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DWELL TIME VARIABILITY AT TANJUNG PERAK PORT: A CARGO FLOW ANALYSIS BASED ON TERMINAL OPERATORS

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Abstract
Ports play a strategic role in supporting the smooth flow of national logistics and trade. Tanjung Perak Port in Surabaya is one of Indonesia's primary harbors. A key performance metric for ports is Dwell Time (DT). This study aims to analyze the variability of Dwell Time at Tanjung Perak Port, adopting a cargo flow approach segmented by terminal operator. Utilizing descriptive quantitative methods and a linear model, the research analyzes secondary data from the National Single Window Institute (LNSW) for the period January 2025 to September 2025. The analytical results indicate that DT variability at Tanjung Perak is significantly influenced by the stages of cargo/container handling at each terminal operator, specifically from stacking to gate-out. For the TPS terminal operator, the distribution of dwell times for the stages of stacking-to-job order, job order-to-gate in, and gate in-to-gate out is right-skewed. Conversely, for the TTL terminal operator, the overall DT and stacking-to-job order distributions are right-skewed, while the job order-to-gate in and gate in-to-gate out times exhibit minimal variability and are relatively uniform. A pronounced right skew indicates a mean value greater than the median, suggesting that while most data points cluster around lower times, significant outliers with extended durations are present. The linear model confirms that these operational stages have a statistically significant influence on overall Dwell Time.
Keywords: Container Flow; Dwell Time; Tanjung Perak; Variability

INTRODUCTION

Ports serve a strategic function as critical nodes in global and national supply chains, directly influencing the efficiency of logistics flows and the competitiveness of trade. As a primary gateway port in Indonesia, Tanjung Perak Port in Surabaya holds a pivotal position, functioning as the principal distribution hub for the eastern region and a key nexus within the national logistics network. The substantial volume of cargo and container traffic handled at this port necessitates highly efficient operational performance, particularly in its stevedoring and port service processes.

A central and widely recognized indicator of port operational efficiency is dwell time (DT), defined as the duration a container or cargo unit remains within the port's jurisdiction—from the moment of discharge from the vessel until its final exit through the port gate. Elevated dwell times are associated with a cascade of adverse economic and operational consequences. These include escalated logistics costs, congestion within port precincts, diminished port competitiveness, and disruptions to the seamless distribution of goods. Consequently, initiatives aimed at reducing and controlling dwell time constitute a paramount concern for port authorities and relevant stakeholders.

In practice, dwell time is a composite metric influenced by a multitude of interconnected factors. These encompass the stevedoring process, yard stacking and storage, document processing and verification, customs clearance procedures, and the internal movement of cargo within the port area. The inherent complexity of this cargo/container flow often obscures the precise identification of specific bottleneck points that contribute to prolonged dwell times, rendering systematic analysis essential.

This complexity underscores the necessity for a granular analysis of the variability within each stage of the cargo/container flow. Such an analysis is crucial for identifying temporal outliers in DT and for constructing a robust dwell time model that accurately represents the complete movement pathway at Tanjung Perak Port. A stage-based, process-flow approach is particularly relevant, as it captures the operational sequence, temporal dimensions, and interdependencies between activities. Through this modeling, a clearer understanding of the dominant factors causing delays can be achieved, revealing actionable potential for process improvements to enhance overall port service efficiency.

Therefore, grounded in the foregoing rationale, this study was conducted with the aim of analyzing the variability of waiting times at Tanjung Perak Port, segmented by terminal operator, and developing a linear waiting time model based on a detailed analysis of cargo/container flows. The findings are intended to serve as a foundational analysis of operational performance and to generate targeted recommendations for process enhancement, ultimately supporting increased port efficiency and strengthened competitiveness.

LITERATURE REVIEW

Dwell Time

According to the World Bank (2018), Dwell Time (DT) is not a singular process but rather an aggregate of several distinct sub-periods, each with different underlying causes. A commonly used analytical framework decomposes Dwell Time into three key components: (i) operational Dwell Time, pertaining to physical handling activities such as unloading, stacking, yard operations, and internal movement; (ii) transactional Dwell Time, associated with processing and administrative procedures including customs clearance and inter-agency documentation; and (iii) discretionary Dwell Time, representing storage duration attributable to shipper or consignee decisions or incentives, such as deliberately delaying cargo retrieval.

Container Dwell Time (CDT) is defined as the total duration a container remains within a port terminal yard (Lee, Park, Lee, Son, & Kim, 2024). The concept of decomposing dwell time to identify critical process stages has been advanced by methodologies such as the World Customs Organization's (2018) Time Release Study, which systematically analyzes the release process to pinpoint bottlenecks. This decompositional approach has been further refined and applied in empirical studies to distinguish between operational, transactional, and discretionary dwell time components (Refas, 2011).

This analytical framework is theoretically grounded in systems theory and stochastic process modeling, where the total system time is the aggregate of processing times at each nodal stage. Within a port context, each stage in the cargo flow can thus be conceptualized as a distinct service system, each with its own unique queuing and waiting time characteristics (Gross & Harris, 1998).

Container Dwell Time (CDT) adalah lama waktu kontainer berada di lapangan/yard terminal pelabuhan (Lee, Park, Lee, Son, & Kim, 2024).

World Customs Organization (2018) melalui Time Release Study memperkenalkan pendekatan dekomposisi waktu pelepasan barang untuk mengidentifikasi tahapan kritis dalam proses kepabeanan. Pendekatan ini kemudian dikembangkan dalam berbagai studi empiris untuk memisahkan operational, transactional, dan discretionary dwell time (Refas, 2011).

Pendekatan dekomposisi ini konsisten dengan teori sistem dan proses stokastik, di mana total waktu sistem merupakan penjumlahan waktu pada setiap node proses. Dalam konteks pelabuhan, setiap tahapan alur barang dapat diperlakukan sebagai sistem layanan dengan karakteristik waktu tunggu yang berbeda (Gross & Harris, 1998).

Cargo/Container Flow Approach and Mathematical Modelling.

The cargo flow approach conceptualizes a port not merely as a point of loading and unloading but as an integrated network of processes (process network). Lee (2024), for instance, employed process mining and explainable AI to identify key factors prolonging container dwell time at an international port, demonstrating that administrative stages often contribute most significantly.

Mathematically, this framework allows for the formulation of dwell time as the sum of its constituent stages:

$$DT = \sum_{i=1}^{n} t_i$$

where t_i represents the duration of each discrete process stage. This foundational summation can be extended into econometric models that incorporate container-specific attributes and process characteristics. A similar methodological approach underpins the predictive modelling of container dwell time using machine learning techniques, as evidenced in the work of Chhetri (2025).

Previous Research

Prolonged container storage within port areas escalates handling frequencies and complicates container placement strategies, ultimately reducing container terminal productivity (Lee, Park, Lee, Son, & Kim, 2024). Consequently, terminal operators (TO) consistently prioritize the reduction of Container Dwell Time (CDT) as a primary operational objective (Lee, Park, Lee, Son, & Kim, 2024).

Research addressing the land requirements of the international container yard at TPS Surabaya reveals a significant increase in container traffic, which reached approximately 1.5 million TEUs in 2024, creating substantial capacity challenges. Utilizing the ARIMA method for flow projection, the study concluded that an additional area of ±3.191 hectares is necessary to avert future operational congestion (Ningrum & Wibisono, 2025). This study focuses specifically on the land capacity aspect of the international terminal area.

A separate study analyzing the existing conditions and challenges of container dwell time at Tanjung Perak Port, Indonesia, found that dwell time performance remains suboptimal and fails to meet government regulatory targets. It identified the container stacking stage and manual inspections as primary contributors to extended dwell times. However, this research employed a qualitative approach and did not involve detailed process flow modeling (Novianto, Setiawan, & Arubusman, 2025).

An analysis of seven years of DT policy at Tanjung Perak Port concluded that the policy's initial goal of reducing logistics costs has not been fully realized, with dwell time performance still missing its targets. The study argues that after more than seven years of implementation, the definition and nature of the dwell time problem have evolved, rendering older policies less relevant. It emphasizes the necessity for cross-stakeholder collaboration. This research was also qualitative (a case study) and did not incorporate an analysis based on operational data (Nugroho, Setijaningrum, & Mustaqim, 2024).

In addition, there are also several other studies indicate that port dwelling times remain predominantly influenced by administrative and clearance procedures. Research by Utami et al. (2020) at Tanjung Emas Port found that clearance factors significantly impacted dwelling time duration, whereas port equipment factors were not statistically significant. Similar findings were reported by Dharmakarja and Wardana (2024) at Tanjung Perak Port, reinforcing the critical importance of non-infrastructure approaches for optimizing dwelling time.

Research Conceptual Framework.

Based on the established literature, the conceptual framework for this research positions dwell time as the cumulative outcome of the operational sequence from stacking to gate-out. This process-flow approach enables more precise identification of bottlenecks and facilitates the formulation of evidence-based policy recommendations.

METHODS

This section outlines the research method employed to address the study's problem statements and test its hypotheses. The chosen methodology is quantitative. A quantitative research method is characterized by its emphasis on the numerical measurement of variables, statistical analysis, and the empirical testing of theories through examining relationships between variables. It utilizes standardized instruments for data collection, employs statistical data analysis, aims to test hypotheses or theories, and seeks to generalize findings to a broader population (Creswell, 2014).

The study utilizes secondary data sourced from the National Single Window Institute (LNSW) for the period January to September 2025. This dataset is cross-sectional in nature, comprising micro-level Container Dwell Time (CDT) data for Tanjung Perak Port. A micro-data-based approach is recommended in recent studies, as it enables more precise identification of process bottlenecks compared to aggregated data (Lee, 2024).

The analytical techniques applied are descriptive statistics and econometric regression. Descriptive statistics are used to summarize and present the data in an interpretable format (Anderson, Sweeney, & Williams, 2011), while regression econometrics aims to identify and quantify the relationship between individual cargo/container flow stages and overall dwell time at Tanjung Perak Port. This approach aligns with the logistics economics literature, which underscores the importance of statistical modeling for evaluating port process efficiency and its impact on supply chain performance (Hausman et al., 2013; Lee, 2024).

The primary methodology employed is a linear regression model specified as follows:

$$DTperak_i = f(t\_stj_i, t\_jtgi_i, t\_gitgo_i)$$

$$DTperak_i = \beta_0 + \beta_1 t\_stj_i + \beta_2 t\_jtgi_i + \beta_3 t\_gitgo_i + \varepsilon_i$$

Operational Definition of Variables

DT Perak	:	Dwell time at Tanjung Perak Port (days)
t_stj	:	Duration from stacking to job order issuance (days)
t_jtgi	:	Duration from job order issuance to truck gate-in (days)
t_gitgo	:	Duration from truck gate-in to gate-out (days)

RESULT AND DISCUSSION

Variability of Tanjung Perak Dwell Time

There are two terminal operators at Tanjung Perak Port: TPS and TTL. Table 1 presents the structure of the micro-level data used in this analysis of container dwell time based on a cargo/container flow approach. Each row reports the statistical measures of central tendency and data dispersion, while the columns represent the sequential process stages a container undergoes from stacking until its exit from the port area.

For the TPS terminal operator, the data for DT, stackingtojoborder, jobordertogatein, and gateintogateout exhibit a right-skewed distribution, as indicated by mean values exceeding their respective medians. The high degree of data variability in DT, stackingtojoborder, and jobordertogatein reflects considerable heterogeneity in the duration of these stages. In contrast, the variability for gateintogateout is low.

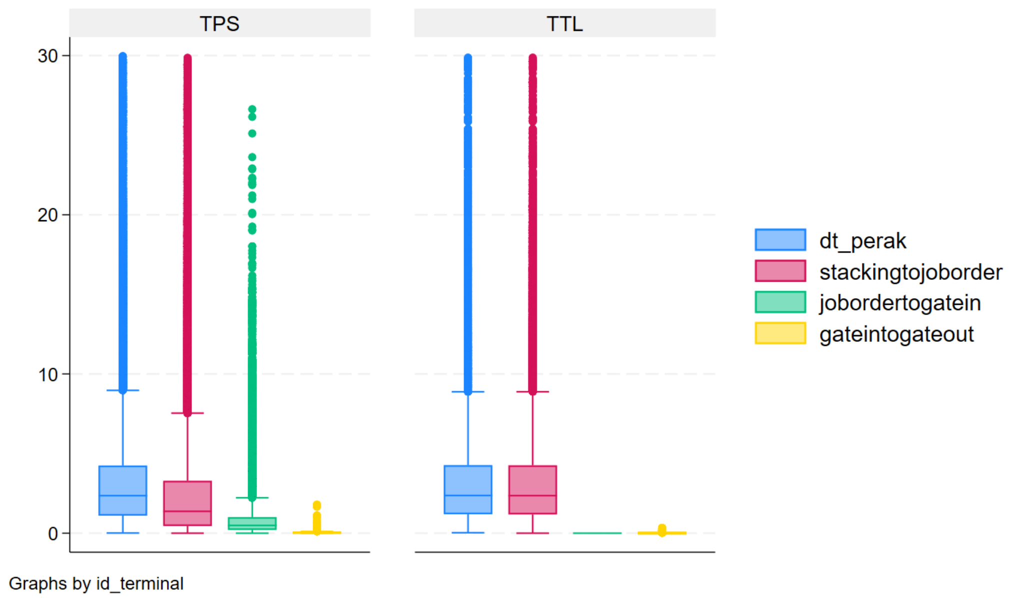
For the TTL terminal operator, the data for DT and stackingtojoborder are also right-skewed (mean>median). Conversely, the distributions for jobordertogatein and gateintogateout are relatively symmetric. This pattern indicates high variability in DT and stackingtojoborder at the TTL operator, while the jobordertogatein and gateintogateout stages demonstrate low variability and more consistent processing times.

Table 1. Descriptive Statistics of Dwelling Time Data

id_terminal	stats	dt_perak	stackingtojoborder	jobordertogatein	gateintogateout
TPS	Mean	3.26	2.40	0.82	0.04
	p50	2.36	1.37	0.49	0.03
	SD	3.27	3.08	1.04	0.03
	Min	0.01	0.00	0.00	0.00
	Max	29.96	29.86	26.63	1.80
	p5	0.35	0.05	0.05	0.01
	p95	9.58	8.20	2.70	0.11
	N	355576	355576	355576	355576
TTL	Mean	3.35	3.35	0.00	0.01
	p50	2.37	2.36	0.00	0.00
	SD	3.36	3.36	0.00	0.02
	Min	0.03	0.00	0.00	0.00
	Max	29.87	29.87	0.00	0.33
	p5	0.42	0.42	0.00	0.00
	p95	9.93	9.90	0.00	0.04
	N	41909	41909	41909	41909
Total	Mean	3.27	2.50	0.73	0.04
	p50	2.36	1.49	0.40	0.02
	SD	3.28	3.13	1.01	0.04
	Min	0.01	0.00	0.00	0.00
	Max	29.96	29.87	26.63	1.80
	p5	0.36	0.05	0.00	0.00
	p95	9.63	8.43	2.59	0.10
	N	397485	397485	397485	397485

Source: (Pelindo, 2025); (LNSW, 2025); Processed by authors (2025)

Figure 1. Distribution of Dwelling Time and Cargo/Container Flow Components by Terminal (TPS and TTL)



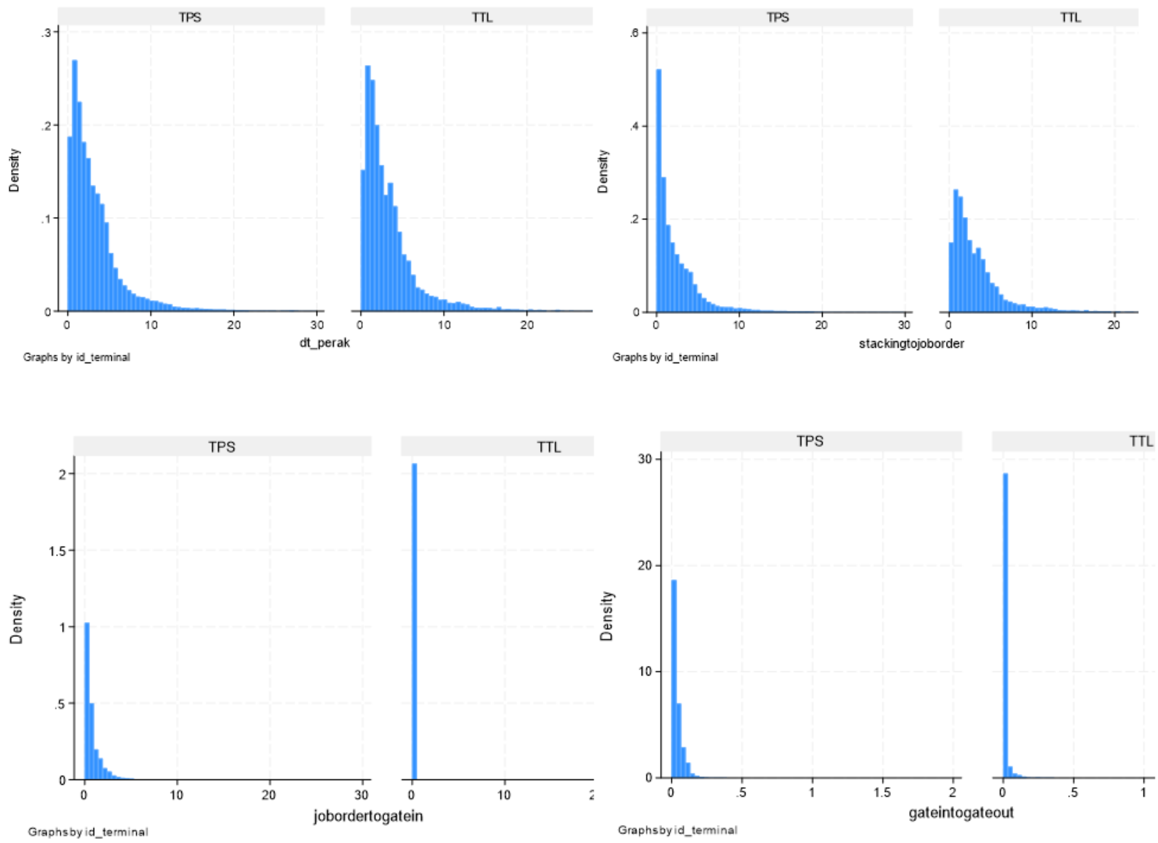
Source: (Pelindo, 2025); (LNSW, 2025); Processed by authors (2025)

Figure 1 presents the distribution of total dwell time (dt_perak) and its constituent cargo/container flow components (stacking to job order, job order to gate in, and gate in to gate out) for the two terminal operators, TPS and TTL, visualized as boxplots. The boxplots illustrate the variability, median, and presence of extreme values (outliers) for each time component. The total dwell time at both terminals exhibits a relatively wide spread with high-value outliers, indicating process heterogeneity and the potential for extreme delays for a subset of containers. The stacking to job order component shows a relatively large and variable contribution to total dwell time at both terminals. Meanwhile, the job order to gate in component displays differing distribution patterns between TPS and TTL, reflecting distinct administrative and operational process characteristics. In contrast, the gate in to gate out component is relatively small and stable at both terminals, suggesting this final process stage tends to be more consistent.

These measures of central tendency and dispersion are further supported by the histograms of each variable (total DT, stacking to job order, job order to gate in, and gate in to gate out) segmented by terminal operator, shown in Figure 2.

The four panels in Figure 2 depict the data distribution for total dwell time (dt_perak) and the three main cargo/container flow components, separated for the TPS and TTL terminals. In general, all variables exhibit a pattern of right-skewed distribution, indicating that most containers experience relatively short processing times, while a long tail represents cases of extreme delay. The distribution of dt_perak shows a similar pattern between TPS and TTL, though with differences in the histogram for low and mid-range values, reflecting variations in process efficiency between terminals. For the stacking to job order component, the relatively wide spread demonstrates that this pre-administrative stage contributes significantly to dwell time variation. In contrast, the distributions for job order to gate in and gate in to gate out are highly concentrated near zero, particularly for TTL, signifying that these final process stages are relatively fast and stable. Collectively, these visualizations confirm that the primary sources of variation and potential bottlenecks for dwell time reside in the early to middle stages of the cargo/container flow.

Figure 2. Distribution of Dwelling Time and Cargo/Container Flow Components by Terminal (TPS and TTL)



Source: processed by authors (2025)

Linear Dwell Time Model for Tanjung Perak: A Cargo/Container Flow Approach

The linear dwell time model for Tanjung Perak Port, based on the cargo/container flow approach, is presented in Table 2.

Table 2. Linear Dwell Time Model for Tanjung Perak Port using a Cargo/Container Flow Approach

dt_perak	Coefficient	std. err.	t	P>t	Decision
X1, stackingtojoborder	1.0000	0.0000029	350000	0.00000	***
X2, jobordertogatein	1.0001	0.0000090	110000	0.00000	***
X3, gateintogateout	0.9986	0.0002607	3830	0.00000	***
_cons	-0.0002	0.0000156	-11	0.00000	
Ket:					
*** : Significant at 1%					
** : Significant at 5%					
* : Significant at 10%					

Source: processed by authors (2025)

The linear model concludes that each stage of the container/cargo flow (from stacking to gate-out) has a statistically significant influence on the total dwell time (DT) at Tanjung Perak. Therefore, the variability observed in each stage of the cargo flow at each terminal operator significantly affects the overall DT.

However, this linear model has a notable limitation. Given that the total DT is defined as the sum of its constituent stages, the model's estimated coefficients are expected to be (or are very close to) 1. This structure essentially makes the model equivalent to an identity equation (DT = t_stj + t_jtgi + t_gitgo), which, while validating the additive nature of the process, offers limited explanatory power for understanding the distinct marginal effects or interactions between stages beyond their direct summation.

CONCLUSION

The variability of Tanjung Perak's dwell time (DT) is significantly influenced by the characteristics of each cargo/container flow stage at the respective terminal operators. At the TPS terminal operator, the distributions for DT, stackingtojoborder, jobordertogatein, and gateintogateout are right-skewed, as evidenced by mean values exceeding their medians and corroborated by histogram distributions. This indicates a high degree of variability in DT, stackingtojoborder, and jobordertogatein, reflecting considerable heterogeneity in processing times for these stages, while gateintogateout demonstrates low variability. Conversely, at the TTL terminal operator, the distributions for DT and stackingtojoborder are also right-skewed (mean > median). In contrast, jobordertogatein and gateintogateout exhibit low variability and are relatively uniform. This pattern underscores that significant variability at TTL is concentrated in DT and the stackingtojoborder stage, a finding supported by the histogram data.

The linear model of Tanjung Perak DT, based on the cargo/container flow, confirms that all stages from stacking to gate-out significantly affect total dwell time. However, a key limitation of this model is its fundamental structure: as the DT is modeled as the sum of its constituent stages, the equation essentially becomes an identity (DT = t_stj + t_jtgi + t_gitgo), offering limited explanatory power beyond this additive relationship.

Based on these findings, DT can potentially be reduced by stabilizing the variability within each process stage at every terminal operator. Furthermore, future modeling efforts should consider employing non-linear (e.g., quadratic) functions. This approach would allow for the identification of optimal values for both total DT and its individual component stages, moving beyond descriptive summation towards prescriptive optimization.

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