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Operation of Automated Rubber Tyred Gantry (ARTG) in Supporting Container Receiving Operations to Minimize Truck Turn Round Time (TRT)

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Abstract: This study investigates the impact of the Automated Rubber Tyred Gantry (ARTG) system on terminal operations at Semarang Container Terminal, with the specific aim of assessing its contribution to efficiency while identifying operational challenges. A qualitative descriptive approach was applied, using field observations, interviews, and document analysis. The findings indicate that ARTG automation enhances container handling efficiency, particularly by reducing truck Turn Round Time (TRT) and minimizing handling errors. The system's advanced features, such as sensors, GPS, and cameras, enabled more precise and reliable container transfers. However, challenges were also identified, including technical malfunctions, weather disturbances, and occasional system failures that disrupted operations and increased TRT. These results suggest that while ARTG significantly improves operational performance, its effectiveness depends on addressing recurring disruptions. Ensuring routine maintenance, timely system upgrades, and operator readiness is critical to sustaining system reliability. In conclusion, the study demonstrates that ARTG provides measurable efficiency gains in container terminal operations, yet its optimal performance requires continuous technical support and proactive problem management. These insights contribute to advancing automation practices in port operations and strengthening competitiveness in the maritime industry.

Keywords: Automated rubber tyred gantry; Container receiving; Turn round time

Introduction

The Automated Rubber Tyred Gantry (ARTG) system at Semarang Container Terminal plays a crucial role in improving container handling efficiency, particularly in reducing Truck Turn Round Time (TRT) and minimizing operational errors (Winarno et al., 2019). Automation not only streamlines container flows but also enhances the terminal's competitiveness as a modern logistics hub. Previous studies have emphasized the benefits of ARTG in efficiency improvement, yet there is limited evidence on how operational challenges, such as technical failures, environmental disruptions, and procedural bottlenecks—affect its performance in Indonesian port contexts. By significantly reducing truck Round Time (TRT) and minimising errors in container handling and stacking, ARTG supports smoother terminal operations (Andriani et al., 2024). The automation embedded in ARTG not only streamlines workflows but also strengthens the terminal's position as a modern, forward-thinking port facility (Ibrahim, 2024). ARTG's

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influence is especially evident in reducing the time trucks spend from gate-in to gate-out, optimising operational efficiency while simultaneously lowering costs and improving customer satisfaction (Juliana Basulo-Ribeiro, 2024). However, despite these advantages, ARTG operations are not without challenges (Feng & Li, 2022). Disruptions during receiving and delivery—such as system failures or delays due to adverse weather, can lead to increased TRT, congestion, and reduced productivity, thereby impacting the terminal's service quality and revenue (Kastner & Jahn, 2022).

Although ARTG has significantly contributed to reducing truck congestion and improving service quality, recurring disruptions may still increase TRT, cause yard congestion, and lower productivity (Kim & Sul, 2006; Winarno et al., 2019; Yang et al., 2022). Such conditions underline the need for systematic investigation of operational vulnerabilities and strategies for sustaining system performance (Akhtar, 2024; Kumar et al., 2025). This study therefore addresses an important research gap: while ARTG has been widely discussed in terms of its efficiency benefits, fewer studies have examined the interplay between its technological potential and the real-world operational challenges it faces in practice. Compared to conventional RTGs, ARTGs are equipped with advanced sensors, automation software, and vision camera systems, which enable precise and safe container movement within the stacking yard (Kemme, 2020). This technological innovation facilitates faster and more accurate container transfers, thereby contributing directly to the reduction of TRT and ensuring timely cargo delivery to customers (Sinha et al., 2022).

The implementation of ARTG is part of a broader initiative to modernise the logistics and operational systems of the Semarang Container Terminal (Winarno et al., 2019). By automating the container handling process, the terminal improves service quality and operational consistency, ensuring it meets the growing demands of international trade (Luo & Wu, 2020). Nonetheless, to ensure that ARTG operates at peak efficiency, there must be targeted measures to address technical failures, environmental constraints, and procedural inefficiencies that can compromise system performance.

Based on this background, the research formulates three primary questions: how ARTG is operated at the Semarang Container Terminal, what challenges are faced in minimizing truck TRT, and what solutions can be implemented to overcome these obstacles. The research aims to explain the operational mechanisms of ARTG, identify the key challenges in its implementation, and determine the most effective strategies to ensure optimal performance in reducing TRT. Understanding these aspects is essential for enhancing the efficiency, sustainability, and competitiveness of port operations in the digital era.

Furthermore, in operational theory, "operation" refers not just to running a tool or system but also to the interconnected and sequential processes required for optimal functionality. Operations can be manual, requiring human expertise, or automated, relying on machines or software programmed to execute specific tasks without human intervention (Cummings, 2014). The ARTG represents this shift toward automation, embodying the transition from manual to intelligent, machine-driven processes in port logistics (Gattuso & Pellicanò, 2023).

Within the terminal, ARTG is dedicated to handling containers—large, standardised units used to transport goods via sea routes (Feng & Li, 2023; Lu et al., 2022). Common container sizes include 20ft, 20hc, 40ft, and 40hc, which can be accommodated in the ARTG stacking yard (Sarpio, 2023). Larger containers such as 45ft and 45hc, exceed the slot capacities and are not supported by the ARTG system (Kim & Sul, 2006). The efficiency of ARTG in handling these containers is integral to minimizing TRT, which is the duration between a truck’s entry and exit from the terminal area (Phiri, 2021). A shorter TRT translates to reduced operational costs, enhanced customer service, and improved profitability—goals that align with the overarching mission of the Semarang Container Terminal in delivering world-class port services.

Method

This study employed a qualitative descriptive method to investigate the operation of the Automated Rubber Tyred Gantry (ARTG) system at Semarang Container Terminal (Winarno et al., 2019). The research was conducted from August 2023 to February 2024, during which the researcher carried out direct observations and participated in relevant operational activities at the terminal.

Data Collection. Three primary techniques were applied: (1) Observation – systematic monitoring of ARTG activities in container receiving and delivery, focusing on operational processes, efficiency, and disruptions; (2) Interviews – conducted with ARTG operators, system supervisors, and terminal staff to capture practical insights into challenges, system performance, and problem-solving practices; (3) Documentation and literature review – including operational logs, technical manuals, and reports from the terminal, complemented by relevant academic studies on automated port operations.

Data validity was a crucial aspect of the research, as data served as a fundamental component for analysis and the basis for concluding (Astriawati et al., 2023; Waluyo et al., 2023; Sulastri et al., 2022). To ensure the validity of the data, the researcher applied triangulation techniques (Maslikhah et al., 2022). Methodological triangulation involved the use of multiple methods interviews, observations, and documentation (Maslikhah et al., 2022; Hendrowati et al., 2025). Data source triangulation was performed by collecting information from various sources, including ARTG operators, field supervisors, and technical staff. These triangulation methods helped confirm the accuracy of the findings and validate observations made during research (Setiati & Jumadi, 2022). In addition, the researcher prepared comprehensive documentation to further ensure the authenticity and validity of the data collected (Rahman et al., 2023).

Result and Discussion

Based on field observations, interviews with operators, and company technical documentation, the initial stage before operating the Automated Rubber Tyred Gantry (ARTG) crane involved a series of standardized procedures. Operators were required to log into the Remote Operating Station (ROS) using their registered ID card. This ensured that only authorized personnel could access and control the crane system. Once logged in, the operator determined whether the ARTG would run in automatic mode—where positioning and container handling relied on GPS sensors and the Ethernet communication module—or in manual mode, where the operator directly controlled the crane functions through the ROS interface. These operational modes were designed to optimize container handling efficiency while maintaining system safety and accuracy.

Figure 1. Operation of ARTG by operator

The figure showed the operator interface at the Remote Operating Station (ROS). The monitor displayed real-time crane positioning, container alignment, and status indicators of the GPS and Ethernet communication modules. The operator could switch between automatic and manual mode via the control panel, which ensured operational flexibility in case of system faults.

Despite these procedures, several major operational errors were identified during the research. These findings were summarized in Table 1.

Table 1. Summary of ARTG Operational Errors

Error / Issue	Technical Cause	Direct Effect	Data Source
Hoist 1 – Brake supervision error when engaging	Magnetic sensor not detected due to unstable network connection	Crane stopped abruptly during hoist operation	Field observation, error log
GPS autosteering selected ON and GPS fault	GPS signal interference, unstable Ethernet module	Autosteering failed → operator switched to manual mode	Operator interview, technical records
Hoist 2 – Hardware stop limit tripped	Encoder sending incorrect signals, improper calibration	Hoist stopped on girder track → potential TRT delay	Technical documentation, maintenance log

Following the findings presented in Table 1, this research examined various problems encountered during the operation of the Automated Rubber Tyred Gantry (ARTG) Cranes at the Semarang Container Terminal. Field practice revealed that ARTG operations involved a series of technical procedures that required high precision, supported by advanced technologies such as monitoring cameras and GPS systems. The primary objective of ARTG operation was to facilitate smooth receiving and delivery activities in order to minimize Truck Turnaround Time (TRT). Before commencing operation, operators ensured that the working area was free from obstructions and verified through the Remote Operator Station (ROS) display that all monitoring cameras were functioning properly. They also confirmed the absence of collision risks with other cranes, equipment, or personnel in the surrounding area. Additionally, the operator was required to scan an identification card at the ARTG workstation, which served both as an identity log and as a record of production activities.

The ARTG had three operating modes applied according to field conditions and operational needs. The first mode was Automatic Operation, in which the ARTG moved autonomously along the container yard block to pick up or place containers, with hoist, trolley, and spreader working automatically within the yard block (but not in the truck lane). The second mode was operation through the Remote Operator Station (ROS), in which specially trained operators manually controlled the hoist, trolley, and spreader, particularly in the truck lane. The third mode was Manual Remote Operator Station (MROS), in which the operation was fully manual, including gantry movement, and communication with truck drivers was carried out via headset.

Despite these structured procedures, several significant challenges were identified during practice. One of the most frequent issues was the "Hoist 1 – Brake supervision error when engaging," the location of which within the crane's structural layout is illustrated in Figure 2.

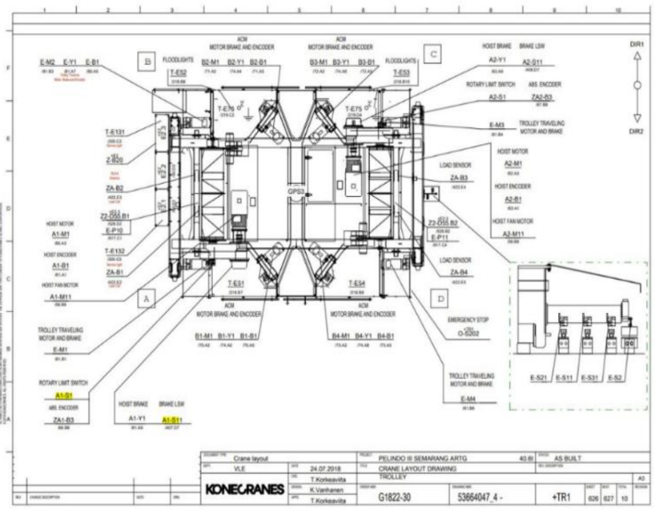

Figure 2. Crane layout drawing trolley

One of the main issues identified was the "Hoist 1 – Brake supervision error when engaging." As illustrated in Figure 2, the hoist and brake system were located on the trolley section of the crane. This placement was critical because the brake mechanism directly regulated the hoisting movement. The occurrence of the supervision error indicated that the brake system did not properly respond during the hoist operation, which could be correlated with potential misalignment or delay in the trolley's brake engagement. By referring to the structural layout shown in the figure, it became clear how the position of the hoist and its brake system contributed to operational disturbances, thereby explaining the source of the error in the field. This problem occurred due to a malfunction in the electromagnetic brake system, which should automatically engage and released as the head block moved. The malfunction was often caused by unreadable magnetic sensors due to unstable network connections. Another challenge was "GPS autosteering selected ON and GPS fault." The structure of the crane's communication and positioning system is shown in Figure 3 below.

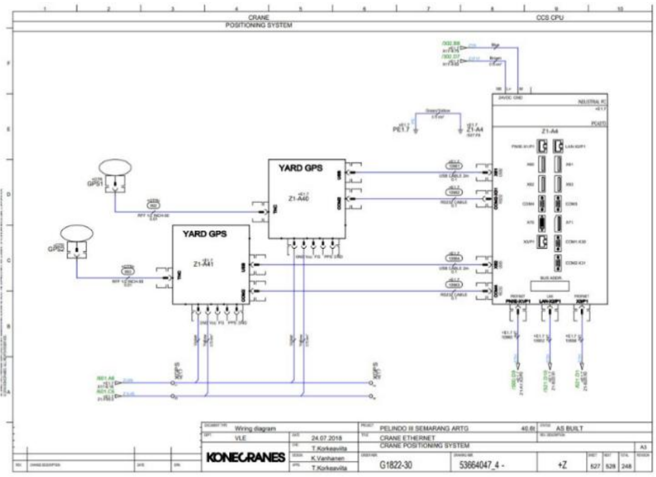

Figure 3. Crane ethernet & crane positioning system

The malfunction was often caused by unreadable magnetic sensors due to unstable network connections. Another challenge was the "GPS autosteering selected ON and GPS fault." As illustrated in Figure 3, the crane's communication and positioning system were integrated through the Ethernet and GPS modules. The occurrence of the GPS fault indicated that the positioning signal was either interrupted or misinterpreted within the network, which disrupted the crane's automated steering function. By referring to the system layout in the figure, it became clear how instability in the Ethernet communication and sensor signal transmission contributed to the malfunction, highlighting the vulnerability of the positioning system to network disturbances. When the GPS signal was weak or satellite communication was disrupted, the ARTG system could not maintain its position accurately. This triggered a request for manual operation (MROS), where the operator had to manually adjust the ARTG's position to stay on track. There was also a case of "Hoist 2 – Hardware stop limit tripped." The general structural layout of the crane's main girders, which may be affected during such faults, is illustrated in Figure 4.

To solve the GPS-related issues, the company purchased GPS licenses from Europe or China and replaced old antennas with more modern ones. This allowed the ARTG to detect more satellites for improved positional accuracy. When necessary, corrections to the ARTG's tilt were made using a manual pendant. In addressing the hardware stop limit tripped issue on hoist 2, the operator reset the system settings from the control room using the MROS system. This helped return the system to normal conditions and allowed operations to continue without major disruption. These efforts aimed to improve the efficiency of receiving and delivery operations and minimize truck turnaround time in the yard. A lower TRT was crucial for the smooth flow of logistics and customer satisfaction, making stable ARTG operations a key success factor. The successful implementation of ARTG at Semarang Container Terminal relied on the synergy between advanced technology and operator skill. The use of devices such as cameras, sensors, joysticks, communication headsets, and GPS-based navigation systems requires continuous training.

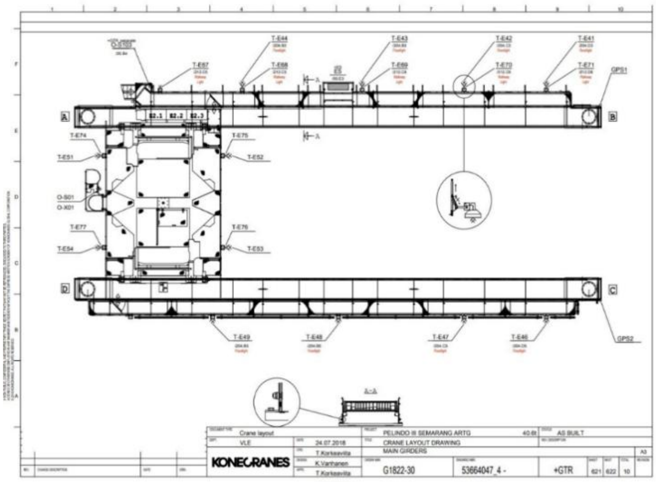

Figure 4. Crane layout drawing main girders

In addition, it was important to have a good documentation and reporting system. With complete documentation, operators and technicians could trace fault histories, perform root cause analysis, and set appropriate corrective actions for future issues. ARTG was a vital technology in supporting port efficiency. However, its successful operation depended on the technical readiness of the equipment, system reliability, and the competence of operators in handling potential disruptions. Periodic evaluations and system updates were essential to support smooth receiving and delivery activities in container terminals (Li et al., 2018).

Conclusion

This study revealed that ARTG operations at Semarang Container Terminal were conducted through three modes—Automatic Operation, Remote Operator Station (ROS), and Manual Remote Operator Station (MROS)—each requiring different levels of operator involvement and system support. The findings indicated that the main challenges in minimizing truck turnaround time (TRT) were related to technical faults, namely brake supervision errors in Hoist 1, GPS autosteering faults, and Hoist 2 hardware stop limit tripped. These issues were primarily caused by sensor misreadings, unstable network connections, and calibration errors. To overcome these challenges, several solutions were implemented: (1) routine maintenance and replacement of brake components to prevent supervision errors, (2) upgrading GPS antennas and licenses to improve positioning accuracy, and (3) system resets and recalibrations through MROS to restore functionality after limit faults. These corrective measures significantly improved operational stability and supported the reduction of TRT in container yard activities. The study concludes that the effectiveness of ARTG operations depends on the integration of advanced technology with continuous operator training, as well as the systematic documentation of fault histories to enable timely corrective action. These findings highlight that sustained improvements in TRT require not only technological upgrades but also human competence and structured maintenance strategies.

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Author Contributions

Conceptualization, F.T; methodology, F.T and S.A.S; validation, F.T and H.P.; formal analysis, F.T, S.A.S and H.P; investigation, S.A.S; resources, F.T, S.A.S and H.P.; data curation, S.A.S : writing—original draft preparation, F.T and S.A.S.; writing—review and editing, F.T.: visualization, and F.T and H.P. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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