Analysis of Implementation of Bonded Logistics Center on Cargo Service Performance at Port: Case Study of Tanjung Priok Port

Achmad Riadi[1], Depitasari[2]

Ports are crucial facilities for export and import activities. Port facilities, such as container terminals, play a significant role in the smooth flow of cargo. The faster containers move, the better the port's performance. The flow of containers is influenced by document handling. The involvement of multiple parties and stringent import document processing often results in lengthy cargo handling times. This issue becomes a national logistics problem for a country. Bonded Logistics Centers, especially in Indonesia, have been established to address this problem. A Bonded Logistics Center (BLC) is a bonded storage place for storing cargo originating from outside the customs area and/or cargo from other places within the customs area, which may be accompanied by one or more simple activities for a specified period before being re-exported. BLC aims to reduce cargo handling activities at the port by transferring some of the cargo inspection activities, originally conducted at the port, to the BLC. The objective of this study is to assess the impact of BLC on the performance of cargo services at the port, particularly for container transport. A port's cargo service performance is evaluated based on the dwelling time duration and container unloading productivity. This study employs a system dynamics model to represent the actual conditions at the port. The results indicate that the use of the BLC can reduce dwelling time by up to 6%, improve unloading productivity by 2%, and increase yard capacity availability by 11%.

KEY WORDS
~ Bonded logistics center
~ System dynamics
~ Port performance
~ Port
~ Import

Universitas Indonesia, Faculty of Engineering, West Java, Indonesia
e-mail: achmadriadi@ui.ac.id
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1. INTRODUCTION

Maritime transportation has become one of the most popular means of the distribution of cargo from international trade (Luo *et al*., 2023). Recorded data shows that 90% of global trade is distributed via sea routes, and 40% of the distribution process passes through Indonesia (Indonesia Ministry of Transportation, 2018). Indonesia must seize this opportunity to strengthen its economy through the maritime sector. A contribution that Indonesia can make is to improve the quality of its ports. Ports are key components of the logistics network and play a crucial role in terms of infrastructure, facilities, and territorial dynamics (González Laxe *et al*., 2022).

All movements of cargos or containers in the port area are highly valuable. The faster the containers move, the more cost-effective it becomes. However, issues such as delays in the handling process, physical inspections of imported cargos, and limited yard capacity can hinder the clearance process (Anggraeni and Mansyur, 2022). This will hinder the flow of imported goods and disrupt some industrial activities. It can also reduce the efficiency of goods production and logistics systems.

World Bank data shows that Indonesia's Logistics Performance Index ranks 48th, with customs clearance being the lowest indicator among the assessment indicators. To address this logistics issue, the Indonesian government implemented the Bonded Logistic Centre through Economic Policy Package Volume 2 to stimulate economic growth (Riadi and Sunaryo, 2023).

A Bonded Logistic Centre (BLC), known in Indonesian terminology as PLB, is a storage warehouse for imported or exported goods. It performs one or more activities such as repackaging, sorting, and cutting for specific items that are to be reissued within a certain period (Indonesian Ministry of Finance, 2015). The advantages of a BLC include longer storage periods compared to regular warehouses, flexibility in goods ownership, suspension of import permits, suspension of taxes and import duties, and flexibility in the origin and destination of goods. Containers destined for the BLC do not undergo customs processes like regular containers at the port but instead go directly to the BLC for customs processing.

The Ministry of Trade's evaluation reveals that the BLC has reduced the time required for handling or inspecting goods, the delivery time, and the shipping costs (Hidayat *et al*., 2018). Indirectly, BLC can minimize handling processes, reduce dwelling time, and decrease container accumulation in the yard. Based on the potential and interrelationship of the aforementioned phenomena, BLC policies are suspected to have a significant impact on the port. A research approach is needed to determine the measurable effects on port performance, particularly in relation to cargo service performance.

Previous research has examined the implementation of the BLC and port performance using various methods. One such study is the implementation of the BLC using a logistics cost comparison method (Yusup, 2022). The study examines the impact of the BLC at Makassar New Port on reducing logistics costs using the case of sugar commodity imports. The results indicate that implementing the BLC at Makassar New Port significantly reduces logistics costs. Specifically, the BLC reduces logistics costs associated with importing sugar commodities. Another study utilized a combination of descriptive and survey methods alongside a literature review. Additionally, data collection was conducted through surveys and interviews with the BLC companies. The findings reveal that the BLC improves logistics costs, and delivery and storage times for goods. The number of the BLC companies increased from 11 to 34 companies, thereby enhancing industry competitiveness (Budilaksono, 2019). Research on the BLC using interviews among the BLC companies has also been previously conducted (Rosdiana *et al*., 2018). The BLC research approach was also conducted using a qualitative method (Dhika Sudi Nurdiana, 2019; Haryana, 2017). Research related to the BLC is also ongoing on various imported commodity objects, including those in the oil and gas industry (Erie Yoewono, 2018). Other research related to port performance based on system dynamics modeling has also been conducted (Aisyah Aulia and Achmad Riadi, 2022; Amrita Jhawar, 2018; Chung and Jeon, 2021; Gurning and Riadi, 2022; Luo *et al*., 2023; Mamatok *et al*., 2019; Sinha and Bagodi, 2019; Sunitiyoso *et al*., 2022; Xu *et al*., 2021). Research on port performance is often conducted using qualitative approaches (Aminatou *et al*., 2018; Peter de Langen *et al*., 2007; Simatupang *et al*., 2021). The performance of ports is greatly influenced by port characteristics and the effects of port-logistic integration. This statement is derived from research using structural equation modeling, which tested the relationships between port characteristics and performance (Ali and Ayelign, 2022). Port performance was also examined from the perspective of unloading cargo from container vessels using modeling frameworks for the planning and management of optimal marine terminal fleets, including yard trucks and quay cranes (Kang *et al*., 2008; Zhen *et al*., 2019). While system dynamics models are typically used to analyze policies by representing the actual conditions of a given problem (Andhika Chyono Putra *et al*., 2019).

Previous research has focused on BLC policies, port performance optimization, and the use of system dynamics models, which have been analyzed separately in various studies. On the other hand, this study aims to integrate the three entities: BLC policies, port performance, and system dynamics modeling.

The objective of this research is to determine the impact of the BLC implementation on cargo service performance at the port using system dynamics modeling. The modeling includes key variables that interact within port operations and ultimately affect port performance. To address this research objective, Tanjung Priok Port, located in Jakarta, Indonesia, is used as the case study.

2. DATA COLLECTION AND METHODOLOGY

2.1. Data Collection

This research utilized Tanjung Priok Port cargo service performance data including average dwelling-time data, unloading productivity data, and average custom-time data for 2 years' duration, from January 2021 to December 2022. The data is secondary data obtained from the port authority. Observations and the data from previous research were also employed to propose the information and data required for this study. Table 1 shows the Tanjung Priok Port cargo service performance data from January 2021 to December 2022.

Period	Average Dwelling Time (days)	Unloading Productivity (TEUS)	Average Custom Time (days)
January 2021	3.10	130,134	1.59
February 2021	2.55	121,046	1.66
March 2021	2.45	149,333	1.54
April 2021	2.49	155,291	1.68
May 2021	3.05	122,419	2.14
June 2021	2.86	148,476	1.84
July 2021	3.64	137,781	2.05
August 2021	2.63	138,691	1.71
September 2021	2.29	130,405	1.51
October 2021	2.45	131,408	1.76
November 2021	2.43	143,518	1.69
December 2021	2.54	160,933	1.74
January 2022	2.76	156,030	1.45
February 2022	2.81	128,508	1.35
March 2022	2.68	164,218	1.31
April 2022	2.82	145,472	1.33
May 2022	3.95	142,770	1.51
June 2022	3.09	162,880	1.34
July 2022	2.66	155,761	1.27
August 2022	2.57	170,389	2.08
September 2022	2.49	140,538	1.33
October 2022	2.55	146,552	1.49
November 2022	2.66	160,333	1.43
December 2022	2.71	150,257	1.50

Table 1. Tanjung Priok Port cargo service performance from January 2021 to December 2022.

2.2. Method

The port logistics sector is notably complex. This intricate system presents significant challenges for analysis, understanding its operations, forecasting its actions, and assessing its effectiveness (Kwesi-Buor *et al*., 2019). Complex systems can be analyzed and designed using system dynamics models (Gurning and Riadi, 2022). This research uses system dynamics as a tool to model port logistics behavior.

Software is required to create system dynamics models. In this study, the model was constructed using Vensim® software, which was also used for simulating the model, verifying the model, and continually adjusting the model based on simulation results.

System dynamics is useful for creating simulation processes and allows for the addition or modification of variables for improved outcomes. Causal Loop Diagram (CLD) is a primary technique used in system dynamics modeling to examine the interactions between system components or variables (Mamatok et al., 2019). To illustrate the causal relationships involved, the CLD is represented by variables and arrows. A positive arrow from one variable (cause) to the next variable (effect) indicates that the cause and effect change in the same direction, while a negative arrow signifies that the cause and effect move in opposite directions (Xia et al., 2021). CLD is a diagram that visualizes the cause-and-effect relationships between variables in a system, as shown in Figure 1.

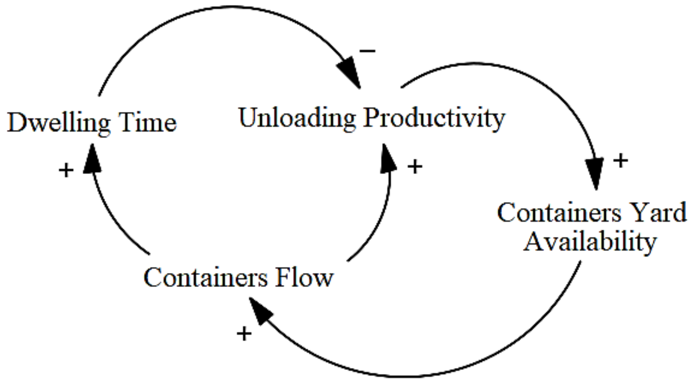


Figure 1. Example of Causal Loop Diagram (CLD)

The relationships between the variables or entities described in the CLD are executed in the Stock Flow Diagram (SFD). **Figure 2** illustrates the general form of the SFD.

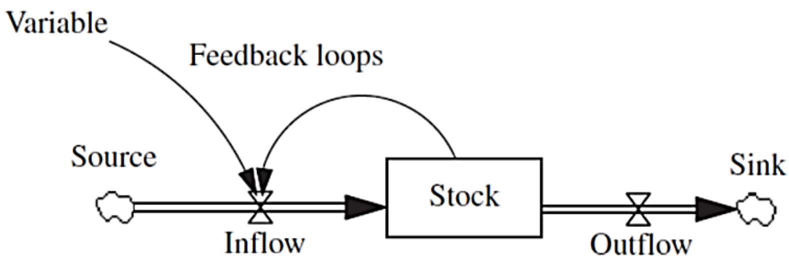


Figure 2. Stock flow diagram form (SFD)

Each variable in the SFD will have a specific form and function that produces values. **Table 2** explains the use of each variable form.

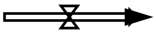
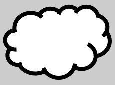
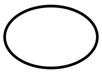
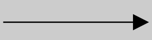
Variables	Symbols	Description
Stock (Level)		It is a variable that has a value based on the accumulated flow over time.
Flow (Rate)		It is a flow that can either increase (inflow) or decrease (outflow) the stock value.
Cloud (Sink and Source)		It is a representation of an infinite source outside the system model's bounds.
Auxiliary		It is an additional variable that may have an impact on stock and rate
Link		It is a connection between the rate and the auxiliary element.

Table 2. Variables of Stock Flow Diagram

System dynamics model must first be verified and validated after the modeling is completed. This is useful for testing the behavior of the system. It is important to consider model accuracy analysis based on rationality. Behavior pattern tests are a type of model validation test that determine how closely the output behavior patterns from the model match those of the real system. The formulas in equations **(1)** and **(2)** are used in this validation by comparing the mean values and standard deviations between the modeling results and actual data.

Mean Values Comparison (E1)

$$E1 = \frac{|\bar{S} - \bar{A}|}{\bar{A}} \quad (1)$$

Description:

$\bar{S}$ = Mean value of the model results

$\bar{A}$ = Actual mean value

The model is considered valid if E1 ≤ 5%.

Standard Deviation Comparison (E2)

$$E2 = \frac{|Ss - Sa|}{Sa} \quad (2)$$

Description:

Ss = Standard deviation of model results

Sa = Actual Standard deviation

The model is considered valid if E2 ≤ 30%.

Based on the system dynamics method, a model was developed to represent the actual conditions at the Tanjung Priok Port, particularly related to the performance of cargo services, with the implementation of the BLC policy.

3. RESULTS AND DISCUSSION

3.1. Stock Flow Diagram Model

A highly complex system, within a port, involves interactions between the internal and external environments (Xu *et al*., 2021). In the development of a model for this condition, SFD sub-model is necessary as it can encompass all the minor interactions between variables at a higher level of complexity. The model in this study is divided into 4 SFD sub-models: Dwelling Time, Flow of Containers to Yard, Port Infrastructure, and Unloading Productivity. Figure 3 shows the SFD sub-model for dwelling time. The duration of dwelling time depends on the values of each variable in this SFD. This SFD sub-model also clearly illustrates how the BLC affects the variables within the system. The SFD sub-model for container flow to the yard is shown in Figure 4. This SFD sub-model simulates the volume of container flow in the container yard. The number of idle containers, incoming containers, and outgoing containers are the key aspects in this SFD. The SFD sub-model of port infrastructure impact is presented in Figure 5, and the SFD sub-model for unloading productivity is presented in Figure 6. These 4 SFD sub-models are systematically interconnected to create a comprehensive overall SFD.

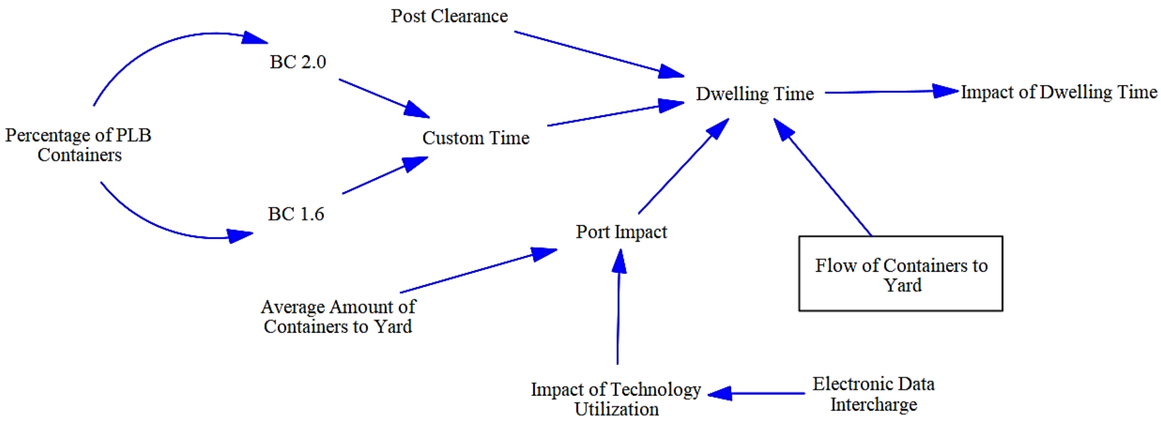


Figure 3. SFD Sub-model dwelling time

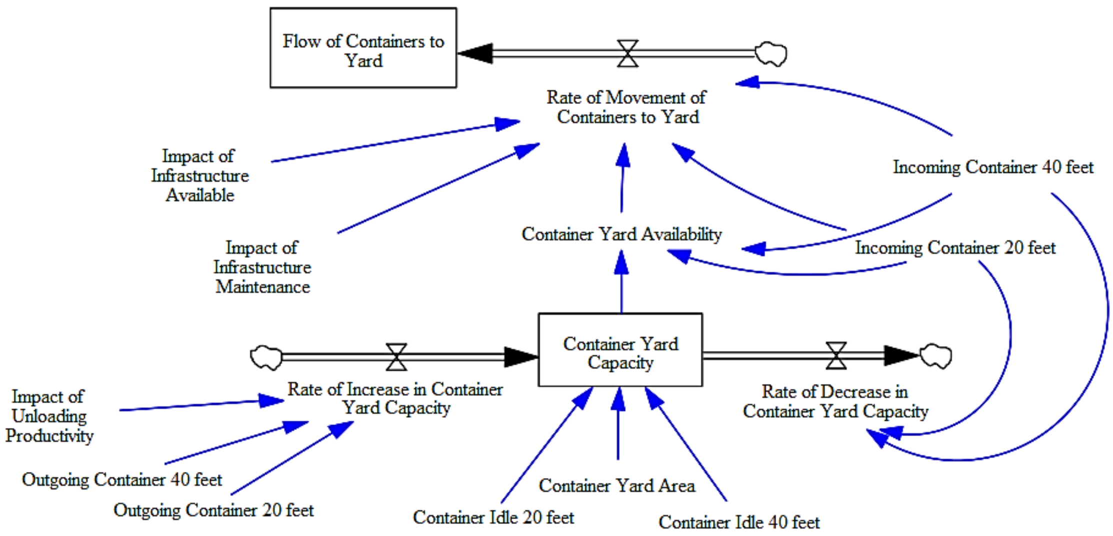


Figure 4. SFD Sub-model flow of containers to yard

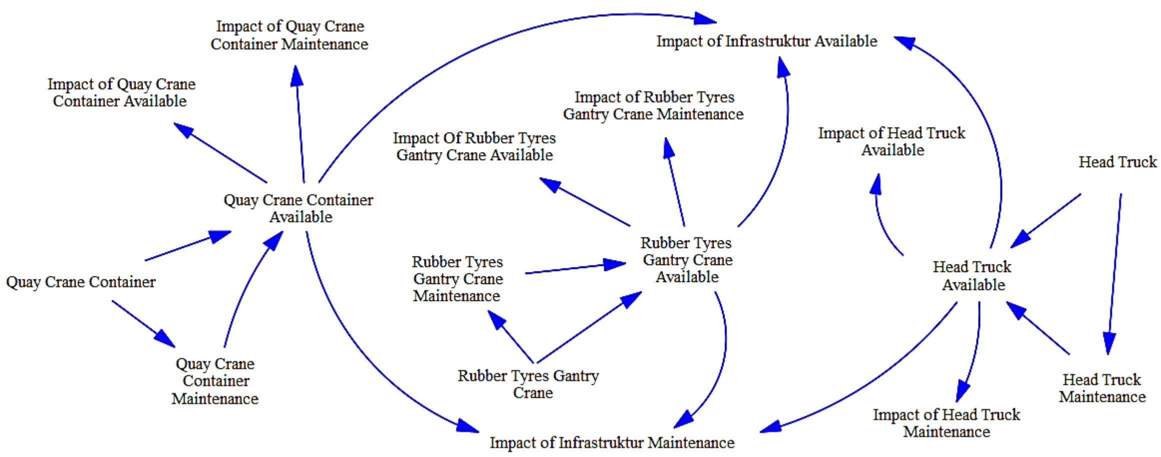


Figure 5. SFD Sub-model port infrastructure

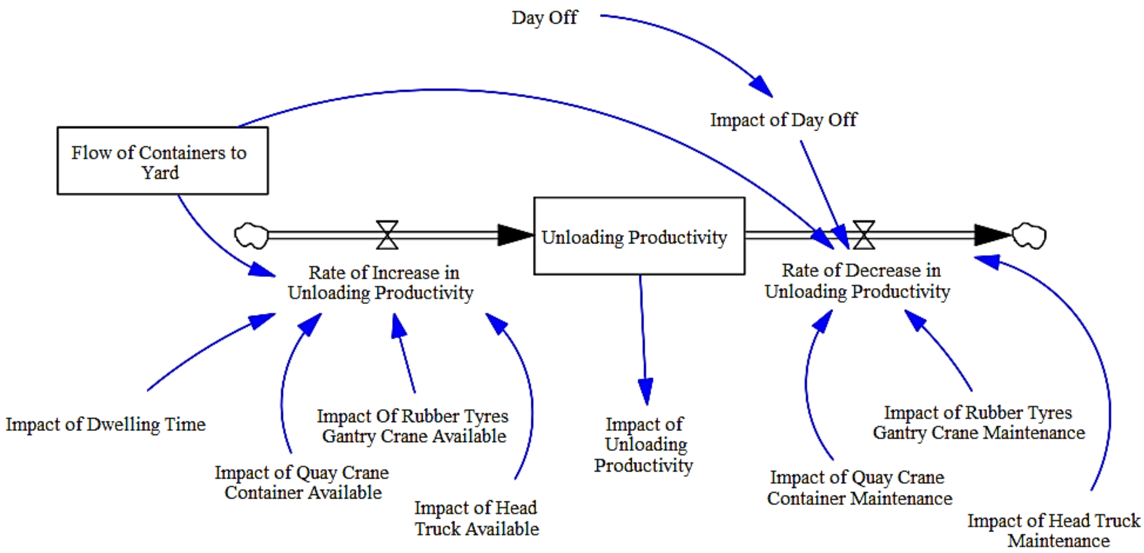


Figure 6. SFD Sub-model unloading productivity

3.2. Results of Dwelling Time

Figure 7 shows the dwelling time comparison between actual realizations at the port and modeling results for the period from January 2021 to December 2022. The actual dwelling time averaged 2.76 days, while the modeled dwelling time averaged 2.75 days. This indicates a substantial level of precision between the actual conditions and the modeling results.

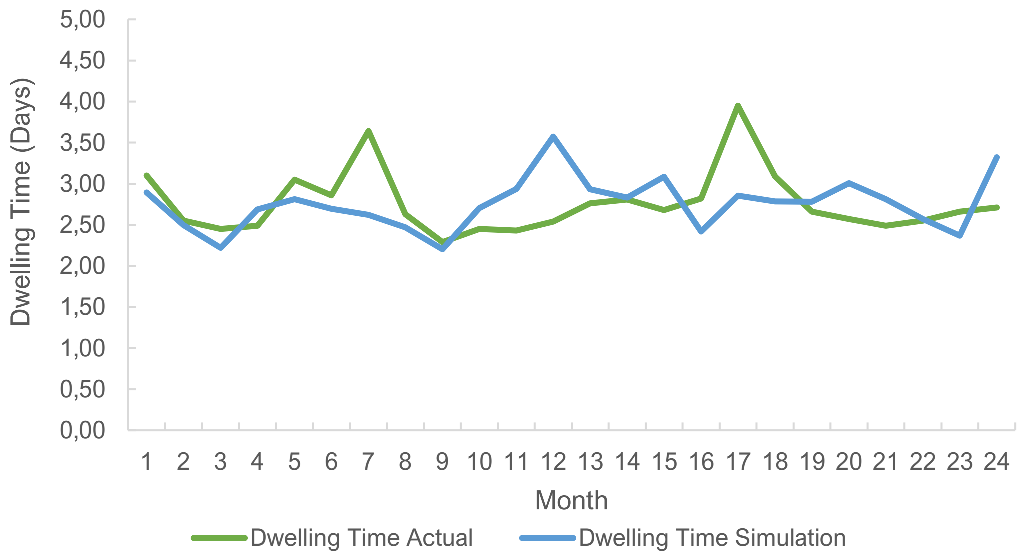


Figure 7. Comparison of actual and modeled dwelling time

3.3. Results of Unloading Productivity

The total number of containers unloaded at the port, expressed in TEUs per month, is known as unloading productivity. The difference between the actual unloading productivity and the model for the period from January 2021 to December 2022 is shown in Figure 8.

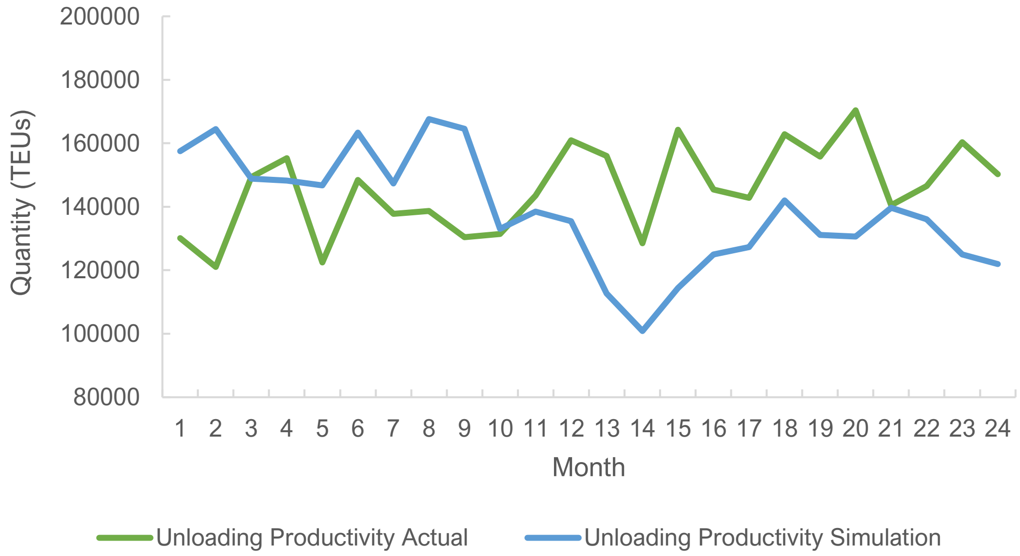


Figure 8. Comparison of actual and modeled unloading productivity

Based on the modeling results, the average unloading productivity is 138,437 TEUs, while the actual average unloading productivity is 145,268 TEUs. Although there is a significant difference between the modeled results and the actual data, the model is still recognized as adequately representing the real conditions because it has validation results with an E1 value below 5% and an E2 value below 30%.

3.4. Scenario

A scenario is a model modification method that helps to improve the efficiency of the results obtained. The port gives special consideration to each container classified under the BLC category. Containers designated for BLC do not undergo the same import clearance process as regular import containers; instead, they proceed directly to the BLC for import clearance there. Thus, the duration of container stay at the port will be reduced. Current data shows that 2% of all import containers are destined for the BLC. Therefore, efforts to increase the percentage of containers destined for the BLC constitute a scenario to test the effectiveness of the BLC on cargo service performance at the port, specifically regarding dwelling time and unloading productivity. The scenario proposed involves increasing the percentage of containers designated for the BLC by increments of 10%, 30%, 50%, 70%, and 90%.

The dwelling time graph for the formation of this scenario is shown in Figure 9. Based on the developed scenario results, each 10% increase in containers destined for the BLC will result in a 6% reduction in dwelling time.

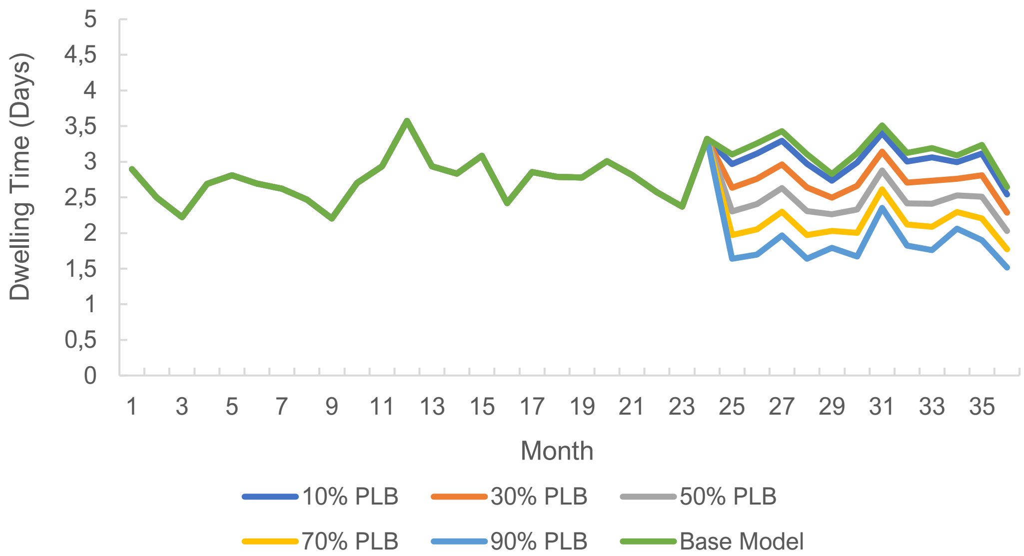


Figure 9. Dwelling time with increase in percentage of containers destined for BLC

Figure 10 shows the unloading productivity with the scenario of increasing the percentage of containers destined for the BLC. Based on the results, it can be concluded that increasing the number of containers destined for the BLC will enhance unloading productivity. Practically, a shorter dwelling time will improve unloading efficiency at the port. The results indicate that a 10% increase in containers destined for the BLC results in a 2% increase in unloading productivity.

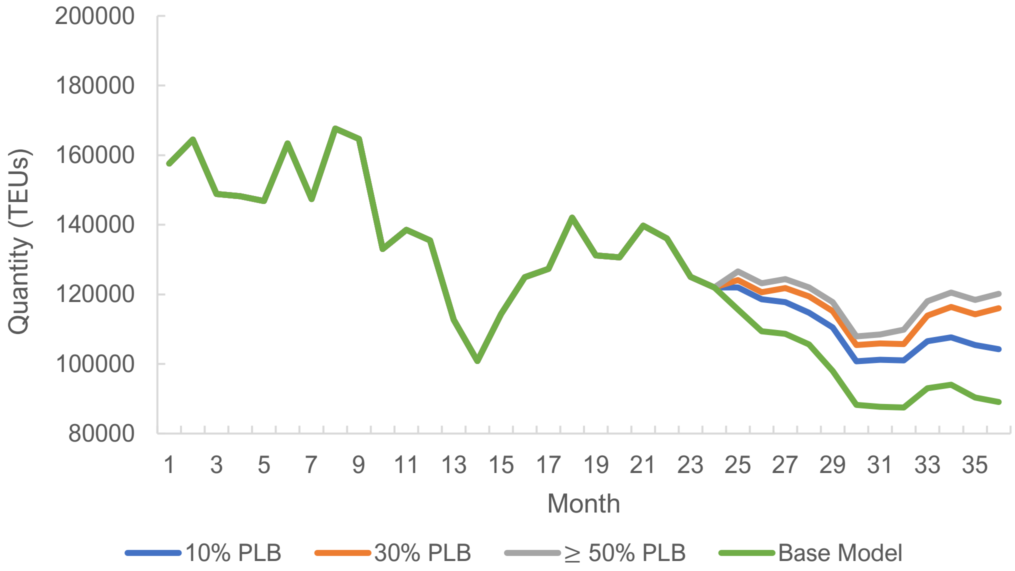


Figure 10. Unloading productivity with increase in percentage of containers destined for BLC

After the unloading activities, some containers destined for the BLC will be taken out of the port by head trucks without being stored in the container yard. The available yard capacity will increase if this assumption is applied to all containers destined for the BLC. Therefore, if no containers destined for the BLC enter the container yard, we can observe an increase in the availability of the container yard capacity.

Figure 11 shows the difference in container-yard availability when containers destined for the BLC either enter or do not enter the container yard. Based on these results, it can be said that yard-capacity availability increases when containers destined for the BLC do not enter the container yard. This results in an 11% increase in container-yard capacity, reflecting an improvement in efficiency.

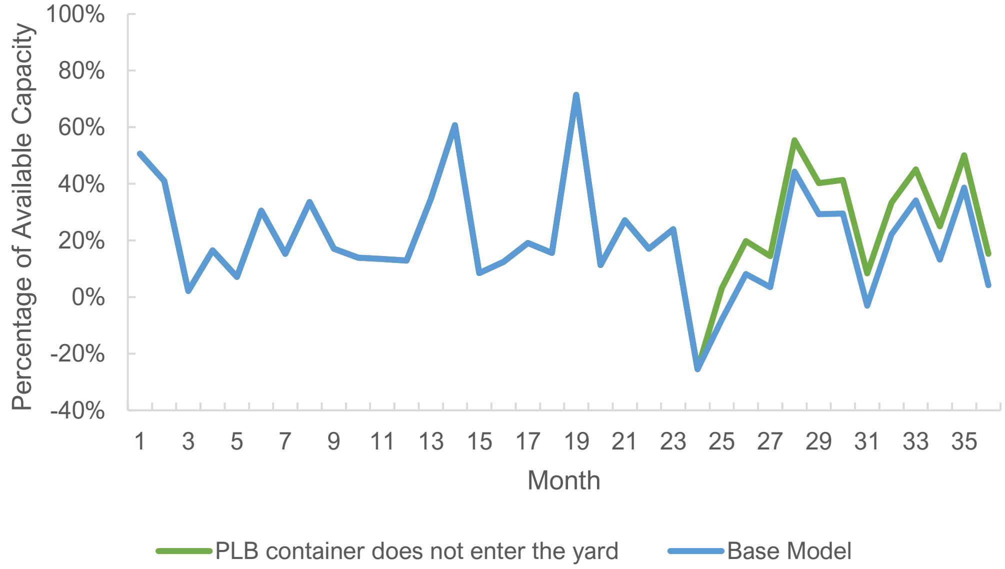


Figure 11. Container-yard availability

3.5. Discussion

The research findings indicate that the implementation of the BLC can reduce dwelling time and enhance container-handling productivity at ports. This can be analyzed through the model, considering that the containers for the BLC bypass the import restriction and prohibition processes at the port. This finding is also supported by previous research, which indicates that the BLC has reduced dwelling time due to the relocation of some customs activities from the port to the BLC (Haryana, 2017). In this study, these conditions are further clarified through the developed models. The modeling results show that port import flows are influenced by reduced customs clearance, import restrictions, and prohibition delays, which are services facilitated by the BLC.

The BLC can shorten logistics delivery times, thereby reducing storage and handling costs at the port. Indirectly, improvements in cargo service performance at the port due to the BLC also yield benefits in terms of reduced logistics costs. This study demonstrates the extent of performance improvement in cargo services at the port, but further research is needed to fully understand the benefits from the perspective of logistics costs.

From the perspective of container-yard utilization and port development, BLC has a significant impact on enhancing port operation efficiency and capacity. With the BLC in place, container yards can be used more efficiently because cargo handled at the BLC often experiences faster turnover rates. Cargo stored in the BLC exits the container yard more quickly due to more organized customs and distribution processes. This allows for better space management, reduces the need for large storage areas, and increases cargo handling capacity.

Regarding waiting times, cargo arriving from abroad and directly entering the BLC reduces the time spent in the container yard before further processing. This reduction in waiting times and queues increases port throughput. By minimizing the time cargo spends in the container yard, the port can handle new containers more rapidly, enhancing cargo flow and reducing congestion.

Additionally, the BLCs are often equipped with advanced logistics management systems that are integrated with container yards to optimize cargo flow. This integration facilitates faster and more efficient cargo handling and distribution. Ports with the BLC are more attractive to investors due to the additional efficiency and reduction in logistics costs. Consequently, this enhances the port's competitiveness in the global market, strengthens its position as a regional or international logistics hub and attracts more trade.

4. CONCLUSION

This study demonstrates the impact of implementing a Bonded Logistics Center (BLC) on the performance of cargo services at Tanjung Priok Port, Indonesia, particularly focusing on container transportation services. The port's cargo service performance is assessed based on dwelling-time duration and container unloading productivity. System dynamics modeling was employed to replicate the actual conditions of cargo services at the port. The modeling was conducted using two years of actual data. It includes key variables that interact within port operations, ultimately affecting port performance. These interactions are illustrated in the stock flow diagram described earlier. The model accurately depicts the actual activities at the port, especially concerning container unloading. Validation tests of the system dynamics model against actual conditions indicate that the model is suitable for scenarios involving the implementation of a BLC.

Based on this modeling, scenarios were created to evaluate the impact of a BLC on port cargo service performance. The scenarios assumed various percentages of containers entering the BLC. The modeling results indicate that a 10% increase in the number of containers entering the BLC reduces port dwelling time by 6% and increases container unloading productivity by 2%. Furthermore, there is an 11% increase in container-yard availability if the yard is no longer used for containers destined for the BLC.

This study's modeling is limited to variables relevant to the port under study. Different variables may be needed if modeling for other ports. Therefore, the modeling presented in this research can serve as a reference example for using system dynamics in port operations and can be adapted for other ports. This can be a suggestion for future research development.

CONFLICT OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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