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Comparative Analysis of Grab, Conveyor, and Excavator Unloading Equipment on Time Efficiency and Port Costs in Bulk Urea Fertilizer Unloading at Tanjung Emas Port, Semarang

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Abstract: *This study aims to analyze the performance and port cost efficiency of bulk urea fertilizer unloading operations at Tanjung Emas Port, Semarang, by comparing three types of unloading equipment: conveyor, grab, and excavator. Data were collected through direct observation and documentation of operations on MV Soemantri Brodjonegoro (conveyor), MV Pusri Indonesia 1 (grab), and TB Del 02/BG Parta Jaya 3006 (excavator) during March–May 2025. Parameters measured include unloading productivity (MT/hour), effective berthing time, downtime percentage, and total port costs (berthage, pilotage, towage, unloading charges) based on Minister of Transportation Regulation No. PM 10 of 2021. Results show that the conveyor achieved the highest productivity at 109.79 MT/hour, followed by excavator at 104.156 MT/hour and grab at 101.006 MT/hour. The grab recorded the lowest downtime percentage (12%), while conveyor (19%) and excavator (18%) were higher. In terms of port cost, excavator was the most economical (IDR 21,549,045), followed by conveyor (IDR 25,337,476), with grab the highest (IDR 29,874,552). Unloading charges dominated more than 74% of total costs across all three methods. These findings provide strategic guidance in selecting unloading equipment based on operational priorities, whether speed or cost efficiency.*

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Introduction

Indonesian, as an agrarian nation, has a high dependence on the availability of fertilizers—particularly urea—to support national food security. Urea is a nitrogen-based fertilizer with a high nitrogen concentration, making it highly effective in stimulating vegetative plant growth. Its distribution is carried out on a large scale via sea routes due to their efficiency and large cargo capacity (Farros et al., 2023). Tanjung Emas Port in Semarang serves as one of Indonesia's primary logistics hubs, functioning as the distribution gateway for Central Java and equipped with dry bulk berth facilities, storage warehouses, and various cargo handling equipment.

Cargo unloading time is a key determinant of port operational efficiency, as it is directly related to vessel berthing duration, which in turn affects port costs and service performance (Defrianto & Purwasih, 2023). Research by Nurjanah (2021) on MV Pusri Indonesia 1 at the Dwimatama Berth in Semarang found that limited unloading equipment, weather disruptions, and insufficient warehouse capacity significantly prolonged vessel berthing time. These factors not only affect operational duration, but also result in proportionally increasing port costs the longer a vessel remains at the berth (Jabalnur et al., 2022; Minister of Transportation Regulation No. PM 10 of 2021).On the other hand, the selection of appropriate unloading equipment is a strategic factor. The grab is considered flexible, though its unloading capacity is relatively limited compared to automated conveyor systems (Kevin & Wilson, 2015; Ramadhan et al., 2025). A comparative study of conventional unloading equipment and conveyors at the Rembang Power Plant by Suharto et al. (2023) revealed significant differences in time and operational costs, underscoring the need to align equipment selection with operational priorities. Manunggal et al. (2025) also confirmed that the effective time-to-berthing time ratio (ET/BT) at Tanjung Emas Port remains below target, indicating room for optimization in dry bulk cargo handling systems.

This study aims to analyze and compare the performance of three types of unloading equipment (conveyor, grab, and excavator) in terms of hourly unloading productivity, berthing duration, and total port costs in the bulk urea unloading process at Tanjung Emas Port, Semarang. The findings are expected to serve as a strategic basis for port operators and cargo owners in planning optimal cargo handling operations.

Research Methods

This study employs a descriptive quantitative approach using comparative research design to systematically measure and compare the performance of three types of unloading equipment (Sahir et al., 2023; Syahroni, 2022). The research was conducted at Tanjung Emas Port, Semarang, during March–May 2025, with three vessels operated by PT Pupuk Indonesia Logistik serving as research subjects: (1) MV Soemantri Brodjonegoro using a conveyor, (2) MV Pusri Indonesia 1 using a grab, and (3) TB Del 02/BG Parta Jaya 3006 using an excavator.

Data were collected through two primary methods: (1) direct observation of cargo handling activities, including recording of operational time, downtime, and unloading capacity per session; and (2) documentation review, encompassing unloading remark reports, vessel cargo data, and port tariff details. Primary data were obtained from field operational records (Sulung & Muspawi, 2024), while secondary data included historical unloading reports and tariff regulations (Faradiba et al., 2024).

Unloading Productivity Analysis

Unloading productivity was calculated based on the average unloading capacity per hour using the formula: Average (MT/hour) = Total Cargo (MT) / Total Effective Unloading Time (hours).

Berthing Time and Downtime Analysis

Berthing time refers to the total duration a vessel remains at the berth from the commencement to the completion of unloading operations. Downtime percentage was calculated as the ratio of total downtime (caused by weather, equipment failure, and external disruptions) to total effective unloading time. Downtime was categorized into weather-related variables, mechanical failures, and external

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factors (blackouts, truck queuing) as identified by Oktavia et al. (2022) and Febriansyah et al. (2023).

Port Cost Analysis

Port costs were calculated based on four components in accordance with Minister of Transportation Regulation No. PM 10 of 2021: (1) berthage costs (GT × berthage rate × number of etmal); (2) pilotage costs ((fixed rate + GT × variable rate) × number of movements); (3) towage costs ((GT × variable rate + fixed rate) × hours); and (4) unloading charges (rate per ton × total cargo). Etmal calculation follows the stipulation: <6 hours = 0.25 etmal; 6–12 hours = 0.50 etmal; 12–18 hours = 0.75 etmal; 18–24 hours = 1 etmal (Haridasari et al., 2024). The cost analysis was linked to the berthing duration of each equipment type to determine the most economical option.

Results and Discussion

Unloading Productivity per Hour

Based on the processing of primary data from nine conveyor voyages (MV Soemantri Brodjonegoro), thirteen grab voyages (MV Pusri Indonesia 1), and one excavator session (TB Del 02/BG Parta Jaya 3006), the average unloading productivity results are as follows:

Table 1. Comparison of Unloading Equipment Productivity

Equipment	Vessel	Total Cargo (MT)	Total Effective Time (Hours)	Average (MT/Hour)
Conveyor	MV Soemantri Brodjonegoro	6,949.71	63 hrs 18 min	109.79
Grab	MV Pusri Indonesia 1	7,000.00	110 hrs 00 min	101.006
Excavator	TB Del 02 / BG Parta Jaya 3006	7,000.00	70 hrs 24 min	104.156

Source: Primary Data Processed by Researcher (2025)

The results above show that the conveyor achieved the highest unloading productivity at 109.79 MT/hour, followed by the excavator at 104.156 MT/hour, and the grab at 101.006 MT/hour. Although the numerical differences are relatively small, the conveyor's superiority reflects its automated and continuous mechanization system compared to the grab's cyclical lift-and-release mechanism. These findings are consistent with Ramadhan et al. (2025), who stated that dry bulk unloading performance is significantly influenced by equipment type and bucket coverage area, and align with Sutini (2022), who demonstrated the efficiency difference between conveyor and conventional methods at the Rembang Power Plant. Meanwhile, the grab—despite its lowest productivity—remains competitive, reflecting its flexibility as a universal unloading tool adaptable to varying hold configurations (Kevin & Wilson, 2015).

Berthing Time and Downtime Percentage

The berthing time and downtime profile for each equipment type are summarized in the following table:

Table 2. Berthing Time and Downtime in Unloading Operations

Equipment	Berthing Duration	Effective Unloading Time	Downtime	% Downtime
Conveyor	4 days 3 hrs 30 min	63 hrs 18 min	15 hrs 6 min	19%
Grab	5 days 18 hrs 42 min	110 hrs 00 min	15 hrs 24 min	12%
Excavator	3 days 13 hrs 47 min	70 hrs 24 min	15 hrs 15 min	18%

Source: Primary Data Processed by Researcher (2025)

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The excavator recorded the shortest berthing duration (3 days 13 hours 47 minutes), followed by the conveyor (4 days 3 hours 30 minutes), and the grab with the longest berthing duration (5 days 18 hours 42 minutes). Notably, the grab had the lowest downtime percentage at only 12%, while the conveyor recorded 19% and the excavator 18%. This finding suggests that the grab's prolonged berthing time is not solely attributable to high operational downtime, but is more strongly influenced by the total cargo volume to be unloaded and its lower per-cycle handling capacity compared to the conveyor.

Downtime in the conveyor was primarily caused by mechanical failures in the belt system and external disruptions, consistent with findings by Laulang (2022), who identified the lack of regular maintenance of MV Soemantri Brodjonegoro's unloading system as the primary cause of downtime. For the grab, the largest source of downtime was weather-related (12 hours 24 minutes out of a total 15 hours 24 minutes), due to the hygroscopic nature of urea fertilizer, which necessitates halting operations during rainfall (Nurjanah, 2021; Prabowo, 2019). This is consistent with Darunanto et al. (2020) at Tanjung Priok Port, who found that crane and unloading equipment productivity correlates strongly with the ET:BT ratio, where weather and equipment failures are the primary obstacles to improving this ratio.

Port Cost Analysis

Total port costs for each equipment type were calculated based on the official rates under Minister of Transportation Regulation No. PM 10 of 2021, as follows:

Table 3. Comparison of Port Costs

Cost Component	Conveyor	Grab	Excavator
Berthage Costs	IDR 2,139,756	IDR 5,081,232	IDR 42,585
Pilotage Costs	IDR 1,315,780	IDR 1,669,280	IDR 809,190
Towage Costs	IDR 2,631,940	IDR 3,874,040	IDR 1,447,270
Unloading Charges	IDR 19,250,000	IDR 19,250,000	IDR 19,250,000
TOTAL	**IDR 25,337,476**	**IDR 29,874,552**	**IDR 21,549,045**

Source: Primary Data Processed by Researcher (2025)

The excavator generated the lowest total port cost at IDR 21,549,045, making it the most economical option. The conveyor ranked second at IDR 25,337,476, while the grab incurred the highest cost at IDR 29,874,552. These cost differences are primarily driven by the highly variable berthage cost components across the three equipment types, reflecting significant differences in berthing duration. The differing Gross Tonnages (GT) of the vessels—the grab vessel at 12,454 GT, the conveyor vessel at 7,404 GT, and the excavator barge at only 167 GT—further contributed to the differences in berthage, pilotage, and towage costs.

Unloading charges constituted the largest cost component across all equipment types, representing 74%–90% of total costs. This proportion is consistent with Widiafina (2018), who found that unloading charges dominate the port cost structure for dry bulk commodities. Zahrani (2018) also affirmed that improvements in unloading equipment productivity can significantly reduce demurrage costs by shortening berthing duration. Therefore, although the unloading cost per ton is relatively consistent, the total cost differences between equipment types are primarily dependent on berthing efficiency, which is influenced by the type and size of vessel employed.

Comprehensive Comparison and Managerial Implications

A comparison across three dimensions (productivity, berthing time, and cost) reveals that no single equipment type outperforms the others across all aspects. The conveyor excels in hourly productivity (109.79 MT/hour) but has the highest downtime percentage (19%) and higher costs than the excavator. The grab demonstrates the lowest downtime percentage (12%) but incurs the highest cost due to the extended vessel berthing duration and large vessel GT. The excavator, while not the fastest, offers the shortest berthing duration combined with the lowest port costs.

These findings align with Suharto et al. (2023) at Sluke Rembang Port, who concluded that the excavator outperforms the conveyor in terms of time, while the conveyor is more economical in

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operational costs; both are superior to the grab in terms of cost. Rusmiyanto & Sumardiatna (2021) affirmed that cargo handling is the most significant factor affecting dwelling time at Tanjung Emas Port, making unloading equipment optimization a strategic intervention for reducing port costs. For management, the following recommendations may serve as considerations: (1) for large-volume cargo prioritizing speed, the conveyor is recommended due to its highest discharge rate; (2) if the primary priority is cost savings, the excavator is the most optimal choice; and (3) the grab is appropriate for vessels with non-uniform hold configurations but requires strict maintenance to minimize weather-related downtime.

Conclusion

This study analyzed and compared the performance of three types of unloading equipment in the bulk urea fertilizer unloading process at Tanjung Emas Port, Semarang. Three key conclusions were drawn. First, in terms of hourly unloading productivity, the conveyor achieved the highest effectiveness at 109.79 MT/hour, followed by the excavator at 104.156 MT/hour, and the grab at 101.006 MT/hour. This difference demonstrates that the type of unloading equipment directly affects the speed of the unloading process, with the conveyor's continuous mechanization system outperforming the cyclical grab mechanism.

Second, in terms of berthing time, the excavator recorded the shortest duration (3 days 13 hours 47 minutes) with an 18% downtime rate, followed by the conveyor (4 days 3 hours 30 minutes, 19% downtime), and the grab (5 days 18 hours 42 minutes, 12% downtime). The grab, despite having the lowest downtime percentage, still had the longest berthing time, demonstrating that berthing duration is not solely determined by downtime but also by cargo handling capacity and total cargo volume.

Third, in terms of port costs, the excavator was the most economical (IDR 21,549,045), followed by the conveyor (IDR 25,337,476), and the grab with the highest cost (IDR 29,874,552). Unloading charges dominated 74%–90% of total costs across all equipment types. Strategic recommendations include using the conveyor for high-volume cargo where speed is the priority, the excavator when cost minimization is the primary objective, and the grab—subject to strict regular maintenance—for vessels with varied hold configurations to minimize weather-related downtime.

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