of a train with the speed of 40km/hour is 4 litres/hour (Wibisono, 2011). From this, the resulting emissions can be calculated.

Total emissions by train = emissions from the industrial area to CIP + CIP handling emissions + train travel emissions + JICT emplacement handling emissions + JICT handling emissions.

- The distance from Cikarang to JICT is 60km.
- Fuel consumption = 60km/hour x 4 litres = 240 litres km.
- Emission level = activity data (km.litre) x emission factor (gr/km)

Table 12 Travel emissions per container from industrial areas to CIP

Location	KM. litre	EF						Emission (gr/km)					
		CO	HC	NO_X	PM_{10}	CO_2	SO_2	CO	HC	NO_X	PM_{10}	CO_2	SO_2
South Tangerang	61,6	8,4	1,8	17,7	1,4	3172	0,83	517,44	110,88	1090,32	86,24	195395,2	51,128
Cilegon	129, 6	8,4	1,8	17,7	1,4	3172	0,83	1088,64	233,28	2293,92	181,44	411091,2	107,568
Tangerang reg.	73,6	8,4	1,8	17,7	1,4	3172	0,83	618,24	132,48	1302,72	103,04	233459,2	61,088
Serang reg.	93,6	8,4	1,8	17,7	1,4	3172	0,83	786,24	168,48	1656,72	131,04	296899,2	77,688
Sumedang reg.	100	8,4	1,8	17,7	1,4	3172	0,83	840	180	1770	140	317200	83
Sukabumi reg.	93,6	8,4	1,8	17,7	1,4	3172	0,83	786,24	168,48	1656,72	131,04	296899,2	77,688
Subang reg.	72	8,4	1,8	17,7	1,4	3172	0,83	604,8	129,6	1274,4	100,8	228384	59,76
Purwakarta reg.	52	8,4	1,8	17,7	1,4	3172	0,83	436,8	93,6	920,4	72,8	164944	43,16
Cikarang reg.	6,4	8,4	1,8	17,7	1,4	3172	0,83	53,76	11,52	113,28	8,96	20300,8	5,312
Karawang reg.	28,8	8,4	1,8	17,7	1,4	3172	0,83	241,92	51,84	509,76	40,32	91353,6	23,904
Bogor reg.	56	8,4	1,8	17,7	1,4	3172	0,83	470,4	100,8	991,2	78,4	177632	46,48
Bekasi reg.	9,6	8,4	1,8	17,7	1,4	3172	0,83	80,64	17,28	169,92	13,44	30451,2	7,968
North Jakarta	48,8	8,4	1,8	17,7	1,4	3172	0,83	409,92	87,84	863,76	68,32	154793,6	40,504
East Jakarta	32,8	8,4	1,8	17,7	1,4	3172	0,83	275,52	59,04	580,56	45,92	104041,6	27,224

Table 13 Emissions handling at JICT and CIP emplacements

Equipment type	N	FUEL	AD	LF	EF						Emission (gr/km)					
					CO	HC	NO_X	PM_{10}	CO_2	SO_2	CO	HC	NO_X	PM_{10}	CO_2	SO_2
Forklift	2	0,0076	0,228	0,3	8,4	1,8	17,7	1,4	3172	0,83	0,009	0,002	0,018	0,0015	3,302	0,0009

Table 14 Emissions during each train journey

Type	Litre KM	EF						Emission (gr/km)					
		CO	HC	NO_X	PM_{10}	CO_2	SO_2	CO	HC	NO_X	PM_{10}	CO_2	SO_2
Cikarang – JICT train	240	8,4	1,8	17,7	1,4	3172	0,83	2016	432	4248	336	761280	199,2

Table 15 JICT handling emissions

Equipment type	N	FUEL	AD	LF	EF						Emission (gr/km)					
					CO	HC	NO_X	PM_{10}	CO_2	SO_2	CO	HC	NO_X	PM_{10}	CO_2	SO_2
RTGC	60	1,82	0,3425	0,43	8,4	1,8	17,7	1,4	3172	0,83	135,079	28,945	284,631	22,513	51008,367	13,347
IHT	115	0,93	0,3425	0,39	8,4	1,8	17,7	1,4	3172	0,83	119,989	25,712	252,834	19,998	45310,17	11,856
Forklift	10	0,008	0,3425	0,3	8,4	1,8	17,7	1,4	3172	0,83	0,066	0,014	0,138	0,011	24,76	0,006
RC	4	0,026	0,3425	0,59	8,4	1,8	17,7	1,4	3172	0,83	0,176	0,038	0,372	0,029	66,655	0,017
SL	6	0,025	0,3425	0,39	8,4	1,8	17,7	1,4	3172	0,83	0,168	0,036	0,355	0,028	63,54	0,0166

Table 16 Total emissions of one train series in scenario 2

Location	Emission (gr/km)					
	CO	HC	NO_X	PM_{10}	CO_2	SO_2
South Tangerang	2788,517	597,5393	5875,803	464,7528	1,05E+06	275,532
Cilegon	3359,717	719,9393	7079,403	559,9528	1,27E+06	331,972
Tangerang reg.	2889,317	619,1393	6088,203	481,5528	1,09E+06	285,492
Serang reg.	3057,317	655,1393	6442,203	509,5528	1,15E+06	302,092
Sumedang reg.	3111,077	666,6593	6555,483	518,5128	1,17E+06	307,404
Sukabumi reg.	3057,317	655,1393	6442,203	509,5528	1,15E+06	302,092
Subang reg.	2875,877	616,2593	6059,883	479,3128	1,09E+06	284,164
Purwakarta reg.	2707,877	580,2593	5705,883	451,3128	1,02E+06	267,564
Cikarang reg.	2324,837	498,1793	4898,763	387,4728	8,78E+05	229,716
Karawang reg.	2512,997	538,4993	5295,243	418,8328	9,49E+05	248,308
Bogor reg.	2741,477	587,4593	5776,683	456,9128	1,04E+06	270,884
Bekasi reg.	2351,717	503,9393	4955,403	391,9528	8,88E+05	232,372
North Jakarta	2680,997	574,4993	5649,243	446,8328	1,01E+06	264,908
East Jakarta	2546,597	545,6993	5366,043	424,4328	9,62E+05	251,628

Table 17 Emission costs in scenario 2

Location	Emission (Rp)						One series emission cost (Rp)	One 20 ft-container emission cost
	CO	HC	NO_X	PM_{10}	CO_2	SO_2		
South Tangerang	9.146,3	420,7	87.808,0	23,6	3.444.000,0	4.408,5	3.545.807,1	59.096,8
Cilegon	11.019,9	506,8	105.794,6	28,4	4.165.600,0	5.311,6	4.288.261,3	71.471,0
Tangerang reg.	9.477,0	435,9	90.982,1	24,4	3.575.200,0	4.567,9	3.680.687,2	61.344,8
Serang reg.	10.028,0	461,2	96.272,3	25,8	3.772.000,0	4.833,5	3.883.620,8	64.727,0
Sumedang reg.	10.204,3	469,3	97.965,1	26,3	3.837.600,0	4.918,5	3.951.183,6	65.853,1
Sukabumi reg.	10.028,0	461,2	96.272,3	25,8	3.772.000,0	4.833,5	3.883.620,8	64.727,0
Subang reg.	9.432,9	433,8	90.558,9	24,3	3.575.200,0	4.546,6	3.680.196,5	61.336,6
Purwakarta reg.	8.881,8	408,5	85.268,7	22,9	3.345.600,0	4.281,0	3.444.463,0	57.407,7
Cikarang reg.	7.625,5	350,7	73.207,1	19,7	2.879.840,0	3.675,5	2.964.718,4	49.412,0
Karawang reg.	8.242,6	379,1	79.132,1	21,2	3.112.720,0	3.972,9	3.204.468,0	53.407,8
Bogor reg.	8.992,0	413,6	86.326,8	23,2	3.411.200,0	4.334,1	3.511.289,7	58.521,5
Bekasi reg.	7.713,6	354,8	74.053,5	19,9	2.912.640,0	3.718,0	2.998.499,8	49.975,0
North Jakarta	8.793,7	404,4	84.422,3	22,7	3.312.800,0	4.238,5	3.410.681,6	56.844,7
East Jakarta	8.352,8	384,2	80.190,1	21,5	3.155.360,0	4.026,0	3.248.334,7	54.138,9

10. Costs in Scenario 1

Scenario 1 requires costs from a truck leaves the depot, enters the container terminal until returns to the garage. It is described as follows.

a. Trip from garage to depot (usually located in the same area and includes a lift-on fee of Rp 600.000),
b. Trip from depot to industrial area,
c. Trip from industrial area to JICT,
d. Handling at JICT,
e. Trip of empty truck back to garage (which is in the same area as JICT).

Table 18 Travel costs from depot to industrial area to JICT

Location	Fuel to JICT		Labor cost (Rp)	Maintenance cost (Rp)	Fuel from depot – industrial area	Total cost (Rp)
	Litre	Rupiah				
South Tangerang	22,4	478.240	1.300.000	40.000	478.240	2.296.480
Cilegon	49,2	1.050.420	1.700.000	40.000	1.050.420	3.840.840
Tangerang reg.	24	512.400	1.300.000	40.000	512.400	2.364.800
Serang reg.	31,2	666.120	1.700.000	40.000	666.120	3.072.240
Sumedang reg.	64	1.366.400	1.700.000	40.000	1.366.400	4.472.800
Sukabumi reg.	42,8	913.780	1.700.000	40.000	913.780	3.567.560
Subang reg.	54,8	1.169.980	1.700.000	40.000	1.169.980	4.079.960
Purwakarta reg.	34	725.900	1.700.000	40.000	725.900	3.191.800
Cikarang reg.	18,8	401.380	1.300.000	40.000	401.380	2.142.760
Karawang reg.	28,4	606.340	1.300.000	40.000	606.340	2.552.680
Bogor reg.	20,8	444.080	1.300.000	40.000	444.080	2.228.160
Bekasi reg.	17,2	367.220	1.300.000	40.000	367.220	2.074.440
North Jakarta	7,6	162.260	1.300.000	40.000	162.260	1.664.520
East Jakarta	6,8	145.180	1.300.000	40.000	145.180	1.630.360

Table 19 Handling costs at JICT

	QCC at JICT	IHT	RTGC
Electric cost (per Teus)	Rp. 2.986,-	Rp. 14.415,-	Rp. 28.210,-
Labor cost (per Teus)	Rp. 3.484,-	Rp. 3.245,-	Rp. 9.496,-
Maintenance cost (per Teus)	Rp. 9.262,-	Rp. 1.809,-	Rp. 7.916,-
Total Cost (Teus)	Rp. 15.732,-	Rp. 19.469,-	Rp. 45.622,-

Table 20. One-time cost of transporting a 20-ft container in scenario 1

Location	Departure travel cost (Rp)	JICT Handling (Rp)			Total (Rp)
		RTGC	IHT	QCC	
South Tangerang	2.296.480	45.622	19.469	15.732	2.377.303
Cilegon	3.840.840	45.622	19.469	15.732	3.921.663
Tangerang reg.	2.364.800	45.622	19.469	15.732	2.445.623
Serang reg.	3.072.240	45.622	19.469	15.732	3.153.063
Sumedang reg.	4.472.800	45.622	19.469	15.732	4.553.623
Sukabumi reg.	3.567.560	45.622	19.469	15.732	3.648.383
Subang reg.	4.079.960	45.622	19.469	15.732	4.160.783
Purwakarta reg.	3.191.800	45.622	19.469	15.732	3.272.623
Cikarang reg.	2.142.760	45.622	19.469	15.732	2.223.583
Karawang reg.	2.552.680	45.622	19.469	15.732	2.633.503
Bogor reg.	2.228.160	45.622	19.469	15.732	2.308.983
Bekasi reg.	2.074.440	45.622	19.469	15.732	2.155.263
North Jakarta	1.664.520	45.622	19.469	15.732	1.745.343
East Jakarta	1.630.360	45.622	19.469	15.732	1.711.183

11. Costs in Scenario 2

Scenario 2 combines the container transportation from industrial area to JICT by trailer trucks and freight trains. Following are the details of the trip:

a. Trip of empty trailer truck from garage to industrial area,
b. Trip of the trailer truck, loaded with a container with the maximum capacity of 20 feet carrying 28 tons and 40 feet container carrying 38 tons,
c. Trip of trailer truck heading to CIP,
d. Handling in CIP from truck chassis to FC,
e. Freight train trip from CIP emplacement to JICT emplacement,
f. Handling at JICT emplacement, container movment from FC to truck chassis,
g. Entry of trucks with loaded containers to JICT,
h. Handling at JICT (RTGC, IHT, and QCC).

Table 21 Travel costs from depot to industrial area to CIP

Location	Fuel to JICT		Labor cost (Rp)	Maintenance cost (Rp)	Fuel from depot – industrial area	Total cost (Rp)
	Litre	Rupiah				
South Tangerang	30,8	657.580	1.300.000	40.000	478.240	2.475.850,80
Cilegon	64,8	1.383.480	1.700.000	40.000	1.050.420	4.173.964,80
Tangerang reg.	36,8	785.680	1.300.000	40.000	512.400	2.638.116,80
Serang reg.	46,8	999.180	1.700.000	40.000	666.120	3.405.346,80
Sumedang reg.	50	1.067.500	1.700.000	40.000	1.366.400	4.173.950,00
Sukabumi reg.	46,8	999.180	1.700.000	40.000	913.780	3.653.006,80
Subang reg.	36	768.600	1.700.000	40.000	1.169.980	3.678.616,00
Purwakarta reg.	26	555.100	1.700.000	40.000	725.900	3.021.026,00
Cikarang reg.	3,2	68.320	1.300.000	40.000	401.380	1.809.703,20

Location	Fuel to JICT		Labor cost (Rp)	Maintenance cost (Rp)	Fuel from depot – industrial area	Total cost (Rp)
	Litre	Rupiah				
Karawang reg.	14,4	307.440	1.300.000	40.000	606.340	2.253.794,40
Bogor reg.	28	597.800	1.300.000	40.000	444.080	2.381.908,00
Bekasi reg.	4,8	102.480	1.300.000	40.000	367.220	1.809.704,80
North Jakarta	24,4	520.940	1.300.000	40.000	162.260	2.023.224,40
East Jakarta	16,4	350.140	1.300.000	40.000	145.180	1.835.336,40

Table 22 Forklift costs at emplacement

Fuel cost (per Teus)	Rp. 15.500,-
Labor cost (per Teus)	Rp. 7.222,-
Maintenance cost (per Teus)	Rp. 33.333,-
Total Cost (Teus)	Rp. 56.055,-

Table 23 Freight train travel costs per trip

Container type	Max. weight (ton)	Cost per ton (Rp)	Total cost per container (Rp)
20	2,8	242.000	677.600
40	4,2	242.000	1.016.400

Table 24 Total costs in scenario 2

Location	Trip to CIP (Rp)	Forklift cost (Rp)	Freight train cost (Rp)	JICT handling cost	Total cost (Rp)
South Tangerang	2.475.850,80	56.055	677.600	80.823	3.290.328,80
Cilegon	4.173.964,80	56.055	677.600	80.823	4.988.442,80
Tangerang reg.	2.638.116,80	56.055	677.600	80.823	3.452.594,80
Serang reg.	3.405.346,80	56.055	677.600	80.823	4.219.824,80
Sumedang reg.	4.173.950,00	56.055	677.600	80.823	4.988.428,00
Sukabumi reg.	3.653.006,80	56.055	677.600	80.823	4.467.484,80
Subang reg.	3.678.616,00	56.055	677.600	80.823	4.493.094,00
Purwakarta reg.	3.021.026,00	56.055	677.600	80.823	3.835.504,00
Cikarang reg.	1.809.703,20	56.055	677.600	80.823	2.624.181,20
Karawang reg.	2.253.794,40	56.055	677.600	80.823	3.068.272,40
Bogor reg.	2.381.908,00	56.055	677.600	80.823	3.196.386,00
Bekasi reg.	1.809.704,80	56.055	677.600	80.823	2.624.182,80
North Jakarta	2.023.224,40	56.055	677.600	80.823	2.837.702,40
East Jakarta	1.835.336,40	56.055	677.600	80.823	2.649.814,40

12. Optimization Scenario

12.1. Equipment Automation

To reduce emissions, the use of diesel for the heavy equipment and vehicles in JICT is converted into electric power. Automatic Container Port (ACT) is able to increase the productivity of the container terminal.

[(Xu et al., 2023)] states that there are parameters to calculate the time required for each step as depicted in figures 5.1 to 5.3. This parameter provides services for 536 discharging containers and 560 loading containers. Yangshan Container Port, which has already used an automatic container port, provides heavy equipment specifications for AQC, AGV, and ARMG for faster loading and unloading container flow time.

In table 3.28, after being totalled, the ACT time is divided by the total containers that can be handled. The cost is then divided by 30 days and 5500, which is the average container entering container terminal JICT.

Table 25 Types of heavy equipment and total time per activity (hour)

Heavy Equipment Type	Activity	Total Time (hour)
AQC	AQC awaits handling orders	5,48
	AQC trolley moves	7,31
	AQC awaits AGV	3,65
	AQC loading	16,97
	AQC unloading	16,80
	AQC totals	50,21
AGV	AGV awaits handling command	20,09
	AGV to loading point	52,97
	AGV waits for AQC or ARMG to carry container	29,87
	AGV waits for AQC or ARMG to lift container from AGV body	21,44
	AGV receives container from AQC or ARMG	23,33
	AGV releases container lifted by AQC or ARMG	18,76
	AGV goes to the loading or unloading point	60,28
	AGV awaits AQC or ARMG to lift the container from the AGV body	24,27
	AGV awaits AQC or ARMG to deliver container from the ship's hold	21,59
	AGV releases container lifted by AQC or ARMG	17,73

Heavy Equipment Type	Activity	Total Time (hour)
	AGV receives container from AQC or ARMG	21,44
	Total AGVs	311,78
ARMG	ARMG awaits handling command	7,31
	ARMG moves	12,79
	ARMG awaits AGV	3,65
	ARMG loading	24,27
	ARMG unloading	19,65
	Total ARMG	67,67
ACT	ACT Totals	429,66
	Handling per container (minutes)	23,52

Table 26 Types of costs in ACT for 30 days

	Type of cost	Cost (RMB)	Cost (Rupiah)
AQC	Operational cost Labor cost Maintenance cost Depreciation cost AQC total cost	105.266 43.152 40.552 5.256 194.226	242.111.800 99.249.600 93.269.600 12.088.800 446.719.800
AGV	Operational cost Labor cost Maintenance cost Depreciation cost AGV total cost	23.882 17.282 3.238 2.042 46.444	54.928.600 39.748.600 7.447.400 4.696.600 106.821.200
ARMG	Operational cost Labor cost Maintenance cost Depreciation cost ARMG total cost	65.809 26.752 17.781 4.106 114.448	151.360.700 61.529.600 40.896.300 9.443.800 263.230.400
ACT	ACT total cost	355.119	816.773.700
	ACT cost per kontainer	2,152236	4950,144

Table 27 Time of heavy equipment use in 30 days

	Time (hour)
AQC	440
AGV	404
ARMG	426

Table 28 Equipment energy requirements in ACT

	Part of equipment	Energy (kwh)

AQC	Crane Trolley Hoist Waiting	280 210 130 160
AGV	Empty trip Full load trip	150 190
ARMG	Crane Trolley Hoist Waiting	130 160 110 120

12.2. New Business Process

Scenario 2 has actually reached optimum condition, but because JICT emplacement is located outside JICT, a trailer truck is still required to enter the container terminal area. If the JICT emplacement is in the terminal area, the percentage of double handling process will be lower because the containers can go directly to the dock without having to transit first in the JICT container yard (CY).

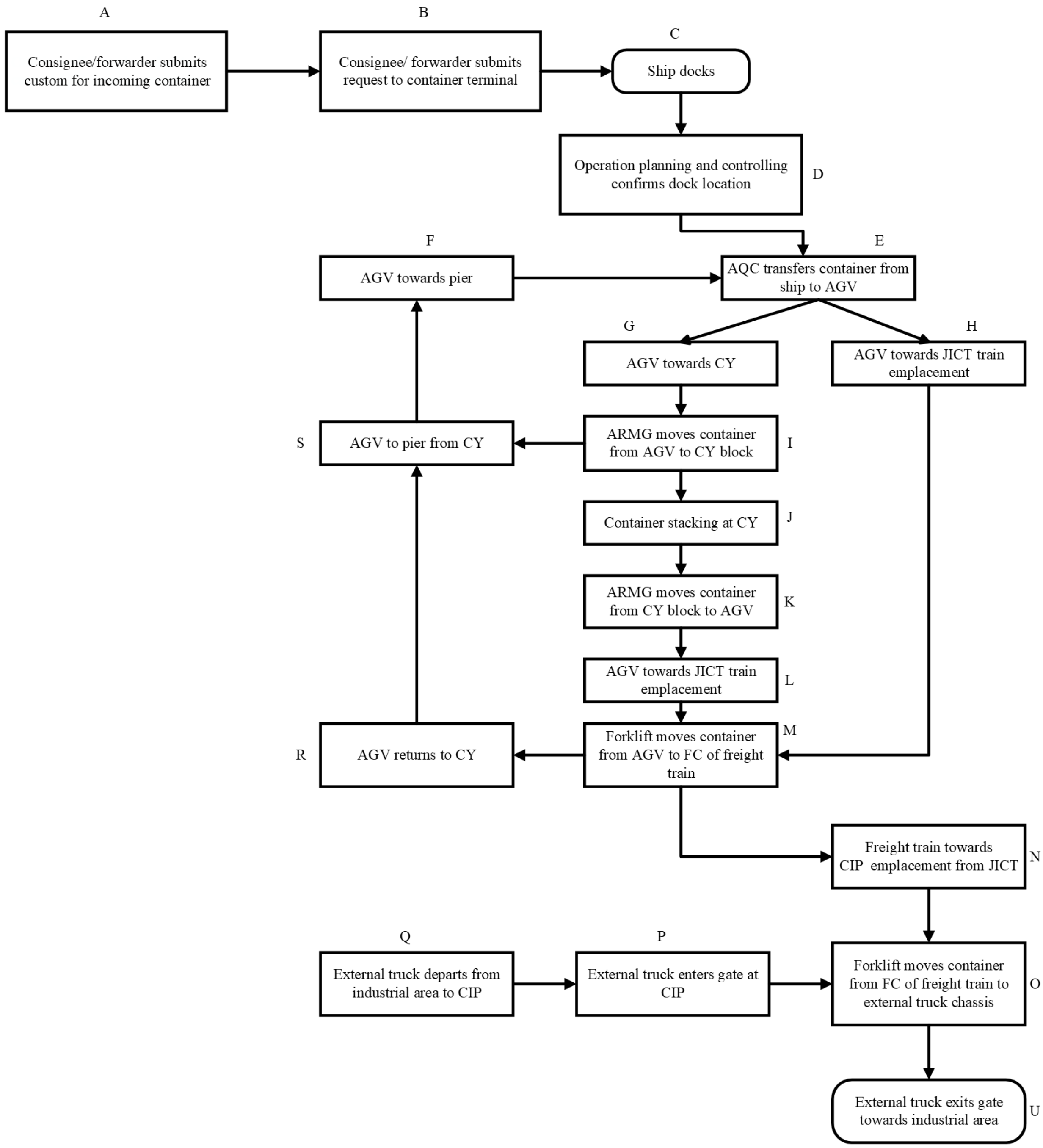


Figure 7 Import flow in scenario 3

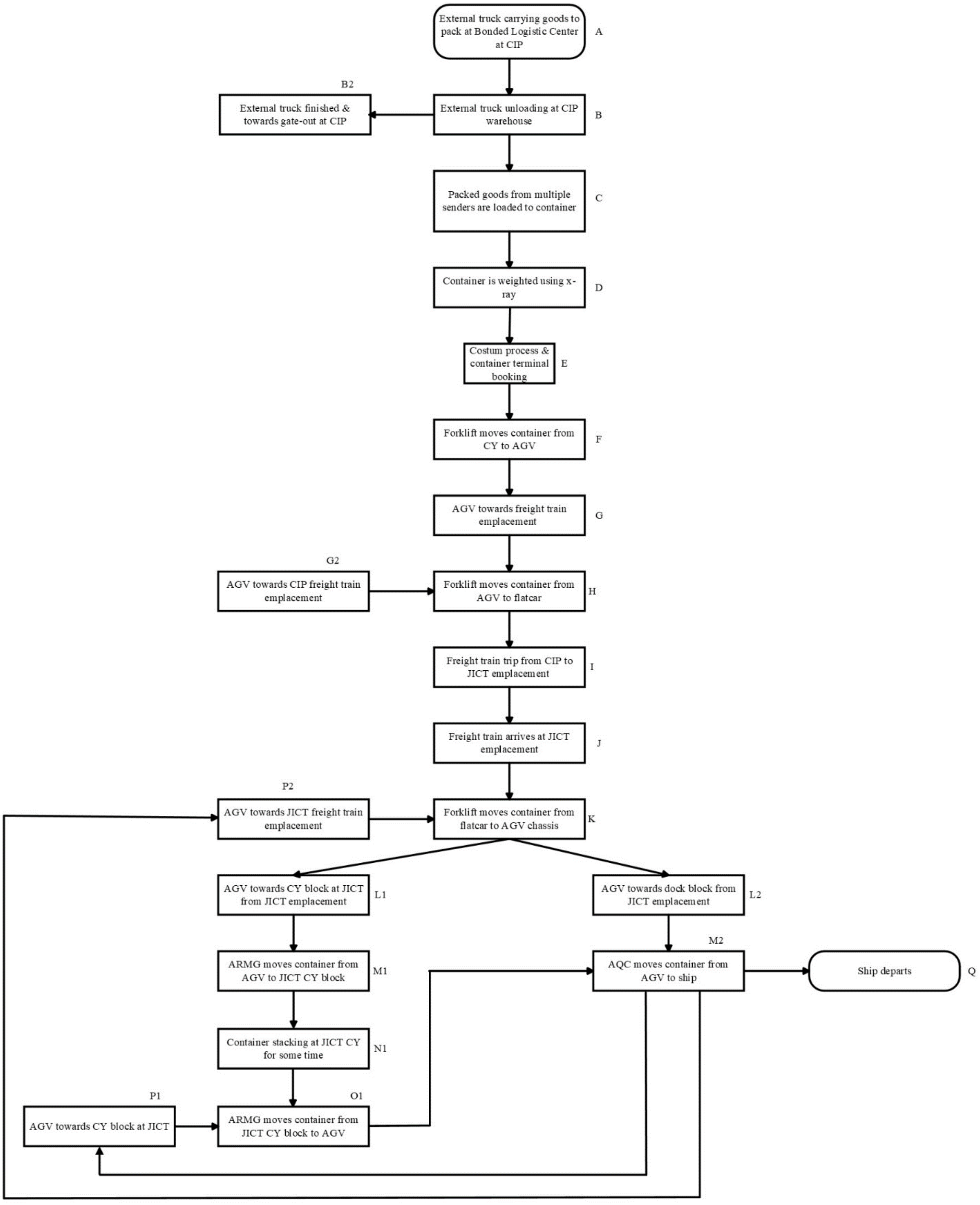


Figure 5 Export flow in scenario 3

12.3. Physical Transportation Optimization

In the existing condition, the depot is located inside the Tanjung Priok Port area; therefore, trucks need to go back and forth twice from the depot to the industrial area before going back to the port. Figure 3.6 shows that for each export and import at least four movements are required. For export, the movement pattern is from the garage – depot – industrial area – port – garage, while for imports, the movement pattern is from the garage – port – industrial area – depot – garage.

Apart from that, in the process of entering and exiting container at the container terminal, truck consolidation has not been done. If the containers are consolidated and the additional depot are relocated close to industrial areas, it will be possible to reduce the costs for container land transportation.

The depot and garage are owned by two (2) different companies. The garage is owned by the goods land transportation trucking company, while the depot is owned by the shipping line. At this depot there is also equipment for lift-on and lift-off in the form of reach stackers or forklifts. According to Transportation Minister Regulation no. 83 of 2016 which regulates container operations and depots, the possibility of adding a depot or moving a depot closer to an industrial area can be done in a condition that if it is a joint venture, the majority of share ownership should belong to a national company.

Moreover, according to DKI Jakarta Provincial Regulation No. 1 of 2014 concerning Detailed Spatial Planning and Zoning Regulations, it is stated that Tanjung Priok area is not intended for goods transportation infrastructure, such as container depots or truck garages. So, if the depot location is closer to the industrial area, and if there is consolidation of containers for export and import, the travel costs will be cheaper.

The location of both the garage and depot in the port area has made the flow of movement between the garage, depot, industrial area, and port becomes less efficient in terms of cost and time. Numerous trucks pass through the port area, resulting in congestion on the port road. If the depot and garage are moved to the industrial area, congestion at the port will not happen because the industrial area is vast, and the locations are spread over several points. Congestion will likely be reduced, even if there are additional truck movements from the port to the industrial area.

Besides moving the depots and garages closer to industrial areas, to reduce transportation costs, consignee trucks should implement container consolidation to reduce the movement of trucks with empty containers. By consolidating the container to single trip, the export and import containers there will be only three or four empty truck trips, whereas without consolidation, it takes three empty truck trips for each export or import activity. Besides, the road between the JICT emplacement and the JICT gate can be used as a container terminal area, so that AGVs can pass through for container distribution.

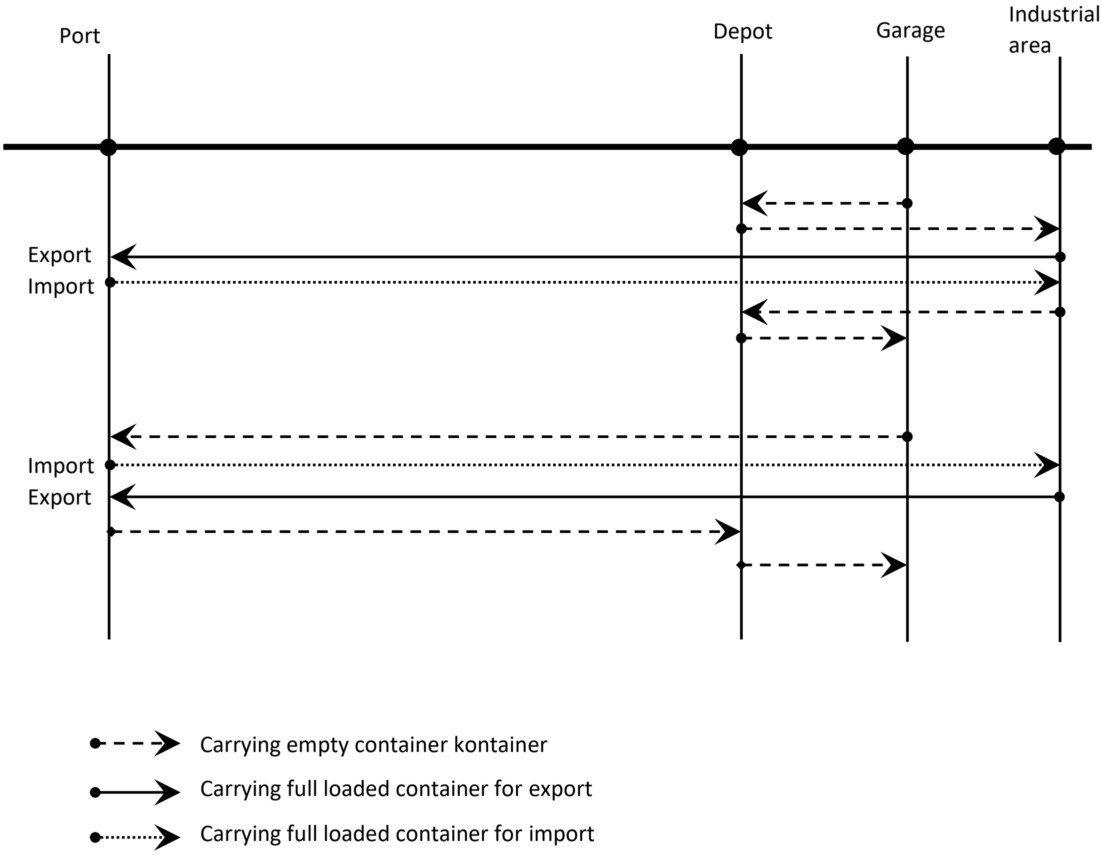


Figure 9 Physical transportation in the optimum condition

Figure 6 Road layout between JICT emplacement and JICT gate

13. Results of Optimization Scenario

From the optimization scenario, the costs, time, and emissions produced can be obtained. Container movement from the beginning until the end can be calculated not only for each export and import, but it can also be calculated all at once because the container physical transportation is consolidated as shown in figure 9.

In the optimization scenario, the depot and garage locations are moved closer to the garage; therefore, fuel costs can be ignored. The trip details are as follows:

a. Movement of export trucks from industrial areas to CIP,

b. CIP handling,
c. Freight train trip from CIP to JICT,
d. JICT handling of export containers directly to the dock,
e. JICT handling of import containers directly to the emplacement,
f. Freight train trip from JICT to CIP,
g. CIP handling,
h. Pick up import trucks containers at CIP.

13.1. Time duration in scenario 3

As previously explained, the time calculation starts from the moving of the export truck from the industrial area to CIP until the return of the import truck to CIP.

Figure 11 Time duration in scenario 3

Location	Departure duration (minutes)	CIP handling time	Train duration for export	JICT handling (export & import)	Train duration for import	CIP handling time	Return duration (minutes)	Total duration (minutes)
South Tangerang	110	1,5	120	23,52	120	1,5	110	486,52
Cilegon	160	1,5	120	23,52	120	1,5	160	586,52
Tangerang reg.	110	1,5	120	23,52	120	1,5	110	486,52
Serang reg.	150	1,5	120	23,52	120	1,5	150	566,52
Sumedang reg.	170	1,5	120	23,52	120	1,5	170	606,52
Sukabumi reg.	160	1,5	120	23,52	120	1,5	160	586,52
Subang reg.	190	1,5	120	23,52	120	1,5	190	646,52
Purwakarta reg.	140	1,5	120	23,52	120	1,5	140	546,52
Cikarang reg.	80	1,5	120	23,52	120	1,5	80	426,52
Karawang reg.	110	1,5	120	23,52	120	1,5	110	486,52
Bogor reg.	80	1,5	120	23,52	120	1,5	80	426,52
Bekasi reg.	80	1,5	120	23,52	120	1,5	80	426,52
North Jakarta	60	1,5	120	23,52	120	1,5	60	386,52
East Jakarta	45	1,5	120	23,52	120	1,5	45	356,52

13.2. Costs in scenario 3

Costs are also calculated starting from when the truck goes to CIP from the industrial area until it returns to the industrial area for one process of export and import.

Figure 7 Costs of scenario 3

Location	Trip cost to CIP	CIP handling cost	Train cost for export	JICT cost (export & import)	Train cost for import	CIP handling cost	Total cost (Rp)
South Tangerang	1.997.580	56.055	677.600	4950,144	677.600	56.055	3.469.840
Cilegon	3.123.480	56.055	677.600	4950,144	677.600	56.055	4.595.740

Location	Trip cost to CIP	CIP handling cost	Train cost for export	JICT cost (export & import)	Train cost for import	CIP handling cost	Total cost (Rp)
Tangerang reg.	2.125.680	56.055	677.600	4950,144	677.600	56.055	3.597.940
Serang reg.	2.739.180	56.055	677.600	4950,144	677.600	56.055	4.211.440
Sumedang reg.	2.807.500	56.055	677.600	4950,144	677.600	56.055	4.279.760
Sukabumi reg.	2.739.180	56.055	677.600	4950,144	677.600	56.055	4.211.440
Subang reg.	2.508.600	56.055	677.600	4950,144	677.600	56.055	3.980.860
Purwakarta reg.	2.295.100	56.055	677.600	4950,144	677.600	56.055	3.767.360
Cikarang reg.	1.408.320	56.055	677.600	4950,144	677.600	56.055	2.880.580
Karawang reg.	1.647.440	56.055	677.600	4950,144	677.600	56.055	3.119.700
Bogor reg.	1.937.800	56.055	677.600	4950,144	677.600	56.055	3.410.060
Bekasi reg.	1.442.480	56.055	677.600	4950,144	677.600	56.055	2.914.740
North Jakarta	1.860.940	56.055	677.600	4950,144	677.600	56.055	3.333.200
East Jakarta	1.690.140	56.055	677.600	4950,144	677.600	56.055	3.162.400

13.3. Emissions in scenario 3

In scenario 3, because the equipment and vehicles in JICT use electricity, no emissions are produced in the JICT area. Emissions are generated from truck transportation from industrial areas to CIP, handling at CIP on freight trains, and handling at JICT and CIP emplacements.

Figure 13 Truck trip emissions from industrial areas to CIP

Location	Trip emission from industrial area to CIP					
	CO	HC	NO_X	PM_{10}	CO_2	SO_2
South Tangerang	517,44	110,88	1090,32	86,24	195395,2	51,128
Cilegon	1088,64	233,28	2293,92	181,44	411091,2	107,568
Tangerang reg.	618,24	132,48	1302,72	103,04	233459,2	61,088
Serang reg.	786,24	168,48	1656,72	131,04	296899,2	77,688
Sumedang reg.	840	180	1770	140	317200	83
Sukabumi reg.	786,24	168,48	1656,72	131,04	296899,2	77,688
Subang reg.	604,8	129,6	1274,4	100,8	228384	59,76
Purwakarta reg.	436,8	93,6	920,4	72,8	164944	43,16
Cikarang reg.	53,76	11,52	113,28	8,96	20300,8	5,312
Karawang reg.	241,92	51,84	509,76	40,32	91353,6	23,904
Bogor reg.	470,4	100,8	991,2	78,4	177632	46,48
Bekasi reg.	80,64	17,28	169,92	13,44	30451,2	7,968
North Jakarta	409,92	87,84	863,76	68,32	154793,6	40,504
East Jakarta	275,52	59,04	580,56	45,92	104041,6	27,224

Figure 14 Emission handling at JICT and CIP emplacements

Equipment type	N	FUEL	AD	LF	EF						Emission (gr/km)					
					CO	HC	NO_X	PM_{10}	CO_2	SO_2	CO	HC	NO_X	PM_{10}	CO_2	SO_2
Forklift	2	0,0076	0,228	0,3	8,4	1,8	17,7	1,4	3172	0,83	0,009	0,002	0,018	0,0015	3,302	0,0009

Figure 15 Emissions during each train journey

Type	Litre KM	EF						Emission (gr/km)					
		CO	HC	NO_X	PM_{10}	CO_2	SO_2	CO	HC	NO_X	PM_{10}	CO_2	SO_2
Kereta Cikarang – JICT	240	8,4	1,8	17,7	1,4	3172	0,83	2016	432	4248	336	761280	199,2

Figure 16 Eemission in scenario 3

Location	Emission (gr/km)					
	CO	HC	NO_X	PM_{10}	CO_2	SO_2
South Tangerang	2533,449	542,882	5338,338	422,2415	956678,5	250,3289
Cilegon	3104,649	665,282	6541,938	517,4415	1172375	306,7689
Tangerang reg.	2634,249	564,482	5550,738	439,0415	994742,5	260,2889
Serang reg.	2802,249	600,482	5904,738	467,0415	1058183	276,8889
Sumedang reg.	2856,009	612,002	6018,018	476,0015	1078483	282,2009
Sukabumi reg.	2802,249	600,482	5904,738	467,0415	1058183	276,8889
Subang reg.	2620,809	561,602	5522,418	436,8015	989667,3	258,9609
Purwakarta reg.	2452,809	525,602	5168,418	408,8015	926227,3	242,3609
Cikarang reg.	2069,769	443,522	4361,298	344,9615	781584,1	204,5129
Karawang reg.	2257,929	483,842	4757,778	376,3215	852636,9	223,1049
Bogor reg.	2486,409	532,802	5239,218	414,4015	938915,3	245,6809
Bekasi reg.	2096,649	449,282	4417,938	349,4415	791734,5	207,1689
North Jakarta	2425,929	519,842	5111,778	404,3215	916076,9	239,7049
East Jakarta	2291,529	491,042	4828,578	381,9215	865324,9	226,4249

Figure 17 Emission costs in scenario 3

Location	Emission cost (Rp)						One series emission cost (Rp)	One 20ft-container emission cost
	CO	HC	NO_X	PM_{10}	CO_2	SO_2		
South Tangerang	8.309,7	382,2	79.776,1	21,4	3.137.905,5	4.005,3	3.230.400,2	53.840,0
Cilegon	10.183,2	468,4	97.762,7	26,2	3.845.390,0	4.908,3	3.958.738,9	65.979,0
Tangerang reg.	8.640,3	397,4	82.950,2	22,3	3.262.755,4	4.164,6	3.358.930,3	55.982,2
Serang reg.	9.191,4	422,7	88.240,4	23,7	3.470.840,2	4.430,2	3.573.148,7	59.552,5
Sumedang reg.	9.367,7	430,8	89.933,3	24,1	3.537.424,2	4.515,2	3.641.695,4	60.694,9
Sukabumi reg.	9.191,4	422,7	88.240,4	23,7	3.470.840,2	4.430,2	3.573.148,7	59.552,5
Subang reg.	8.596,3	395,4	82.527,0	22,2	3.246.108,7	4.143,4	3.341.792,9	55.696,5
Purwakarta reg.	8.045,2	370,0	77.236,8	20,7	3.038.025,5	3.877,8	3.127.576,1	52.126,3
Cikarang reg.	6.788,8	312,2	65.175,2	17,5	2.563.595,8	3.272,2	2.639.161,9	43.986,0
Karawang reg.	7.406,0	340,6	71.100,2	19,1	2.796.649,0	3.569,7	2.879.084,7	47.984,7
Bogor reg.	8.155,4	375,1	78.294,9	21,0	3.079.642,2	3.930,9	3.170.419,5	52.840,3
Bekasi reg.	6.877,0	316,3	66.021,7	17,7	2.596.889,2	3.314,7	2.673.436,6	44.557,3
North Jakarta	7.957,0	366,0	76.390,4	20,5	3.004.732,2	3.835,3	3.093.301,4	51.555,0
East Jakarta	7.516,2	345,7	72.158,3	19,4	2.838.265,7	3.622,8	2.921.928,0	48.698,8

14. Comparison Between Scenarios

The optimization results in this research can be compared with existing scenarios 1 and 2 as shown in the following table:

14.1. Time duration comparison

Container travel time duration in scenarios 1 and 2 is the time duration for just one export or one import. Meanwhile, the time duration in scenario 3 is for one export and import altogether; therefore, the actual time needed is shorter.

Figure 18 Time duration comparison for one 20 feet container

Location	Scenario 1 (minutes)	Scenario 2 (minutes)	Scenario 3 (minutes)
South Tangerang	480,044	611,044	486,52
Cilegon	630,044	785,044	586,52
Tangerang reg.	510,044	694,044	486,52
Serang reg.	570,044	761,044	566,52
Sumedang reg.	600,044	762,044	606,52
Sukabumi reg.	580,044	831,044	586,52
Subang reg.	590,044	724,044	646,52
Purwakarta reg.	520,044	658,044	546,52
Cikarang reg.	410,044	553,044	426,52
Karawang reg.	490,044	632,044	486,52
Bogor reg.	430,044	632,044	426,52
Bekasi reg.	400,044	581,044	426,52
North Jakarta	360,044	578,044	386,52
East Jakarta	345,044	567,044	356,52

14.2. Cost comparison

Even though the cost for scenario 3 looks higher, it is actually half smaller than the cost in scenario 1 and 2. This is because in scenario 3, the cost is for one export and import altogether, while in scenarios 1 and 2 the cost is for one time export or one time import.

Figure 19 Comparison of one 20-ft container transportation cost

Departure location	Scenario 1 (Rp) Destination location JICT	Scenario 2 (Rp) Destination location CIP	Skenario 3 (Rp) Destination location CIP
South Tangerang	2.377.303	3.290.328,80	3.469.840
Cilegon	3.921.663	4.988.442,80	4.595.740
Tangerang reg.	2.445.623	3.452.594,80	3.597.940
Serang reg.	3.153.063	4.219.824,80	4.211.440
Sumedang reg.	4.553.623	4.988.428,00	4.279.760
Sukabumi reg.	3.648.383	4.467.484,80	4.211.440
Subang reg.	4.160.783	4.493.094,00	3.980.860
Purwakarta reg.	3.272.623	3.835.504,00	3.767.360
Cikarang reg.	2.223.583	2.624.181,20	2.880.580
Karawang reg.	2.633.503	3.068.272,40	3.119.700
Bogor reg.	2.308.983	3.196.386,00	3.410.060

Bekasi reg.	2.155.263	2.624.182,80	2.914.740
North Jakarta	1.745.343	2.837.702,40	3.333.200
East Jakarta	1.711.183	2.649.814,40	3.162.400

14.3. Comparison of exhaust emission costs

Emissions in each scenario need to be converted into costs, and these emissions result from a single export and import process that occurs simultaneously.

Figure 20 Comparison of emission costs

Location	Scenario 1 (Rp)	Scenario 2 (Rp)	Scenario 3 (Rp)
South Tangerang	666.428,9	59.096,8	53.840,0
Cilegon	1.463.744,8	71.471,0	65.979,0
Tangerang reg.	713.986,1	61.344,8	55.982,2
Serang reg.	928.202,9	64.727,0	59.552,5
Sumedang reg.	1.903.959,6	65.853,1	60.694,9
Sukabumi reg.	1.273.303,4	64.727,0	59.552,5
Subang reg.	1.630.404,4	61.336,6	55.696,5
Purwakarta reg.	1.011.532,7	57.407,7	52.126,3
Cikarang reg.	559.320,5	49.412,0	43.986,0
Karawang reg.	844.869,9	53.407,8	47.984,7
Bogor reg.	618.658,9	58.521,5	52.840,3
Bekasi reg.	511.550,6	49.975,0	44.557,3
North Jakarta	225.998,7	56.844,7	51.555,0
East Jakarta	202.220,8	54.138,9	48.698,8

The third scenario gives better efficiency in terms of time, costs, and emissions in container transportation from industrial areas to ports.

14.4. Comparison with Existing Literature

In the journal "Intermodal Transport Cost Model and Intermodal Distribution in Urban Freight" (Kordnejad, 2014) it is also mentioned that an intermodal transport system based on rail can help reduce costs and time when transporting daily consumable materials in urban areas. Additionally, the journal suggests that establishing intermediate stops along the rail route can increase demand and reduce costs for freight transport.

The use of forklifts in handling between train GD and trucks is also considered more efficient for container transfer than using larger cranes. The journal also indicates that for transhipment stations that are not very large and for intermediate distances such as the distance between CIP and JICT, which is only 50 km, the use of forklifts is more efficient because they are easier to use and quicker in transferring 20-foot containers. Moreover, forklifts require only one operator, compared to cranes used in container terminals, which typically need at least two people per shift.

In another study (de Jong et al., 2016), it is suggested that container transport by truck should have differentiated tariffs for each time window to prevent continuous truck traffic on the port area roads. While ports already provide alternative modes of transport for containers via freight trains, currently, the number of containers arriving at the port is higher at night, causing container terminals to be over-occupied at night and underutilized during the day.

Furthermore, the current situation where the number of containers entering the container terminal is unrestricted leads to container congestion at the JICT gate. If quota restrictions were implemented for each time window, it is likely that cargo owners would be able to adhere to their arrival schedules at the container terminal.

14.5. Implications for Policy and Practice

Although regulations governing urban planning in port areas exist, many companies still operate distribution infrastructure such as container depots or truck garages within the port area. It would be more beneficial if container depots and garages were located in each industrial zone. The implication, of course, is that companies would require additional investment; however, overall, relocating depots and garages would reduce transportation costs and decrease exhaust emissions from road transport.

Additionally, the tariffs for using freight trains to transport goods such as containers have not been specifically regulated. This study is expected to serve as a reference for regulators when determining freight transportation tariffs. It is crucial to establish lower and upper tariff limits to ensure that no parties are disadvantaged in the container distribution business. Freight train operators would still profit from providing distribution services, and consumers, including forwarders, dry ports, and other clients, would find the prices reasonable. Moreover, considering that the cost of transporting containers by rail is higher than by truck, the government can take several steps to increase demand for freight trains, including:

- Providing subsidies for businesses that choose to transport containers by train,
- Monitoring the flow of subsidized fuel to ensure it is not used for industrial purposes or for fueling trailer trucks,
- Enhancing export potential so that freight trains consistently carry goods during their journeys, as currently, only imported containers use freight trains to reach industrial areas

14.6. Limitations of the Study and Recommendations for Future Research

In this study, the authors did not analyze the customs administration process, which can be a significant factor causing delays in container exports or their delivery to importers.

Additionally, synergy among stakeholders, including regulators, operators, and users, is needed to address the heavy traffic of container trucks at the port and provide a comprehensive solution.

Furthermore, this study does not differentiate between Full Container Load (FCL) and Less than Container Load (LCL) containers, even though these two types of containers have different forwarder responsibilities. FCL containers can be directly handled by the forwarder upon receiving orders from owners, whereas LCL containers go through co-loaders, who act as intermediaries for shipping line companies. The limitation of the data obtained also restricts the representation and generalization of the logistics situation in other regions. Additionally, the optimization of freight train frequency to meet the demand for container distribution has not been comprehensively addressed.

CONCLUSION

The results of this research explain the cost, time, and emission efficiencies that occur in scenario three. By consolidating containers, relocating depot, automating equipment at container terminals, and changing the business processes, travel costs can be reduced by 50%

compared to scenarios 1 and 2. In terms of time, although it seems there is no significant difference in the duration, scenario 3 is still more efficient because by consolidating containers, trucks departing and returning are always fully loaded, and there is no more empty truck trip. In terms of emission, the variable is clearly the smallest compared to the other two scenarios because of the use of electric powered equipment and freight train for long-distance container transportation.

Scenario 3 could strengthen DKI Jakarta Provincial Regulation No. 1 of 2014 concerning Detailed Spatial Planning and Zoning Regulations which states that the Tanjung Priok area is not intended for goods transportation infrastructure, such as container depots or truck garages. However, there is no regulation governing the basic tariff for container transportation by freight train and equipment automation that requires investment costs. If scenario 2 is maximized, this can be done as long as the JICT – CIP return trip carries cargo. In the current conditions, cargo is carried only when the freight train departs from JICT to CIP because exporters still tend to choose trucks to deliver containers to the port. This happens because the cost difference between scenario 1 and 2 is not very significant.

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