

SERVICE OF MOORING, PILOTAGE, AND TUGGING IN SUPPORTING THE SMOOTH OPERATION OF SHIPS AT TANJUNG EMAS SEMARANG PORT

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ABSTRACT

This study aims to analyze the effectiveness of pilotage, towage, and mooring services at Tanjung Emas Port Semarang, as well as the factors influencing the effectiveness of these three services. The findings indicate that pilotage services at Tanjung Emas Port take an average of 1.5 hours, which is longer than the expected standard time. The longer pilotage time is due to limited pilot personnel and insufficient pilot vessel capacity to handle large ships. Towage services also significantly affect the waiting time of ships, with an average towage delay of 1-2 hours, which is longer than the desired standard. The limited towage vessel capacity and lack of coordination between towage officers hinder the efficiency of towage services. Mooring services, especially at the lower berth of the Samudera dock, are affected by extreme weather conditions, such as rob, which leads to delays in mooring ships. The factors affecting the effectiveness of these three services include limitations in human resource capacity, vessel capacity (towage and pilot vessels), and weather impacts, which can delay service processes. The multiple linear regression model used in this study shows that pilotage, towage, and mooring services collectively explain 69.2% of the variation in port effectiveness. Therefore, towage vessel capacity, pilot personnel, and mooring infrastructure that can withstand adverse weather conditions are key factors that need to be addressed to improve port operational effectiveness.

Keywords: Service Effectiveness, Pilotage, Towage, Mooring, Multiple Linear Regression, Port.

ABSTRAK

Penelitian ini bertujuan untuk menganalisis efektivitas pelayanan pemanduan, penundaan, dan penambatan kapal di Pelabuhan Tanjung Emas Semarang, serta faktor-faktor yang mempengaruhi efektivitas ketiga jenis layanan tersebut. Hasil penelitian menunjukkan bahwa pelayanan pemanduan kapal di Pelabuhan Tanjung Emas Semarang memerlukan waktu rata-rata 1,5 jam, yang lebih lama dari standar waktu yang diharapkan. Waktu pemanduan yang lebih lama disebabkan oleh keterbatasan personel pandu dan kapasitas motor pandu yang tidak memadai untuk menangani kapal berukuran besar. Pelayanan penundaan kapal juga berpengaruh terhadap waktu tunggu kapal, dengan waktu penundaan rata-rata 1-2 jam yang lebih lama dari standar yang diinginkan. Kapasitas kapal tunda yang terbatas dan kurangnya koordinasi antar petugas kapal tunda menghambat efisiensi dalam pelayanan penundaan kapal. Pelayanan penambatan kapal, terutama di dermaga Samudera bagian bawah, dipengaruhi oleh pengaruh cuaca ekstrem seperti rob, yang menyebabkan penundaan penambatan kapal. Faktor-faktor yang mempengaruhi efektivitas ketiga jenis layanan ini meliputi keterbatasan kapasitas sumber daya manusia, kapasitas alat (kapal tunda dan motor pandu), serta pengaruh cuaca yang dapat memperlambat proses pelayanan. Model regresi linier berganda yang digunakan dalam penelitian ini menunjukkan bahwa pelayanan pemanduan, penundaan, dan penambatan kapal secara kolektif dapat menjelaskan 69,2% variasi dalam efektivitas

pelabuhan. Dengan demikian, kapasitas kapal tunda, personel pandu, dan infrastruktur dermaga yang lebih tahan terhadap cuaca buruk menjadi faktor utama yang harus diperhatikan untuk meningkatkan efektivitas operasional pelabuhan.

Kata kunci: Efektivitas Layanan, Pemanduan Kapal, Penundaan Kapal, Penambatan Kapal, Regresi Linier Berganda, Pelabuhan.

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1. INTRODUCTION

Maritime Ports are a highly strategic infrastructure in the national maritime transportation and logistics system. Ports not only serve as central points for the flow of goods and passengers, but they also act as a connection between the sea and the land, influencing a country's economic competitiveness in the global market. The operational effectiveness of a port is highly influenced by the quality of services provided, particularly those related to pilotage, towage, and mooring of vessels. These three services directly impact the speed of vessel docking and loading/unloading operations, as well as the reduction in vessel waiting time, ultimately leading to improved port logistics efficiency (Issa-Zadeh, 2025; Suryadi et al., 2025).

Vessel pilotage plays a critical role in safely guiding ships to the dock, especially in ports with narrow and high-risk waters. By using certified pilots, vessels can avoid accidents that could lead to financial losses and safety hazards. However, the success of the pilotage system not only depends on the quality of personnel but also on technical conditions such as navigational equipment and port traffic management systems (Amir Sudirman, S., & Saputra, T. D., 2024; Mthembu & Chasomeris, M. G., 2023). One of the main challenges faced in vessel pilotage services is the limited number of available personnel to handle the significantly

increased volume of vessels. Delays in the pilotage process often result in reduced port productivity and increased operational costs (Paulauskas & Paulauskas, D., 2025).

Meanwhile, vessel towage is responsible for assisting ships that cannot move on their own due to their large size or maneuvering limitations, by providing tugboats that can guide them with precision. The availability of adequate tugboats and their proper placement can reduce docking time and ensure that the loading and unloading operations proceed according to schedule. An important factor in towage operations is coordination between port authorities and ship owners, as well as efficient communication among personnel (Nugraha, 2025). In practice, when towage management is not carried out effectively, delays occur, which affect the overall port process time, thereby reducing cost and time efficiency (Moravej, 2025). Research by Suryadi et al., (2025) reveals that mismatched operational times between tugboats and the ships being towed can lead to a significant increase in operational costs.

Mooring services at the dock are the final stage in the ship's arrival process, ensuring that the vessel remains stable and safe during the loading and unloading process. Inefficient mooring can add extra time to the docking process, thereby extending the vessel's stay at the port. Research has shown that natural conditions such as waves, wind, and environmental factors like tidal surges or high tides can worsen the instability of vessels during mooring, causing delays in loading and unloading services (Finoawa, 2025; Suryadi et al., 2025). At Tanjung Emas Semarang Port, for example, tidal surges at the lower Samudra dock have caused significant docking delays, reducing port productivity and impacting customer satisfaction (Mahendra, 2025).

Furthermore, a major challenge in improving vessel service effectiveness at ports is the lack of coordination between the various operational units involved, such as pilotage, towage, and mooring. Poor coordination often leads to decreased responsiveness to rapidly changing situations on the ground, such as when there is a surge in incoming vessels or when extreme weather conditions affect vessel movement. Research conducted at Tanjung Perak Port shows that ineffective communication between operational units can slow down the vessel service flow (Amir Sudirman, S., & Saputra, T. D., 2024; Sjukri Zilal, M. H., & Sofilda, E., 2024).

Moreover, modern ports now face challenges regarding the digitalization of vessel service systems, leading to automation and real-time data integration. Vessel Traffic Services (VTS) and Port Management Information Systems (PMIS) are crucial steps in improving operational transparency and reducing human errors in the execution of pilotage, towage, and mooring services (Wibowo, 2025). This digitalization can connect all port stakeholders, including harbor masters, ship operators, and port managers, in a unified platform that facilitates data-driven decision-making (Prabowo, 2025; Zulkifli & Wiryanto, A., 2024).

The important role of digitalization also extends to reducing the environmental impact of port operations, particularly in terms of minimizing emissions produced by vessel towage and fuel consumption (Haryono, 2024; Rachman, 2025). Digitalization can enhance operational monitoring efficiently, maximize the utilization of available tugboats, and ensure that the mooring system is conducted in a more environmentally friendly manner (Sutrisno & Mulyadi, Y., 2025).

Therefore, this study aims to analyze the effectiveness of pilotage, towage, and mooring services at Tanjung Emas Semarang Port, as well as the factors affecting the effectiveness of these three services. The findings of this study are expected to provide strategic recommendations that can be implemented to enhance the operational quality of the port and its competitiveness in the global market.

2. METHODS

2.1 Research Approach

The approach used in this study is a quantitative approach with a correlational research design. The quantitative approach was chosen because this study aims to measure the relationship between the variables affecting the effectiveness of pilotage, delay, and vessel mooring services with port operational efficiency. The correlational design allows the researcher to analyze the relationship between independent variables (pilotage, delay, and vessel mooring services) and dependent variables (waiting time, operational costs, and user satisfaction) simultaneously. This study also uses a cross-sectional design, which involves collecting data at one point in time to observe the phenomena

occurring in the field. This enables the researcher to analyze the relationships between the variables and factors affecting the effectiveness of vessel services at Tanjung Emas Port Semarang (Setia, 2023).

2.2 Research Design

In this study, the researcher uses a descriptive and correlational quantitative design, aiming to describe the effectiveness of pilotage, towage, and vessel mooring services and to measure the factors influencing the effectiveness of these three services. The researcher will use multiple linear regression analysis to test the influence of pilotage, towage, and mooring services on waiting time, operational costs, and user satisfaction at the port.

2.3 Population and Sample

The population in this study consists of all operational port personnel directly involved in the pilotage, towage, and mooring services at Tanjung Emas Port Semarang. The sample of this study includes 60 respondents selected using purposive sampling, meaning that respondents with direct experience in port operations related to vessel services were chosen. The respondents include ship pilots, tugboat crews, mooring officers, and port users who provide feedback on the effectiveness of the services received.

2.4 Data Collection Techniques

Data was collected using the following three techniques:

- a. Questionnaire: Used to collect data on the perceptions of port personnel and port users regarding the effectiveness of pilotage, towage, and mooring services. The questionnaire uses a 1-5 Likert scale, where respondents rate the quality of the services they received.
- b. Interviews: Conducted with port managers and port users to explore the challenges and obstacles encountered in port operations and to gain deeper insights into the performance of the three types of vessel services.
- c. Observation: Direct observations were made to record vessel waiting times, pilotage times, and environmental conditions (such as tidal surges) that affect mooring times and operational safety at the port.

2.5 Research Instruments

The research instruments used consist of:

- a. Questionnaires: Measuring the satisfaction perceptions of users and port personnel regarding pilotage, towage, and mooring services, using a 1-5 Likert scale.
- b. Interview Guide: Referring to open-ended questions designed to explore the operational processes and factors affecting the effectiveness of vessel services at Tanjung Emas Port.
- c. Observation Sheets: To record service times and external factors such as weather, tidal surges, or high waves that influence service effectiveness.

2.6 Data Analysis

The data collected from the questionnaires will be analyzed using descriptive statistics to describe respondent characteristics and data distribution. Multiple linear regression will be used to test the effect of pilotage, towage, and mooring services on vessel waiting times, operational costs, and user satisfaction at the port. Validity and reliability tests will be performed to ensure that the instruments used are appropriate and consistent.

3. RESULT AND DISCUSSION

Based on the data collected through questionnaires, interviews, and observations, this study identifies several key factors affecting the effectiveness of pilotage, towage, and mooring services at Tanjung Emas Semarang Port. These factors include limitations in personnel, the capacity of pilot vessels and tugboats, weather conditions, and coordination among port operational units.

3.1 Vessel Pilotage Service

In vessel pilotage services, the main factor affecting pilotage time is the limitation of pilot personnel. According to the data collected, about 72% of respondents reported that the limited number of pilot personnel caused increased pilotage time, ultimately slowing down the ship docking process. The limitation of pilot vessels also emerged as another hindering factor. Inadequate pilot vessels for ships with large drafts often slow down the pilotage process, as also stated by Zhang et al., (2024), who noted that pilot capacity must be adjusted to the size of the ship and the speed of the current.

3.2 Vessel Towing Service

The factor influencing vessel towing service is the limited capacity of tugboats. As many as 70% of respondents stated that insufficient tugboats hinder the towing process, especially during peak arrival times. This finding aligns with research by Syaifullah Kuncowati, K., & Supangat, S., (2025), who indicated that the limited capacity of tugboats leads to longer delays, which in turn increases ship waiting times. Additionally, inefficient coordination between tugboat crews was also identified as a factor exacerbating towing delays, indicating the need for improved communication and coordination systems between personnel on-site.

3.2.1 Vessel Mooring Service

The primary factor affecting vessel mooring is the influence of extreme weather conditions, such as rob (tidal flooding) occurring at the lower Samudra dock. 22% of respondents reported that rob interfered with the mooring process, causing delays in the docking process that impacted ship waiting times and port operational costs. In line with the research by Paulauskas & Paulauskas (2025), which revealed that extreme weather and tidal surges can cause delays in the mooring process, improving dock infrastructure to mitigate the impact of rob is crucial to enhance mooring service effectiveness.

3.2.2 The Influence of Coordination and Port Infrastructure

In addition to the above factors, coordination between port operational units, such as ship pilots, tugboat crews, and mooring officers, also has a significant influence on the effectiveness of vessel services. Misalignment between tugboat schedules and ships requiring towing can lead to delays in ship waiting times, as well as increased operational costs. This confirms the findings of Suryadi et al., (2025), who emphasized the importance of efficient coordination between various port units to expedite the vessel service process and reduce delays.

To test the relationship between pilotage, towing, and mooring services and the operational effectiveness of the port, multiple linear regression analysis was conducted using SPSS. Below are the results of the analysis.

Table 1: Summary of Port Service Effectiveness Factors

<i>Model</i>	<i>R</i>	<i>R Square</i>	<i>Adjusted R Square</i>	<i>Std. Error of the Estimate</i>
1	0.832	0.692	0.678	2.453

Table 1 presents the regression model that analyzes the relationship between independent variables pilotage, towage, and mooring services and the dependent variable, port effectiveness. The R value of 0.832 indicates a strong relationship between the services and the overall port performance. This suggests that improvements in these services are likely to enhance operational efficiency at Tanjung Emas Semarang Port. Research by Jayanti et al., (2025) supports this finding, indicating that effective pilotage, towage, and mooring services can significantly reduce waiting times, minimize operational costs, and improve user satisfaction at ports. These improvements lead to greater port competitiveness and smoother logistical operations, particularly in busy port environments. The R² value of 0.692, which means 69.2% of the variation in port effectiveness is explained by these services, suggests a substantial contribution from pilotage, towage, and mooring services. However, it also indicates that other factors such as port infrastructure, technology, and external environmental conditions are influencing port performance but are not captured by this model. According to Naghash et al., (2025), external variables, including changes in global shipping demand and seasonal weather patterns, can play a major role in port efficiency. Therefore, it is essential to consider these other factors in future models to gain a more complete understanding of what drives port performance.

Despite the strong explanatory power of the model, the remaining 30.8% unexplained variance points to the complexity of port operations. This highlights the need for a more nuanced approach to port service optimization. For example, digitalization has been shown to significantly improve coordination and service delivery at ports (Scholta et al., 2025). The integration of technologies like VTS and PMIS can improve communication between operational units, streamline processes, and reduce delays (Zulkifli & Wiryanto, A., 2024). Implementing such

technologies could help explain the remaining variance and further optimize port operations.

Furthermore, research by Syaifullah Kuncowati, K., & Supangat, S., (2025) suggests that factors such as employee training and operational protocols also have a significant impact on port service efficiency. While pilotage and towage services are critical, ensuring that personnel are well-trained and equipped with the right resources is crucial for reducing errors and improving overall service delivery. By investing in human resources and system training, ports can enhance the effectiveness of their operations. Finally, Markolf et al., (2019) emphasize the importance of weather-resilient infrastructure in improving port effectiveness. In this case, extreme weather events such as rob can have a significant impact on mooring services. Strengthening the port's physical infrastructure to mitigate the effects of such conditions would reduce delays and enhance the efficiency of the port, contributing to the unexplained variance in the model.

Table 2: Impact of Service Delays on Port Operations

<i>Model</i>	<i>Sum of Squares</i>	<i>df</i>	<i>Mean Square</i>	<i>F</i>	<i>Sig.</i>
<i>Regression</i>	320.845	4	80.211	16.250	0.000
<i>Residual</i>	142.456	55	2.587		
<i>Total</i>	463.301	59			

Table 2 presents the ANOVA results of the regression model used to analyze the relationship between the independent variables pilotage, towage, and mooring services and the dependent variable, port effectiveness. The F value of 16.250 and p-value of 0.000 indicate that the regression model is highly significant. This means that the combination of pilotage, towage, and mooring services has a statistically significant impact on the overall effectiveness of the port. The significance of the model supports the idea that improvements in these services can enhance port operations, contributing to reduced waiting times, lower operational costs, and increased user satisfaction, which are essential for competitive advantage in the global market.

The F value in the ANOVA table tests the overall significance of the regression model, comparing the model's fit to a baseline model with no predictors. A high F value, like 16.250, suggests that the model explains a substantial amount of the variability in port effectiveness. This is consistent with research by Nikghadam et al., (2025), which found that optimizing port services such as pilotage and towage significantly impacts the efficiency and productivity of ports. The statistical significance of the regression model highlights the collective importance of pilotage, towage, and mooring services in determining port effectiveness. This finding aligns with previous studies, such as those by Issa-Zadeh & Garay-Rondero, C. L., (2025), which emphasize the integral role of these services in improving port operational efficiency. However, the model does not account for other factors that could also influence port performance, such as technological infrastructure, environmental conditions, and workforce capacity. As suggested by Wibowo (2025), integrating digital technologies like PMIS could offer additional insights and improvements, thereby further optimizing the port's effectiveness. Moreover, while the regression model is significant, it remains essential to address the external factors not covered by the current analysis. Research by Sunitiyoso et al., (2022) highlights how environmental conditions, like tidal surges, can disrupt the operational efficiency of ports, particularly mooring services. Incorporating such variables in future models could provide a more holistic understanding of the factors influencing port effectiveness.

Table 3: Relationship Between Weather Conditions and Mooring Delays

<i>Variable</i>	<i>B</i>	<i>Std. Error</i>	<i>Beta</i>	<i>t</i>	<i>Sig.</i>
<i>(Constant)</i>	3.842	1.512		2.537	0.014
<i>Pilotage</i>	0.451	0.134	0.325	3.362	0.002
<i>Towage</i>	0.301	0.121	0.218	2.489	0.017
<i>Mooring</i>	0.245	0.116	0.197	2.115	0.039
<i>Weather Impact</i>	0.189	0.089	0.152	2.123	0.037

Table 3 presents the coefficients from the multiple linear regression analysis, showing the influence of pilotage, towage, mooring services, and weather conditions on port effectiveness. The pilotage service ($B = 0.451$, $p = 0.002$) has a significant effect on both ship waiting times and operational costs. This suggests that improving the efficiency of pilotage services, such as increasing the number of qualified pilots and upgrading pilot vessels, can reduce delays and associated costs. Similarly, towage services ($B = 0.301$, $p = 0.017$) are significantly impacted by the capacity of tugboats. A sufficient number of tugboats helps expedite the towage process, particularly in busy periods, reducing waiting times and improving the port's overall efficiency. Furthermore, mooring services ($B = 0.245$, $p = 0.039$) also significantly influence mooring times and operational costs. This highlights the importance of enhancing mooring infrastructure to optimize docking efficiency and reduce vessel dwell time at the port.

Additionally, weather conditions ($B = 0.189$, $p = 0.037$), such as tidal flooding (rob), have a significant impact on the mooring process. Adverse weather conditions lead to delays in mooring ships, which not only increases waiting times but also raises operational costs. This finding supports previous studies, such as those by Verschuur et al., (2020), which indicate that weather-related disruptions can significantly affect port operations. To address these issues, it is essential to invest in weather-resilient infrastructure and improve coordination across services to minimize delays caused by external factors. Overall, the regression results underscore the importance of optimizing each service and considering external factors, such as weather, to enhance port efficiency and reduce operational costs.

4. CONCLUSION

This study successfully identified the factors influencing the effectiveness of pilotage, towage, and mooring services at Tanjung Emas Semarang Port, measured through vessel waiting times, operational costs, and user satisfaction. The analysis showed that limited pilot personnel, insufficient tugboat capacity, and the impact of extreme weather conditions (such as tidal flooding) are the main factors affecting

the effectiveness of these three services. Pilotage, towage, and mooring services significantly influence port operational costs and service process speed. This research also introduces novelty by using multiple linear regression analysis, which found that the three types of vessel services make a significant contribution to port effectiveness, explaining 69.2% of the variation in vessel waiting times and operational costs.

In light of these findings, this study provides important recommendations for the future development of the port. Enhancing tugboat capacity and pilot personnel, as well as improving dock infrastructure that is more resilient to adverse weather conditions, will speed up the processes of pilotage, towage, and mooring, thereby reducing vessel waiting times and operational costs. Additionally, implementing port digitalization, such as VTS and PMIS, can reduce human errors, improve coordination among personnel, and accelerate decision-making. Therefore, to improve overall port effectiveness, it is recommended that the port focus on enhancing human resources, digital technology, and port infrastructure improvements.

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