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Port Performance in the Perspective of Ship Arrival and Departure Report Data

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Abstract

The seaport as a gateway to the regional, national and international economy must pay attention to the performance of operational services, including the level of service quality of ships, goods and port facilities. Activities at the port such as sea transportation operations must be reported to the Port Operator in accordance with the format of the ship arrival and departure report (LK3) which includes the type of ship, docking terminal, arrival time data and departure time from the Port. One perspective of port performance measurement is ship service which can be measured from how long the ship is at the terminal until it leaves the port. This research method uses a quantitative approach and the Data Envelopment Analysis (DEA) method. This study aims to determine the statistical approach and measure port performance, namely turnaround time and performance efficiency. The results of the study for 2022 obtained for the type of container ship, Tanjung Emas Port has a turnaround time of 23 hours while Tanjung Priok Port and Tanjung Perak Port are more than 24 hours and port performance efficiency with DEA efficient rating value Θ =1 at Tanjung Priok and Tanjung Perak ports.

Keywords: *Turnaround time, LK3, ship traffic, DEA*

INTRODUCTION

Ports serve as pivotal hubs for government and business activities, playing a crucial role in economic growth and development. Monitoring and evaluating the performance of ports are essential to ensure their efficiency and effectiveness in facilitating trade and commerce. Among the key economic gateway ports on Java Island are Tanjung Priok Port, Tanjung Perak Port, and Tanjung Emas Port, which serve as major points of entry and exit for goods and commodities.One of the primary business activities at these ports is sea transportation, whereby companies operate liner and tramp ships to facilitate the movement of goods both domestically and internationally. To ensure the smooth operation of sea transportation activities, companies are required to submit LK3 ship arrival and/or departure plan reports to the Port Operator, as per regulations.

The performance of a port is influenced by various factors, including its infrastructure, operations, and management practices. Efficient port operations require effective coordination between various stakeholders, including port authorities, shipping companies, customs officials, and other relevant agencies. Improvements in port infrastructure, such as the expansion of berths and

the installation of modern cargo-handling equipment, can significantly enhance the port's capacity and efficiency. Moreover, the adoption of advanced technologies, such as automated container terminals and digital tracking systems, can streamline port operations and reduce turnaround times for ships. These technological advancements not only improve the overall efficiency of the port but also enhance its competitiveness in the global market.

In addition to infrastructure and technological advancements, the implementation of effective management practices is also crucial for enhancing port performance. This includes the adoption of best practices in port management, such as efficient cargo handling procedures, effective risk management strategies, and the implementation of environmental sustainability measures. Furthermore, ports play a vital role in facilitating trade and commerce, serving as key nodes in the global supply chain. As such, the performance of ports has a direct impact on the overall competitiveness of a country's economy.

Ports that are efficient and well-managed can help reduce transportation costs, improve supply chain reliability, and enhance trade facilitation. The performance of ports is critical for economic growth and development. Ports serve as key gateways for trade and commerce, and their efficiency and effectiveness are essential for ensuring smooth and reliable transportation of goods. By focusing on infrastructure development, technological advancements, and effective management practices, ports can enhance their performance and contribute to the overall economic competitiveness of a region or country.

Regulation of the Minister of Transportation Number PM 93 of 2013 concerning the Organization and Operation of Sea Transportation. Ship time at the port can be calculated from the time the ship arrives until the ship leaves the port or what is called turnaround time is one of the port performance indicators. With turnaround time as a material for evaluating port performance because by reducing ship time at the port can save fuel, reduce emissions, and reduce costs in ship operations. Saving time at the port will certainly reduce greenhouse gas emissions at the port, according to UNTACD 2023 that from world shipping carries more than 80% of world trade in goods and is responsible for greenhouse gas emissions of nearly 3% (percent) so this is an important priority in the IMO program [10].

Port performance is integral to the efficiency of maritime transportation which impacts port earnings [16]. Recent port performance indicators and data show that the world's ports have benefited from doing well during the recent global supply chain crisis. Supply chain processes have embarked on a recovery path, supported by policy reforms and digital innovation. In this context, facilitating maritime freight trade is essential for smooth trade and efficient supply chains, including at ports and beyond, which will result in efficiencies and benefits as well as cost reductions in trade procedures by streamlining and harmonizing regulatory procedures in the handling of goods at ports (UNTACD, 2023). In 2024 IMO will introduce a significant development in port infrastructure with the mandatory implementation of *maritime electronic single windows*. This mandate will have far-reaching implications in terms of interoperability and *seamless* coordination between port stakeholders. *Maritime electronic single windows* aims to build a digital framework for Port optimization [13], where there is integration with all government regulations in the port and data exchange. The application of *maritime electronic single windows* technology in Indonesia is implemented with the use of inaportnet.

With new technologies and the increasing role of digitization and the industry's desire to work collectively to achieve system-wide improvements, it provides an opportunity to measure and compare the performance of reliable container ports. The World Bank and S&P Global Market Intelligence produced the *Container Port Performance Index* (CPPI) for 2021 and 2022 data - A Comparable Assessment of Performance based on Vessel Time in Port, which for Tanjung Priok Port, Tanjung Perak Port and Tanjung Emas Port as shown in Table 1 (World bank, 2023). From the table, there is an increase in ranking for Tanjung Perak Port and Tanjung Emas Port, but Tanjung Priok Port has decreased.

Table 1. CPPI

Port	2021		2022
	Statistics	Admin	Statistics dan Admin
Tanjung Priok	114	124	281
Tanjung Perak	103	107	97
Tanjung Emas	144	153	132

Tanjung Priok Port is the busiest port in Indonesia. The port handles more than 30% of Indonesia's non-oil and gas commodities, in addition to 50% of all goods flowing in/out of Indonesia passing through Tanjung Priok port. Therefore, Tanjung Priok is a barometer of the Indonesian economy. Complete intermodal facilities are able to connect Tanjung Priok with

all cities in Indonesia. With modern technology and facilities, Tanjung Priok has been able to serve the latest generation of ships directly to various international trade centers but has not been able to improve its CPPI ranking. Tanjung Perak Port is a port located in Surabaya, East Java. Tanjung Perak Port has a container terminal and is the second largest and busiest port in Indonesia after Tanjung Priok Port and also as a trade center to the eastern part of Indonesia can increase the port *performance index* rating, and Tanjung Emas Port is a port located in Semarang City, Central Java, which is the gateway to the economy of the Central Java and Yogyakarta regions, so the role of the three ports is very influential on the national economy which needs to improve the efficiency and performance of its services.

The research on efficiency and performance focuses on the efficiency of the largest container port in the Mediterranean aiming to understand how the port's resources for containers reflect its level of activity and efficiency. The research uses the output-oriented model *Data Envelopment Analysis* (DEA) and two modeling approaches, namely the Charnes Cooper Rhodes (CCR) model and the Bankers Charnes Cooper (BCC) model. The analysis compares port efficiency estimates in relation to the classification of medium and large ports and their market share. The main findings show an average efficiency of 0.88 and 0.89 assuming constant and variable returns to scale, which implies that ports can increase their output level by about 1.2 times without any change in inputs [9].

Data Envelopment Analysis (DEA) is a powerful *benchmarking* and service management technique developed by Charnes, Cooper and Rhodes to evaluate both public and not-for-profit organizations. DEA is a technical tool to help managers to improve service performance. DEA can do among others [4]:

1. DEA compares service units considering all existing systems and services and identifies the most efficient and least efficient units where efficiency can be improved, by comparing the volume of existing services and systems of each unit with other units.
2. DEA calculates the amount and type of costs and systems that can be saved by making inefficient systems as efficient as best practice.
3. Specification changes to inefficient service units were identified that could be implemented by management to achieve potential savings as per DEA.
4. Management receives information on service unit performance that can be used to help transfer systems and managerial expertise from better managed and relatively efficient units to inefficient units. This will increase the productivity of the inefficient units, reduce operating costs and increase profitability.

So *Data Envelopment Analysis* (DEA) is a non-parametric method used to assess the (comparative) efficiency of a decision-making unit's services by comparing them to the services of other homogeneous units. A homogeneous operating unit service, which is defined as the entity whose performance is to be compared. Service units use the same amount of inputs to produce the same amount of outputs, make decisions about the production process and its level of efficiency and have control over the transformation of their inputs. Therefore, the initial stage for applying the DEA method is to define the decision-making unit service and to identify the appropriate input and output variables. As this method is comparative in nature, the result of this method, i.e. efficiency, is relative. Efficiency is based on the assumption that production shows constant returns to scale, which means that the conversion of inputs into outputs is characterized by constant returns to scale. If a constant variation is applied to an input, then the same variation is applied to the output. This study is to determine the performance of the three ports for *TurnRound Time* and efficiency with the DEA method during 2022. The study uses LK3 data which is data from inaportnet per month both domestic and foreign.

METHOD

Data for research from LK3 inaportnet in the form of excel files consisting of domestic and foreign data for the year 2022. The research method for processing and analyzing the file data is carried out as shown in Figure 1, and the applications used are Microsoft excel and python programs, to calculate the length of time the ship is at port or *TurnRound Time*. *TurnRound Time* (TRT-ship time at port) is the sum of the time between arrivals and departures for all ships divided by the number of ships. The purpose is to find out the average amount of ship service time at the port, from the arrival of the ship until the ship leaves the port in a report / monthly period.

$$TRT = \sum(Jbp - Jdp) / \sum K \quad \text{.....1}$$

Jbp= Departure time from Port
Jdp = Arrival / arrival time at the port
K=Vessel

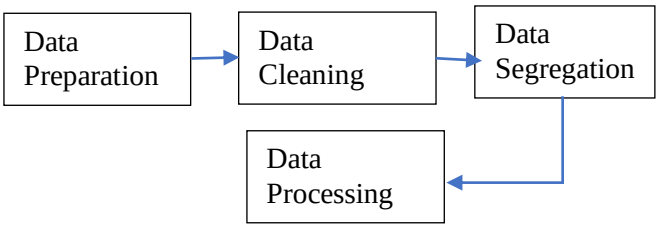

Fig 1. Method chart

The performance of a port should be able to serve *ships* as efficiently as possible, which means that the turnaround time should be smaller with the optimal number of *ships* (*ship traffic*) [18]. *Data envelopment analysis* is used to evaluate efficiency [17]. Service units (Port of Tanjung Priok, Tanjung Perak, and Tanjung Emas) as an element of DEA compare all service units. *Best practice* unit services are relatively efficient and identified by DEA efficiency rating with Θ = 1, less efficient unit services with Θ < 1. DEA uses mathematical linear program technique, with mathematical model [21] as follows:

Maximize Θ=

$$\frac{u_1y_{1o} + u_2y_{2o} + \cdots \ldots + u_ry_{ro}}{v_1x_{1o} + v_2x_{2o} + \cdots \ldots + v_mx_{mo}} = \frac{\sum_{r=1}^{s} u_ry_{ro}}{\sum_{i=1}^{m} v_ix_{io}}$$

Where:
j = Number of service unit (Service Unit- SU)
Θ= efficiency rating of SU
yrj = Amount of output r used for SUj
xij = Number of inputs r used for SUj
i= number of inputs
r = number of outputs
ur = coefficient of DEA output r
vi = coefficient of DEA input i

$$SU1 \ \frac{u1y11 + u2y21 + \cdots \ldots + uryr1}{v1x11 + v2x21 + \cdots \ldots + vmxm1} = \frac{\sum_{r=1}^{s} uryr1}{\sum_{i=1}^{m} vixi1} \leq 1$$

$$SU2 \ \frac{u1y12 + u2y22 + \cdots \ldots + uryr2}{v1x12 + v2x22 + \cdots \ldots + vmxm2} = \frac{\sum_{r=1}^{s} uryr2}{\sum_{i=1}^{m} vixi2} \leq 1$$

.....

$$SUo \ \frac{u1y1o + u2y2o + \cdots \ldots + uryro}{v1x1o + v2x2o + \cdots \ldots + vmxmo} = \frac{\sum_{r=1}^{s} uryro}{\sum_{i=1}^{m} vixio} \leq 1$$

$$SUj \ \frac{u1y1j + u2y2j + \cdots \ldots + uryrj}{v1x1j + v2x2j + \cdots \ldots + vmxmj} = \frac{\sum_{r=1}^{s} uryrj}{\sum_{i=1}^{m} vixij} \leq 1$$

$$u1, \ldots, us > \text{and } v1, \ldots, vm \geq 0$$

The system used to obtain the efficiency value according to the linear mathematical formula is using Microsoft Excel software with the add-in-solver feature. The calculation of efficiency using DEA uses the output variable is ship traffic and the input is turnaround time and berthing terminal as in Table 2. The berthing terminal data is obtained from LK3 data, where every month from each port lists the name of the berthing terminal from each port.

Table 2. Input and Output Variables

No	Variable	categori	Unit
1	*Ship Traffic*	Output	Unit
2	*Turnaround Time*	Input	hours
3	Berth Terminal	Input	Unit

RESULTS AND DISCUSSION

Data Preparation

Data preparation is to collect the data files of the three ports, and it is found that the number of ship services during Year 2022 for the LK3 reports of the three ports is as in Table 3.

Table 3. Recapitulation of LK3 Data

No	Port	Domestic	Overseas	Amount
1	Tanjung Priok	10,664	4,053	14,717
2	Tanjung Perak	11,434	1,637	13,071
3	Tanjung Emas	2,660	695	3,355

Data Cleaning

Data cleaning is done by removing unnecessary components and continuing with data separation, namely the data used is for general cargo and container ship types, arrival time, departure time, berthing.

Data Segregation

The data is in accordance with the desired then the data is separated for general cargo and containers based on PKK (Ship Arrival Notification) both domestic and foreign. Arrival time and departure time from excel files are converted to time format to facilitate calculations.

Data Processing

Data processing uses the phyton application to facilitate calculations and the results of data processing for Tanjung Priok Port, Tanjung Perak Port and Tanjung Emas obtained *ship traffic* (ST) and *turnaround time* at the port for ship types as follows:

1. The domestic general cargo of Tanjung Priok Port is shorter at 124 hours (5.18 days) while Tanjung Emas Port is 152 hours (6.34 days) and Tanjung Perak Port is 249 hours (10.37 days) as shown in Table 4.

Table 4. General cargo for domestic

Month	Tanjung Priok		Tanjung Perak		Tanjung Emas	
	ST	TRT (hour)	ST	TRT (hour)	ST	TRT (hour)

January	76	339	173	275	16	3
February	74	76	155	201	13	101
March	73	134	173	227	15	104
April	66	92	183	262	19	109
May	64	106	157	292	17	207
June	83	128	183	262	16	248
July	86	86	183	295	15	99
August	77	96	196	289	12	295
September	91	93	173	206	18	154
October	96	118	204	211	10	117
November	98	141	175	272	11	214
December	78	83	171	195	8	175
Average	80	124	177	249	14	152

2. For the category of overseas general cargo ship types, it is found that Tanjung Emas Port is shorter at 68 hours (2.83 days) while Tanjung Priok Port is 69 hours (2.89 days) and Tanjung Perak Port is 109 hours (4.55 days) as shown in Table 5.
3. For the domestic container ship type category, it is found that Tanjung Emas Port is shorter at 24 hours (1 day) while Tanjung Priok Port is 80 hours (3.33 days) and Tanjung Perak Port is 83 hours (3.45 days) as shown in Table 6.

Table 5. General cargo for overseas

Bulan	Tanjung Priok		Tanjung Perak		Tanjung Emas	
	ST	TRT (hour)	ST	TRT (hour)	ST	TRT (hour)
Januari	62	88	11	126	3	62
Februari	54	82	17	127	5	39
Maret	62	66	14	178	7	116
April	60	70	25	104	4	97
Mei	51	67	14	178	4	128
Juni	58	58	16	101	3	107
Juli	54	66	13	58	4	38
Agustus	68	78	17	126	7	60
September	44	59	15	53	1	14
Oktober	65	71	21	77	4	30
Nopember	66	63	11	84	2	68
Desember	60	64	17	98	3	56
Average	59	69	16	109	4	68

4. For the category of overseas container ship types, it is found that Tanjung Emas Port is shorter at 21 hours (0.88 days) while Tanjung Perak Port is 23 hours (0.96 days) and Tanjung Priok Port is 37 hours (1.53 days) as shown in Table 7.

Table 6. Container for domestic

Bulan	Tanjung Priok		Tanjung Perak		Tanjung Emas	
	ST	TRT (hour)	ST	TRT (hour)	ST	TRT (hour)
Januari	213	84	272	91	18	24
Februari	200	73	254	79	21	21
Maret	232	71	282	95	28	21
April	204	67	262	83	25	25
Mei	183	142	209	133	14	32
Juni	223	73	269	80	31	18
Juli	234	76	283	62	25	19
Agustus	228	78	295	96	25	19
September	211	69	273	61	26	12
Oktober	234	79	297	74	26	53
Nopember	212	76	279	67	29	11
Desember	227	70	283	73	26	36
Average	217	80	272	83	25	24

Table 7. Container for overseas

Bulan	Tanjung Priok		Tanjung Perak		Tanjung Emas	
	ST	TRT (hour)	ST	TRT (hour)	ST	TRT (hour)
Januari	160	36	80	25	41	22
Februari	152	40	92	25	41	24
Maret	162	35	76	23	42	24
April	164	38	88	27	42	25
Mei	158	38	81	23	38	30
Juni	175	46	83	25	42	22
Juli	174	38	83	22	45	20
Agustus	190	38	93	23	45	20
September	173	31	85	23	45	15
Oktober	184	31	94	21	47	15
Nopember	181	36	88	19	44	19
Desember	188	35	97	20	47	17
Average	172	37	87	23	43	21

Graphs for the results of *Turnaround Time* data processing for general cargo and containers are shown in Figure 2 and Figure 3.

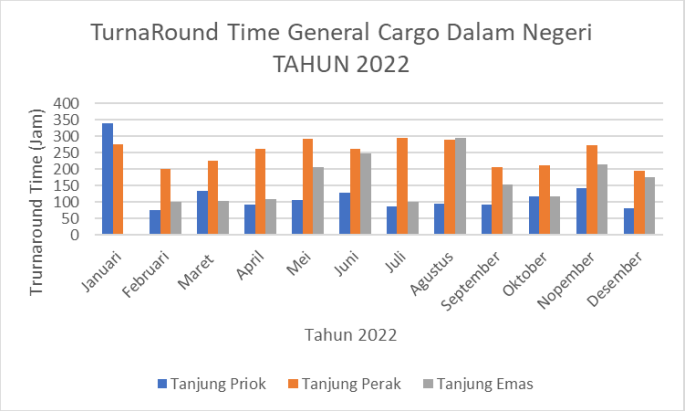

Fig 2. TRT of Domestic General Cargo

Fig 3. TRT Container Overseas

The results of statistical data processing for the three ports are that the difference between departure time and arrival time is negative, meaning that the arrival time precedes the departure time and there is also a value of 0, meaning that the arrival time and departure time are the same. For the maximum ship time at the port of each domestic and overseas port can be seen in Table 8 and Table 9.

Table 8. Maximum time of domestic vessels

Month	Tanjung Priok		Tanjung Perak		Tanjung Emas	
	GC (h)	Container (h)	GC (h)	Container (h)	GC (h)	Container (h)
January	745	22	196	41	1	3
February	28	21	77	56	16	3
March	89	12	79	93	10	3
April	24	11	121	53	12	3
May	19	77	79	56	84	6
June	56	22	121	70	27	2
July	36	35	176	22	12	2
August	36	27	140	142	76	4
September	45	14	243	21	39	1
October	128	117	99	52	9	47
November	258	21	496	35	38	1
December	43	12	102	41	27	23
average	126	32.6	161	57	29	8

Table 9. Maximum time of overseas vessels

Bulan	T. Priok		T. Perak		T. Emas	
	GC (h)	Container (h)	GC (h)	Container (h)	GC (h)	Container (h)
Januari	14	4	12	2	3	2
Februari	29	13	29	8	4	4
Maret	21	5	38	2	12	9
April	11	9	20	2	8	3
Mei	14	12	38	4	15	4
Juni	9	32	10	3	7	2
Juli	11	10	8	2	4	2
Agustus	60	33	46	2	5	10
September	13	4	6	12	1	1
Oktober	60	4	6	2	3	1
Nopember	12	8	12	2	5	2
Desember	48	11	29	2	6	2
Rata-rata	25	12	21	4	6	4

Based on the data in Table 4 to Table 7, the average for *ship traffic* and *turnaround time* as variables in the calculation of efficiency using *data envelopment analysis*, while for the number of berths (terminals) data filters are carried out from the data source. That with the input of the number of berths and *turnaround time* will output the number of ships that can be served maximally. The results of the calculation using the *adds-in-solver* feature as shown in Table 10 through Table 13 based on general cargo and container criteria for domestic and overseas.

Table 10. DEA of Domestic General Cargo

Port	Output	Input		Value
	ST	Terminal	TRT (hour)	Θ
Tanjung Priok	80	15	124	0.91
Tanjung Perak	177	14	249	1
Tanjung Emas	14	4	152	0.28

Table 11. DEA of Domestic Container

Port	Output	Input		Value
	ST	Terminal	TRT (hour)	Θ
Tanjung Priok	217	8	80	1
Tanjung Perak	272	11	83	1
Tanjung emas	25	1	24	0.92

Table 12. DEA of Overseas General Cargo

Port	Output	Input		Value
	ST	Terminal	TRT (hour)	Θ
Tanjung Priok	59	4	69	1
Tanjung Perak	16	3	109	0.36
Tanjung emas	4	1	68	0.27

Table 13. DEA of Overseas Container

Port	Output	Input		Value
	ST	Terminal	TRT (hour)	Θ
Tanjung Priok	172	6	37	1
Tanjung Perak	87	2	23	1
Tanjung emas	43	1	21	0.99

The idea of DEA is that the efficiency of the *Data Management Unit* (DMU) is determined by the ability to transform the selection of inputs into outputs, such as the Port in Malaysia for their largest port has a relative efficiency of 100% from

its DEA measurement [15], as well as for Tanjung Priok Port which is the largest port in Indonesia. The results of statistical data processing also show that the length of time of ships at the Port of *TurnaRound Time* (TRT) at Tanjung Emas Port has a shorter time except for the domestic general cargo category. In general, for overseas containers the three ports have a TRT of less than 2 days, while for domestic it is approximately 3.5 days. For the type of general cargo ship for overseas the Port of Tanjung Priok and Tanjung Emas is less than 3 (three) days, while the Port of Tanjung Priok is 4.5 days. The performance of the length of time of the ship in the three ports and the ranking of the Worldbank CPPI that is actually not much different, but the difference in ranking is quite different, from the construction of the CPPI assessment that the assessment is based on five large size groups of ships and ten productivity size groups of cranes, so that all stakeholders must pay attention to port performance. The purpose of the Worldbank's CPPI is to look at performance comparisons and opportunities to make fuel savings and reduce emissions. The analysis considers that the larger the vessel, the more fuel it consumes, and the higher the potential to save fuel and reduce emissions[13].

Taking into account the IMO program related to carbon gas emissions that minimizing time at port will certainly support the reduction of greenhouse emissions, so that ship time at port can be efficient and effective. According to the processing results that the data on the maximum time of ships at the port with a varied average of 4 days, 6 days and even reached more than one month, so that the Port Operator and Port operators must coordinate with each other so that the maximum ship time at the port can be minimized to be able to reduce greenhouse gas emissions at the port.

The results of the statistical description of the three ports that the LK3 report data has a negative time value from the difference in departure and arrival times, and there is also a difference value of 0, meaning that the ship actually does not enter the port but is recorded with a value of 0, this data needs to be questioned the validity of data entry, so that LK3 report data needs to be validated so that there are no errors in reporting or recording data for each ship at Tanjung Priok Port, Tanjung Perak Port and Tanjung Emas Port.

The calculation results for DEA obtained that from the service unit according to the DEA model based on the given input will produce optimal output for the three ports where the efficiency rating for the Θ value obtained a value of 1, 0.91, 0.28, 0.92, 0.36, 0.27 and 0.99, where the service unit that obtained the Θ value is 1, relatively efficient compared to other service units. Based on the input variables, the productivity must be high enough to be considered efficient (Tatiana, 2023). Tanjung Priok Port and Tanjung Perak Port for container ship types both domestic and overseas have Θ values equal to 1, meaning that they are relatively efficient from Tanjung Emas Port, but the value is close to 1 (0.99) in value is close to being relatively efficient. For the domestic general cargo category, Tanjung Perak Port is relatively efficient, but for the foreign general cargo category, Tanjung Priok Port is relatively efficient compared to Tanjung Perak and Tanjung Emas Ports.

CONCLUSION

Port performance is part of the *Key Performance Indicator* as a manifestation of *good governance* in serving stakeholders and needs to increase the efficiency of the Port so that the port as a catalyst for the economy can be realized. Based on the results of LK3 inaportnet data processing of Tanjung Priok Port, Tanjung Perak Port, and Tanjung Emas Port, it can be conveyed as follows *Turnaround time of* ships for overseas container ship types at Tanjung Perak and Tanjung Emas Ports is less than one day while Tanjung Priok Port is 1.45 days, while domestic services at Tanjung Emas Port are only 1 (one) day and for Tanjung Priok Port 3.33 days and Tanjung Perak Port 3.45 days, based on the results of the calculation of the efficiency rating of DEA. From descriptive statistics that the maximum ship time at the port is still very long exceeding one month. The results of the calculation of *Data Envelpoment Analysis* (DEA) for the three ports are efficient on the type of container ships both domestic and foreign. LK3 inaportnet data needs to be validated properly by the relevant person in charge so that the data is in accordance with applicable rules. Cooperation between Port Operators and Port Operators and stakeholders at the port to be able to improve the efficiency and effectiveness of ship services at the port so that ships no longer take a long time at the port, the maximum data on ship time at the port can be reduced and also help the greenhouse gas emission reduction program in the port area and of course reduce logistics costs.

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