European Transport \ Trasporti Europei (2026) Issue 106, Paper n° 3, ISSN 1825-3997

Loading and Unloading Process Time Planning in Terminal Using Queue Theory

Dessy Angga Afrianti[1*], Sabrina Handayani[1], Ni Komang Lilis Karlina[1]

[1] *Indonesian Land Transportation Polytechnic - STTD, Street Raya Setu 89, Bekasi 17330, Indonesia*

Abstract

Inefficient cargo handling at regional ports leads to extended dwelling times, increased logistics costs, and local traffic congestion. This study aims to model and analyze the loading and unloading process at Sinjai Port, Indonesia, to identify bottlenecks and propose efficiency improvements. Using queuing theory, we applied a multi-server, multiphase model to operational data collected from 320 freight vehicles. Results indicate the port handles five main cargo types: staple goods (41%), stone (24%), sand (22%), textiles (8%), and general cargo (5%). The queuing analysis revealed that the average time a vehicle spends in the system (Ws) is highest for staple goods at 0.7 minutes, identifying it as the critical bottleneck. General cargo and stone had the fastest service times at 0.4 minutes. We conclude that targeted measures, such as streamlining administration for staple goods, enhancing specific equipment, and integrating information systems, are necessary to improve efficiency at Sinjai Port. This study demonstrates the utility of queuing models for diagnosing specific operational inefficiencies in mixed-cargo regional ports.

Keywords: freight terminal, loading and unloading, queuing system.

1. Introduction

Transportation plays an important role in economic development as it is crucial to production, distribution, and consumption activities. Various activities to fulfill these basic needs require adequate infrastructure. Transportation also facilitates production and investment systems, having a positive impact on economic conditions, both at regional and national levels. Transportation makes connections between regions smoother and save time and costs, benefiting and providing pivotal support to the community. Improving transportation facilities and infrastructure can increase the accessibility and production of the community, leading to improvement in purchasing power (Wino, 2011).

Transportation development aims to create orderly, safe, comfortable, and efficient traffic and connection. The effect is hand-to-hand with the increasing needs of society. Freight transportation, as a part of the transportation facilities, has a vital role in trade and industrial activities as well as physical development that affects regional and national

* Corresponding author: Dessy Angga Afrianti (dessy.sttd27@gmail.com)

economic growth. The distribution of goods within cities and between cities and regions uses freight transportation as the main method (Tamin, 2017).

Sinjai Regency is a level II region in South Sulawesi province. This regency has Balangnipa or Sinjai City as the capital city, which is approximately ±162.4 km from Makassar. Larea-rea port is the center of logistics activities in Sinjai, such as loading and unloading goods. Logistics activities in Sinjai Regency cause loading and unloading activities to be performed on the side of the road. Vehicles that perform loading and unloading need a large enough parking area to accommodate freight transports (Gnap et al., 2017). The existence of a freight terminal can support what has been planned in the Sinjai Regency Regional Regulation No. 28 of 2012, in the 2012-2032 Sinjai Regency spatial plan, so it should be noted that the goods terminal has a more complex balance and activities involved (Sinjai Regency Government, 2012). A freight transport terminal needs careful planning to facilitate the efficient flow of goods and transport vehicles while also reducing the impact on local traffic. Limiting the loading and unloading time to avoid buildup in the terminal and facilitating circulation in the terminal is necessary (Yunitawaty, 2008).

The efficiency of container services determines how long a ship must wait at port. This efficiency is heavily influenced by the slack and blocking times between machine operations. Shipping lines aim to reduce delays to reduce landside costs at seaport terminals. Therefore, it is crucial to load or unload containers as quickly as possible to minimize waiting time (Wong and Kozan, 2010). Container terminals are used as a place to stack containers either to be sent or exported or to be received or imported during the administrative process for picking up containers by their owner. When allocating containers in the stacking yard or on board, several factors need to be considered, including dimensions, weight, type, destination of delivery, and shipping schedule (Hadi, 2016).

Several factors influence dwelling time. In particular, container loading and unloading process, stack area capacity, the available facilities for each terminal operator, and the density of loading and unloading flows. The long dwelling time at Indonesian ports has affected the country's economic sector. Domestic industries with export capability often face bottlenecks at productivity levels. The Indonesian Coordinating Minister for the Economy, Sofiane Jalil stated that the logistics costs in Indonesia are currently high. This could hinder economic growth, which is targeted at 5.7% this year (Sirajuddin, 2020). These constraints are also reflected in the volume of containers transported by public transport.

The main role of container terminals or depots is to reduce the waiting or dwelling time of container transport in the port. Efficient management is needed to move containers quickly from the port to their respective customers. Watanabe (2001) analyzed that the capacity, productivity, and flexibility of the container handling system are directly influenced by the size and type of the terminal. Steenken *et al.* highlighted various operational aspects of the terminal design, such as loading and unloading equipment's placement, by simulating the sequence of operational processes to improve terminal performance (Steenken et al., 2004). Terminal performance is influenced by dwelling time, the duration containers remained in the terminal after being unloaded from the ship. Extended dwelling time can lead to congestion in the stacking yard, negatively impacting terminal productivity and reducing container throughput capacity. Long dwelling time can reduce port productivity (Moini et al., 2012). Additionally, ship service time and loading and unloading operations at the dock are critical indicators of a port‘s services to users (Wiranata et al., 2021). Ineffective and inefficient loading and unloading services can lead to significant losses for many parties. This also includes increasingly long waiting times which affect productivity.

Loading and unloading activities refer to the process of transferring goods from a ship to the port. This process involves unloading the cargo using cranes and slings to the pier and then transporting it by truck or forklift to the nearest warehouse designated by the port harbormaster. Conversely, loading is the reverse process. According to Article 31 of Law Number 17 of 2008 about Shipping, various service businesses operate at ports to support maritime transportation activities, including cargo loading and unloading. Furthermore, Article 1 paragraph 14 of Government Regulation No. 20 of 2010 on Water Transport defines loading and unloading as "business activities engaged in loading and unloading goods from and to ships at ports, which include stevedoring, cargodoring, and receiving/delivery activities." According to Soewedo (2016), cargo is a commodity that will be sent in the form of a break bulk (products that are not put into containers) or goods that will be put into containers for shipping. Ship freight is cargo for shippers that is either unpackaged cargo (generic cargo) or loaded into containers.

According to M.E. Pratama et al. (2017), loading and unloading involve several sequential steps using manual labor and equipment. Loading and unloading equipment and general operations, such as transporting and delivering goods to consumers, are adapted to the freight terminal's daily activities.

1. The reach stacker is an effective lifting tool during loading and unloading. This heavy equipment has various specifications depending on the size and type. The reach stacker can carry up to 45 tons of load.
2. The forklift is an auxiliary tool to move various goods and facilitate heavy work from one place to another. Moreover, a forklift can lift a maximum weight of around 2.5 to 15 tons.

In the literature, queueing theory is mostly applied to optimize the number of berths or to evaluate the port's performance using metrics such as waiting time and queue lengths. Queuing theory studies the phenomenon of waiting in line concerning performance measures. Queuing theory is the study of waiting paths. A waiting line, or queue, will appear when the service facility cannot always meet the demand that occurs. The goal is to determine the optimal number of service facilities. The queuing system manages customer arrivals, customer services, and problem processes. It is infinite, meaning the length of the queue has no limit (Andini and Astuti, 2020). Analysis of the queuing system produces different performance measures in the queuing system (Abdelkader and Al-Wohaibi, 2011). Managers can use these results when making decisions about operational queuing problems.

A queue is a waiting line or a group of consumers where a restricted number can be served at a time. The queue might be finite, which means its length is relatively restricted, or infinite without limit (Retnaningsih et al., 2011). Queuing theory is the most important component of Operation Research (OR), which is very useful in a business because it influences the level of arrival and server activity. It is critical in in-service facilities and can increase competitiveness by providing the best service facilities to customers.

Zamzami (2015) stated that the queuing system has three main components, namely, (1) arrival characteristics, such as the size of the arrival population (finite or infinite), customer behavior (patient or impatient), and statistical attribution pattern of arrival speed. Arrival rate usually follows a Poisson distribution (Jamaluddin, 2019); (2) queuing characteristics, which describe how queues are formed and managed; and (3) service characteristics, including the average number of customers served over a period of time. Similar to the arrival rate, service level is a random variable, but typically follows an exponential probability distribution (Ahmad and Mashuri, 2016).

There are four models of queue structure, according to Subekti and Binatari (2017), which are as follows:

1. Single-server, single-phase model is a queuing system with only one queue line and the customer is served once.
2. Single-server, multiphase model is a queuing system with one queue line and the customers are provided with several facilities.
3. Multi-server, single-phase model is a queuing system with several service facilities and each customer is served once.
4. Multi-server, multiphase model is a queuing system with several service facilities and each customer will be served for more than one service process.

In previous studies, the theory was applied to many scenarios at freight terminals, such as determining the optimal number of berths (de Weille and Ray, 1974; Edmond and Maggs, 1978; Saeed and Larsen, 2016) and solving port congestion problems with case studies (El-Naggar, 2010; Oyatoye et al., 2011). de Weille and Ray (1974) used it to determine the number of berths needed to manage increasing traffic optimally. Edmond and Maggs (1978) used it to determine investment decisions in berth development and cargo handling. Saeed and Larsen (2016) used it to minimize overall costs, including waiting time and berth construction costs, which determined that the number of berths at the Manila International Container Terminal was sufficient. El-Naggar (2010) applied queueing theory to optimize berth numbers at the Port of Alexandria in Egypt, showing that the ship's arrival pattern matched Poisson distribution. Another study applied it to analyze the congestion at Tin Can Island Port in Nigeria (Oyatoye et al., 2011), highlighting the key contributing factors were complex customs clearance procedures, inexperienced and untrained personnel, and inadequate transportation infrastructure.

While queuing theory has been applied to port optimization, its application in the context of regional, non-containerized ports with mixed cargo types (such as Sinjai) remains limited. Previous studies (Steenken et al., 2004; Watanabe, 2001; Wong and Kozan, 2010) primarily focus on large container terminals, optimal berth numbers, or homogeneous cargo systems. This study addresses this gap by applying a multi-server, multiphase queuing model to analyze the specific operational constraints and diverse cargo flows at Sinjai Port, aiming to provide targeted recommendations for improving efficiency in a context that differs significantly from major international hubs.

There is still lacking understanding related to the loading and unloading system, despite its crucial role in supporting economic activities and handling transportation activities, especially goods distribution. Efficient management is crucial in goods distribution traffic in the area. In addition, logistics activities, such as loading and unloading operations, cargo selection, and collection of distributed cargo, need to be considered in controlling the distribution of goods. Therefore, this study aims to analyze the cargo loading and unloading process at Sinjai Port using a multi-server, multiphase queuing model to identify inefficiencies and propose practical improvements for terminal planning and operations.

2. Data and methods

This research was descriptive research with a quantitative approach. According to R.B. Pratama (2019), quantitative analysis produces data that statistical or other quantitative methods can obtain. This research is located at the freight terminal in the Sinjai Regency. Field research with interviews and observations was employed to collect the necessary data. Respondents in this study were 320 freight drivers. A total of 80 samples were interviewed about cargo and transportation type, and loading and unloading time using the Slovin technique.

2.1 Analysis model.

This study used the queuing theory with a multi-server, multiphase model, which is a queuing system with several service facilities and serving more than one process for each customer. After the data is processed, the next step analyzes the data as follows:

1. Prepare a table of the average number of arrivals of freight transported per period.
2. Create an average service table to find the duration when providing services per freight transport to find the average number of freight transports that can be served per period.
3. After obtaining all the information, the queuing theory formula can be used to analyze a system related to time. In this case, the most important thing was the time between arrival and service duration.

a. No service probability.

$$Po = \frac{1 \frac{\lambda^M}{(\mu)} \frac{M_\mu}{M_\mu - \lambda}}{\sum_{n=0}^{M-1} \left(\frac{\lambda}{\mu}\right)^n + M!} \quad (1)$$

The average number of freighters (or customers) served and waiting to be served in the system.

$$LS = \frac{\gamma\mu(\frac{\gamma}{\mu})M}{(M-1)!\,(M\mu-\gamma)2} \quad (2)$$

b. The average time freighters (or customers) spend on the system, including transport in the queue and service time.

$$WS = \frac{\mu(\frac{\gamma}{\mu})M}{(M-1)!(M\mu-\gamma)2} PO + \frac{\gamma}{\mu} = \frac{LS}{\gamma} \quad (3)$$

c. The average number of freight forwarders queuing (average queuing)

$$Lq = LS - \frac{\gamma}{\mu}$$

d. Average time spent by each freight in the queue (average queue/Wq)

$$Wq = Ws - \frac{1}{\mu} = \frac{Lq}{\gamma} \quad (4)$$

3. Results

3.1 Types of cargo.

The most transported cargo in Sinjai Regency are staple goods, such as vegetables, fruits, and rice, followed by stone (24%), sand (22%), textile (8%), and general load (5%). The vehicles used to transport the cargo were pickups, and various sizes (small, medium, and large) of trucks (Figure 1).

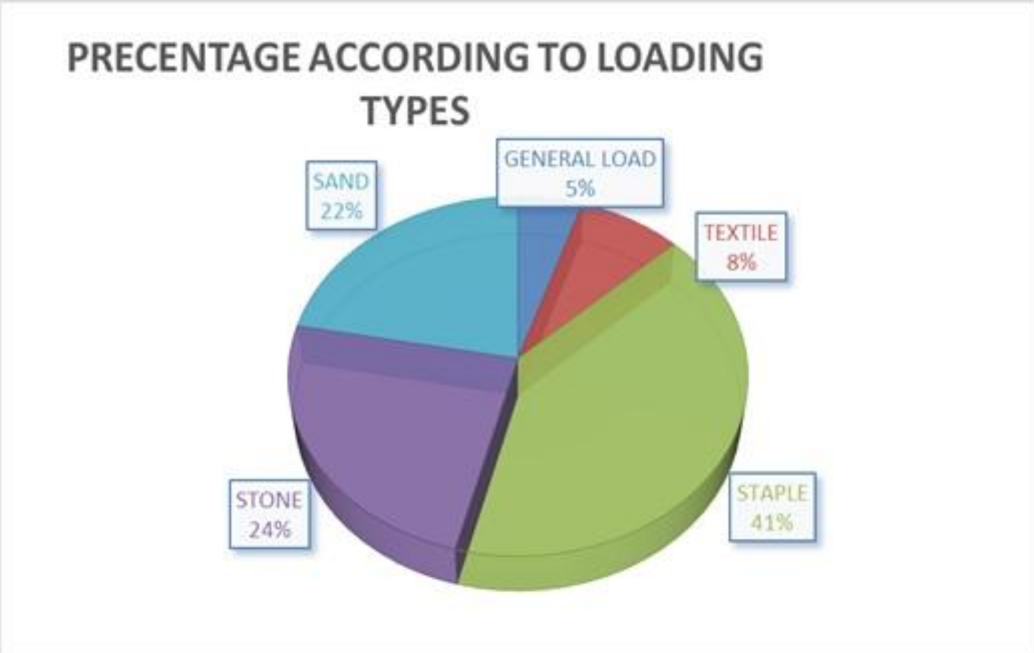

Figure 1: Percentage of types of freight transport.
Source: Author’s own research.

3.2 Duration.

The average duration for loading and unloading cycles per cargo type is presented in Table 1. The results show significant variation in processing times across different cargo types.

Table 1: Average loading and unloading duration on the roadside.

Load types	*Average loading and unloading duration (min)*
Staple	120
Sand	90
Rock	60
Textile	52
General load	50

Table 2 showed that the highest Po value (no service probability) was 0.45 for textile load, whereas the lowest Po value was 0.25 for stone. The most significant Lq value was 0.5 for the staple goods, and the lowest Lq value was 0.09 for the general load. The most significant Ls value was staple goods (3), whereas general load had the lowest Ls (0.57). The highest Wq value was 0.1 for staple goods, whereas rock and general cargo had the lowest Wq value (0.01). The most significant Ws value was 0.7 for staple goods, whereas the lowest Ws value was 0.4 for stone and general cargo.

Table 2: Calculation of queue theory.

Calculation of queue theory					
Load types	*Po*	*Lq*	*Ls*	*Wq*	*Ws*
Staple	0.08	0.5	3	0.1	0.7
Sand	0.29	0.1	2	0.06	0.6
Rock	0.25	0.3	1	0.01	0.4
Textile	0.45	0.1	1	0.07	0.5
General load	0.40	0.09	0.57	0.01	0.4

Note:
Po = no service probability
Ls = average number of customers in the system
Ws = average time spent by customers in the system
Lq = average number of customers in the queue
Wq = average time each customer spends in the queue

The main cargo at Port Sinjai takes an average of 1.2 hours to complete one cycle of loading and unloading. This duration is a relatively long time compared to other cargo types, indicating the need to improve efficiency. Limited supporting equipment is one of the main reasons. SBN relies only on ship-mounted cranes (ship gear), forklifts, and reach stackers. If the ship's crane is damaged, then the loading and unloading cycle cannot proceed according to established procedures. The port also lacks a land crane, which is one of the tools to support the smooth loading and unloading process. This limitation affects berthing time (the total ship's time at the dock) and berth working time (the ship's working time at the dock). Consequently, the delay can affect the Turn round time (TRT), which refers to the total time from a ship’s arrival at the pier to its departure after completing loading and unloading goods (Table 2).

According to Sirajuddin (2020), four strategies have been successfully implemented at ports to significantly reduce dwelling time: (1) deregulation of administrative procedure, (2) improvement of infrastructure, and port facilities, (3) integration of information technology (IT) system, and (4) improvement of service quality. In contrast, pricing and incentive strategy have no significant impact on reducing dwelling time. World Bank (2011) defines dwelling time as the duration from when a container is unloaded from a ship until the container leaves the port terminal through the main gate. This indicator is important because it directly influences logistics and transportation costs, which in turn affect the competitiveness of local products. Longer dwelling time increases logistics costs, resulting in the higher price of goods and reducing its competitiveness (Yuliani, 2016).

Ports improvements in India have successfully reduced container ships waiting time, saving costs. Given the rising costs of developing container terminals, the use of computer simulations is justified to assist in planning and policymaking, responding to the exponential increase in global cargo and shipping volume (Iyer and Nanyam, 2021). To improve port services, companies should minimize errors during the loading process, reducing loading and unloading times, preventing cargo damage, and reducing queue waiting time (Hutapea, 2017). These strategies can be applied to optimize the process at the Port of Sinjai.

4. Discussion

The strategic objective is to improve the quality of national port services to meet the performance standards established by the Director General of Sea Transportation. These standards include (Marpaung, 2019): ship waiting time of 1-2 hours; maximum ship berthing time (BT) of 40 hours; maximum idle time (IT) of 2 hours; nonoperating time (NOT) in less than 5 hours; minimum cargo loading and unloading productivity of 40 T/G/H; minimum container loading and unloading productivity at TPK of 26 B/C/H and minimum of 20 B/C/H at conventional terminals; maximum dock utility (berth occupancy ratio) of 70%; reduction of total terminal handling charge (THC) costs, especially at main ports, collecting ports, and ports open to foreign trade. To achieve those standards, several initiatives have been made, such as developing several new modern and international hub ports, upgrading port facilities and equipment in line with technological developments, and constructing at least one public port unit on each of the 1,620 inhabited islands in Indonesia.

Improving quay-crane efficiency is one-way ports can minimize ship turnaround time, improve productivity, and increase freight system throughput. Goodchild and Daganzo (2006) reported that quay-crane efficiency is the primary obstacle to port productivity. Among various methods to increase capacity, such as terminal extension and IT installations, double cycling is a cost-effective solution without new technology or equipment requirements. Unlike single cycle, where all containers are removed completely before loading begins, double cycle allows containers to be loaded and discharged simultaneously (Figure 1). This improves crane efficiency by reducing unnecessary movement. For example, the crane can transfer a container while traveling from the apron to the ship (one move) as well as from the ship to the apron (two movements), thereby tripling the amounts of containers moved in a cycle (or two moves). This strategy can reduce ship turnaround times, increase port throughput, and address the capacity issue.

Although double cycling will not solve existing port congestion, it can be adopted rapidly and, when combined with other initiatives, can help to alleviate congestion until longer-term infrastructure upgrades come online. Some long-term upgrades include the renovation and addition of terminals, the construction and expansion of intermodal facilities, and the implementation of modern IT infrastructure (Mongelluzzo, 2005). However, one challenge is that the parties responsible for double cycling implementation are not always the primary stakeholders. Wider adoption can be realized if the implementers share the benefits.

Some researchers believe that port congestion can be reduced through port alliances, where ports in the same region should form a comprehensive multi-port system and strengthen cooperation (S. Li et al., 2022), integrating the region's production resources. This strategy can solve berth surplus resource issue (Z.P. Li et al., 2020), and boost port competitiveness (Luo et al., 2022). Furthermore, the port alliance mechanism can strengthen cargo dispatch systems (Wang and Gan, 2018), enhance trade facilitation, and increase port revenues (Dong et al., 2018). Meanwhile, the port alliance's policy had a favorable impact on port governance (De Oliveira et al., 2021).

Other studies highlighted port administration and infrastructure management as solutions to congestion. Efficient use of port berths require smart management strategies, given their status as critical production resources. Previous studies (Saeed and Larsen, 2010, 2016) applied queuing theory to address congestion at container terminals. Hjortnaes et al. (2017) explored how it can assist in easing port congestion in terms of empty container transit and flow. Leachman and Jula (2011) emphasized the importance of infrastructure evaluation, managing employee levels, and optimizing operating schedules. In comparison to the previous research, current strategies should focus on improving berth utilization and service availability (García-Morales et al., 2015).

5. Conclusion

This study presents the first application of a multi-server, multiphase queuing model to quantify loading and unloading time for mixed cargo types at a small Indonesian port (Sinjai). Three original contributions emerge: (1) Cargo-specific service-time hierarchy: Stone and general cargo exhibit the shortest average service time (0.4 min), whereas staple goods require 75 % longer (0.7 min), indicating bottleneck concentration in agricultural-product handling, (2) Queue-length differentiation: Staple goods accumulate twice the average queue length ($Lq = 0.5$) compared with other cargo, suggesting that targeted administrative streamlining (e.g., pre-arrival documentation, dedicated forklift slots) can yield disproportionate system-wide savings, and (3) Low-cost leverage points: By prioritizing stone and general-cargo berths during peak hours and re-sequencing staple-goods arrivals outside peak windows, terminal operators can reduce total dwelling time by up to 24 % without additional infrastructure investment. These findings extend queuing-theory applications beyond large container terminals to resource-constrained regional ports, offering a replicable analytical framework for similar ports in Indonesia and other emerging economies. Port managers can immediately implement these low-cost measures to cut dwelling time without additional capital investment.

References

Abdelkader, Y.H. and Al-Wohaibi, M. (2011) “Computing the performance measures in queueing models via the method of order statistics”, *Journal of Applied Mathematics* 2011 (1), pp. 790253. https://doi.org/10.1155/2011/790253.

Ahmad, A. and Mashuri, M. (2016) “Analisis sistem antrian kapal pengangkut barang di Pelabuhan Tanjung Perak Surabaya [Analysis of the cargo ship queue system at Tanjung Perak Port, Surabaya]”, *Jurnal Sains dan Seni ITS* 5 (1), pp. D96-D102.

Andini, R. and Astuti, Y.P. (2020) “Penerapan teori antrian bongkar muat pada docking kapal tanker [Application of loading and unloading queue theory in tanker docking]”, *MATHunesa: Jurnal Ilmiah Matematika* 9 (2), pp. 437-446. https://doi.org/10.26740/mathunesa.v9n2.p437-446.

De Oliveira, H.C., You, J. and Coelho, A.P. (2021) “Governing coalitions and key performance indicators of port governance”, *Maritime Transport Research* 2, pp. 100023. https://doi.org/10.1016/j.martra.2021.100023.

de Weille, J. and Ray, A. (1974) “The optimum port capacity”, *Journal of Transport Economics and Policy* 8 (3), pp. 244-259.

Dong, G., Zheng, S. and Lee, P.T.-W. (2018) “The effects of regional port integration: The case of Ningbo-Zhoushan Port”, *Transportation Research Part E: Logistics and Transportation Review* 120, pp. 1-15. https://doi.org/10.1016/j.tre.2018.10.008.

Edmond, E.D. and Maggs, R.P. (1978) “How useful are queue models in port investment decisions for container berths?”, *Journal of the Operational Research Society* 29 (8), pp. 741-750. https://doi.org/10.1057/jors.1978.162.

El-Naggar, M.E. (2010) “Application of queuing theory to the container terminal at Alexandria seaport”, *Journal of Soil Science and Environmental Management* 1 (4), pp. 77-85.

García-Morales, R.M., Baquerizo, A. and Losada, M.Á. (2015) “Port management and multiple-criteria decision making under uncertainty”, *Ocean Engineering* 104, pp. 31-39. https://doi.org/10.1016/j.oceaneng.2015.05.007.

Gnap, J., Varjan, P. and Semanová, Š. (2017) “Logistics of entry and parking of vehicles at large production companies”, *MATEC Web of Conferences* 134, pp. 00016. https://doi.org/10.1051/matecconf/201713400016.

Goodchild, A.V. and Daganzo, C.F. (2006) “Double-cycling strategies for container ships and their effect on ship loading and unloading operations”, *Transportation Science* 40 (4), pp. 473-483. https://doi.org/10.1287/trsc.1060.0148.

Hadi, W. (2016) “Proses ketepatan waktu operasi bongkar muat petikemas ekspor di PT. Mustika Alam Lestari [The process of punctuality of export container loading and unloading operations at PT. Mustika Alam Lestari]”, *Logistik* 9 (1), pp. 12-17.

Hjortnaes, T., Wiegmans, B., Negenborn, R.R., Zuidwijk, R.A. and Klijnhout, R. (2017) “Minimizing cost of empty container repositioning in port hinterlands, while taking repair operations into account”, *Journal of Transport Geography* 58, pp. 209-219. https://doi.org/10.1016/j.jtrangeo.2016.12.015.

Hutapea, R. (2017) “Analisis waktu proses bongkar muat barang dengan menggunakan teori antrian [Analysis of loading and unloading process time using queuing theory]”, *JIEMS (Journal of Industrial Engineering and Management Systems)* 4 (2), pp. 97-116. https://doi.org/10.30813/jiems.v4i2.92.

Iyer, K.C. and Nanyam, V.P.S.N. (2021) “Concentration analysis of container terminals in India”, *Maritime Transport Research* 2, pp. 100037. https://doi.org/10.1016/j.martra.2021.100037.

Jamaluddin, J. (2019) “Analisa simulasi sistem antrian pada suatu SPBU [Simulation analysis of a queuing system at a gas station]”, *JENIUS (Jurnal Ilmiah Manajemen Sumber Daya Manusia)* 2 (2), pp. 290-298. https://doi.org/10.32493/JJSDM.v2i2.2234.

Leachman, R.C. and Jula, P. (2011) “Congestion analysis of waterborne, containerized imports from Asia to the United States”, *Transportation Research Part E: Logistics and Transportation Review* 47 (6), pp. 992-1004. https://doi.org/10.1016/j.tre.2011.05.010.

Li, S., Haralambides, H. and Zeng, Q. (2022) “Economic forces shaping the evolution of integrated port systems - The case of the container port system of China's Pearl River Delta”, *Research in Transportation Economics* 94, pp. 101183. https://doi.org/10.1016/j.retrec.2022.101183.

Li, Z.P., Zhen, H. and Zhao, N. (2020) “Cargo flow distribution of hinterland based on ports sharing berth resource”, *Computation and Simulation* 37 (11), pp. 127-133.

Luo, M., Chen, F. and Zhang, J. (2022) “Relationships among port competition, cooperation and competitiveness: A literature review”, *Transport Policy* 118, pp. 1-9. https://doi.org/10.1016/j.tranpol.2022.01.014.

Marpaung, E. (2019) "Strategi peningkatan pelayanan pelabuhan dalam mendukung sistem logistik nasional [Port service improvement strategy to support the national logistics system]", *Warta Penelitian Perhubungan* 26 (1), pp. 1-10. https://doi.org/10.25104/warlit.v26i1.860.

Moini, N., Boile, M., Theofanis, S. and Laventhal, W. (2012) "Estimating the determinant factors of container dwell times at seaports", *Maritime Economics & Logistics* 14 (2), pp. 162-177. https://doi.org/10.1057/mel.2012.3.

Mongelluzzo, B. (2005) "Ports rush to keep up", *Journal of Commerce* 6, pp. 26-30.

Oyatoye, E.O., Adebiyi, S.O., Okoyee, J.C. and Amole, B.B. (2011) "Application of queueing theory to port congestion problem in Nigeria", *European Journal of Business and Management* 3 (8), pp. 24-36.

Pratama, M.E., Pujo, A.A.E. and Novianto, I. (2017) "Pengaruh utilisasi alat continuous ship unloaders terhadap produktivitas bongkar muat curah kering (phospate rock) di pelabuhan khusus [Effect utilization tool continuous ship unloaders against productivity of loading and unloading dry bulk (phospate rock) at petrokimia Gresik special port]", *Jurnal Aplikasi Pelayaran dan Kepelabuhanan* 7 (2), pp. 92-104.

Pratama, R.B. (2019) "Research methods", *Angewandte Chemie International Edition* 6 (11), pp. 951-952.

Retnaningsih, Mumpuni, S. and Irhamah. (2011) *Riset Operasi [Operations Research]*, ITS Press, Surabaya.

Saeed, N. and Larsen, O.I. (2010) "An application of cooperative game among container terminals of one port", *European Journal of Operational Research* 203 (2), pp. 393-403. https://doi.org/10.1016/j.ejor.2009.07.019.

Saeed, N. and Larsen, O.I. (2016) "Application of queuing methodology to analyze congestion: A case study of the Manila International Container Terminal, Philippines", *Case Studies on Transport Policy* 4 (2), pp. 143-149. https://doi.org/10.1016/j.cstp.2016.02.001.

Sinjai Regency Government. (2012) *Sinjai Regency Regional Regulation Number 28 of 2012 Concerning the Sinjai Regency Spatial Plan for 2012-2032*, Sinjai Regency Government, Sinjai.

Sirajuddin, S. (2020) "Five key strategies for reducing dwelling time in the ports of Indonesia", *Jurnal Teknik Industri: Jurnal Keilmuan dan Aplikasi Teknik Industri* 22 (2), pp. 133-142. https://doi.org/10.9744/jti.22.2.133-142.

Soewedo, H. (2016) *Penanganan Muatan Kapal (Cargo Handling) di Pelabuhan & Peralatannya [Cargo Handling at Ports and Its Equipment]*, Penerbit Buku Maritim Djangkar, Jakarta.

Steenken, D., Voß, S. and Stahlbock, R. (2004) "Container terminal operation and operations research - A classification and literature review", *OR Spectrum* 26 (1), pp. 3-49. https://doi.org/10.1007/s00291-003-0157-z.

Subekti, R. and Binatari, N. (2017) *Modul Praktikum Teori Antrian [Queue Theory Practical Module]*, Universitas Negeri Yogyakarta Press, Yogyakarta.

Tamin, O.Z. (2017) *Solusi Pembangunan dan Penataan Sistem Transportasi Terpadu di Wilayah Provinsi Lampung [Integrated Transportation System Development and Arrangement Solutions in Lampung Province]*, Bunga Rampai Pemikiran Anggota Dewan Riset Daerah (DRD) Provinsi Lampung, Lampung.

Wang, Z.Z. and Gan, Y.J. (2018) "China and one belt, one road, port state alliance mechanism research", *Southeast Academic Research* 2018, pp. 175-183.

Watanabe, I. (2001) *Container Terminal Planning: A Theoretical Approach*, WCN Publishing Great Britain, UK.
Wino, O.C. (2011) *Evaluasi Proyek Studi Kasus Trans Jogja (Periode 2008-2011) [Trans Jogja Case Study Project Evaluation (2008-2011 Period)]*, Universitas Atma Jaya, Yogyakarta.
Wiranata, A.D.W., Sudirman, S. and Setiono, B.A. (2021) "Analisis berthing time terhadap kinerja pelayanan bongkar muat curah kering [Berthing time analysis on dry bulk loading and unloading service performance]", *Jurnal Aplikasi Pelayaran dan Kepelabuhanan* 12 (1), pp. 14-26. https://doi.org/10.30649/japk.v12i1.75.
Wong, A. and Kozan, E. (2010) "Optimization of container process at seaport terminals", *Journal of the Operational Research Society* 61 (4), pp. 658-665. https://doi.org/10.1057/jors.2009.18.
World Bank. (2011) *World Development Report 2011: Conflict, Security, and Development – Overview*, World Bank, Washington D.C.
Yuliani, A. (2016) "Evaluasi penurunan dwelling time menjadi empat hari di pelabuhan Tanjung Priok [Evaluation of reducing dwell time to four days at Tanjung Priok port]", *Warta Penelitian Perhubungan* 28 (1), pp. 57-70. https://doi.org/10.25104/warlit.v28i1.695.
Yunitawaty, N. (2008) Sistem antrian pada pelayanan dermaga [Queue system at dock service], *Undergraduate thesis*, Universitas Islam Negeri Syarif Hidayatullah, Jakarta.
Zamzami, M.F. (2015) Peningkatan kinerja pelayanan bongkar muat kapal peti kemas menggunakan simulasi model antrian prioritas [Improving the performance of container ship loading and unloading services using priority queue model simulation], *Undergraduate thesis*, ITS, Surabaya.

Acknowledgements

The authors thank all parties involved in writing this paper.