LEAN-BASED OPTIMIZATION OF DRY BULK COAL UNLOADING USING VALUE STREAM MAPPING: A CASE STUDY AT CIREBON PORT, INDONESIA

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Abstract

This study aims to optimize the dry bulk coal loading and unloading process at the Port of Cirebon using a Lean and Value Stream Mapping (VSM) approach. Data was collected through field observations, document review, and a time study of loading and unloading activities. A Current State Map (CSM) was developed to map the actual operational conditions, while waste was identified using Seven Waste Analysis. The results showed that the dominant waste was waiting, overprocessing, and idle time, primarily caused by equipment imbalance, limited forklift availability, and operational schedule asymmetry. A Future State Map (FSM) was developed to provide recommendations for improvements, focusing on standardizing procedures, redistributing heavy equipment, and improving real-time operational coordination. The implementation of FSM is projected to significantly reduce loading and unloading cycle times and increase process efficiency.

Keywords: Loading And Unloading, Lean, Value Stream Mapping, Efficiency, Port

Abstrak

Penelitian ini bertujuan untuk mengoptimalkan proses bongkar muat curah kering batubara di Pelabuhan Cirebon melalui pendekatan Lean dan Value Stream Mapping (VSM). Data dikumpulkan melalui observasi lapangan, studi dokumen, dan time study terhadap aktivitas bongkar muat. Current State Map (CSM) disusun untuk memetakan kondisi aktual proses operasional, sedangkan identifikasi pemborosan dilakukan menggunakan Seven Waste Analysis. Hasil penelitian menunjukkan bahwa pemborosan dominan berupa waiting, overprocessing, dan idle time yang terutama disebabkan oleh ketidakseimbangan alat berat, keterbatasan forklift, serta ketidaksinkronan jadwal operasional. Future State Map (FSM) disusun sebagai rekomendasi perbaikan dengan fokus pada standardisasi prosedur, redistribusi alat berat, dan peningkatan koordinasi operasional berbasis waktu nyata. Implementasi FSM diproyeksikan mampu menekan waktu siklus bongkar muat dan meningkatkan efisiensi proses secara signifikan.

Kata kunci: bongkar muat, Lean, Value Stream Mapping, efisiensi, pelabuhan

INTRODUCTION

Maritime transportation is a key infrastructure for international trade, with over 90% of global trade volume transported by sea (UNCTAD, 2020). For Indonesia, the world's largest archipelagic nation, ports play a vital role in supporting logistics connectivity and national competitiveness. The transportation and warehousing sector contributed 10.7% to national GDP in 2022 (BPS, 2022), demonstrating a high dependence on port efficiency.

Coal is a strategic dry bulk commodity that dominates loading and unloading activities at various Indonesian ports. At the Port of Cirebon, coal loading and unloading volume reached over 300,000 tons in 2020, with vessel call volumes increasing annually. However, the loading and unloading process at this port still faces challenges such as fluctuating productivity, long waiting times, heavy equipment distribution bottlenecks, and significant operator idle time (Laporan Tahunan Pelindo, 2024).

Several previous studies have applied Lean and VSM in the manufacturing, logistics, and service sectors (Saputro,et al, 2024 ; Irsyad and Hartini, 2024), but their application in the context of dry bulk loading and unloading at Indonesian ports remains very limited. Most Indonesian port research focuses on container terminals, while research on bulk terminals is relatively rare. This research gap indicates the need for empirical studies focusing on coal loading and unloading activities using a lean approach (Dewa,2021).

The main problem that arises in the loading and unloading process is waste that leads to low efficiency, such as waiting due to equipment, overprocessing during cargo clearance, and idle time due to suboptimal coordination (Zaeni, 2025; Firmanda et al., 2025). Based on these phenomena, this study aims to answer two main questions:

1. How can Lean and Value Stream Mapping be used to identify and reduce waste in the coal loading and unloading process?
2. What factors cause waste, and what are the recommendations for improvement?
3. This research provides a theoretical contribution to enriching Lean applications in the port sector, particularly for dry bulk commodities, as well as a practical contribution in the form of an operational process optimization model.

METHODOLOGY

A case study approach was employed to analyze the coal unloading operations at Cirebon Port in real operational conditions. Data collection combined direct field observations, time measurements, and analysis of internal port documents. Direct observations were conducted to record the actual flow of heavy equipment, the sequence of unloading cycles, and operator behavior throughout daily operations. These observations enabled the identification of real-time delays, queuing patterns, and inconsistencies across shifts (Huseynov et al., 2025; Kovtun, 2025)

A time study was carried out for 30 consecutive days to quantify the duration of each activity within the unloading cycle. Recorded times included equipment movement, material handling, truck turnaround, waiting periods, and operator idle time (Natarajan and Bookbinder, 2024). All data were validated through uniformity and adequacy tests to ensure reliability. Document analysis supplemented field data and included productivity reports, equipment specifications, berth layout, and historical unloading performance. These documents provided a broader operational context and supported cross-verification of field findings. Lean-based analytical tools were then applied.

A Current State Map (CSM) was constructed to visualize the entire unloading process and distinguish value-added (VA) from non-value-added (NVA) activities. Process inefficiencies were further examined through Seven Waste Analysis, identifying specific waste types such as waiting, overprocessing, unnecessary motion, and equipment idle time. Based on these insights, a Future State Map (FSM) was developed to propose an optimized workflow. The FSM incorporates standardized procedures, improved equipment allocation, and better synchronization of truck arrivals and equipment scheduling.

Overall, the analysis focused on identifying NVA activities, resolving bottlenecks, improving equipment utilization, and enhancing process synchronization to increase operational efficiency.

RESULT AND DISCUSSION

The analysis of the coal unloading operations at Cirebon Port begins with the construction of the Current State Map (CSM), which provides a detailed visualization of the end-to-end workflow—from vessel arrival to truck departure.

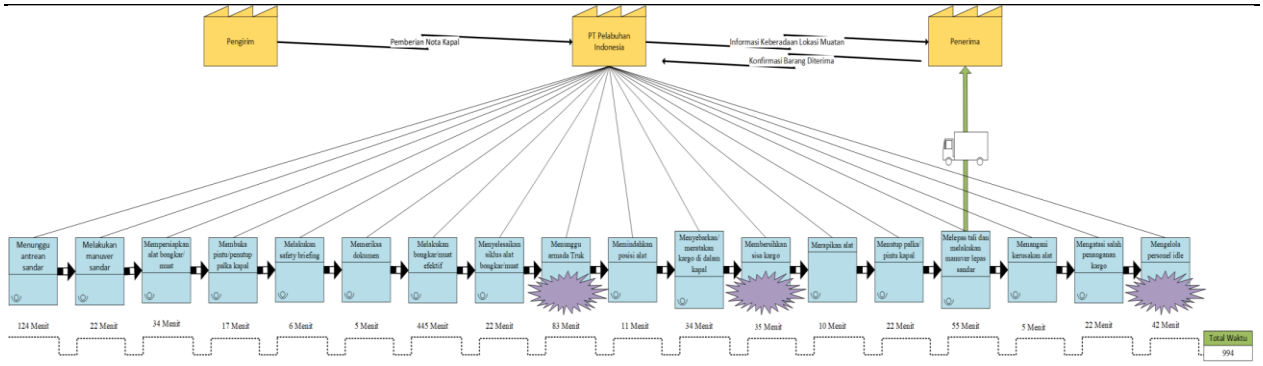

Figure 1. Current State Map of PT. Pelindo's loading and unloading process

The CSM reveals that only approximately **77%** of activities contribute direct value to the unloading process, while the remaining **11%** consist of non-value-added (NVA) and **11%** consist of necessary non-value added activities such as waiting, unnecessary motion, equipment idling, and duplicated processing steps. This imbalance highlights systemic inefficiencies embedded throughout the workflow.

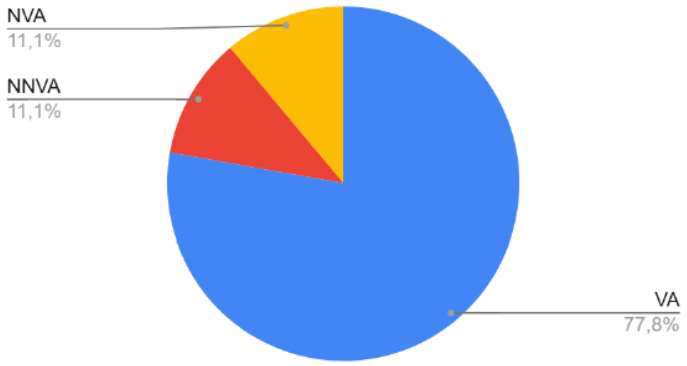

Figure 2. Percentage of Value Added, Non-Value Added, and Necessary Non-Value Added categories at CSM

One of the most prominent findings is the excessive waiting time, which emerges as the dominant waste category. Waiting occurs at multiple points in the process, including delays in truck arrival, excavator queues, and operator downtime during shift transitions. These delays are linked to poor synchronization between equipment availability and operational scheduling. For instance, the imbalance between the six excavators and the single available forklift creates significant bottlenecks, disrupting the continuity of material flow and causing repetitive stoppages. The time study further reveals considerable overprocessing**,** primarily in the form of repeated cleaning stages due to inconsistent work procedures across shifts. This not only extends cycle time but also increases operator fatigue and equipment usage unnecessarily.

Table 1. Activities that need to be eliminated

No	Waste	Activities
1	*Overprocessing*	Clearing remaining cargo Activities:
2	*Overprocessing*	Managing idle worker time Activities:

3	*Waiting*	Waiting for truck fleets

Source: Data processing results (2025)

Additional waste categories—such as unnecessary motion and equipment idle time—were also identified, largely stemming from unstructured operator movement and insufficient coordination during peak unloading periods.

The **Future State Map (FSM)** was developed to address the root causes of these inefficiencies. The proposed improvements include standardized operating procedures, real-time scheduling for truck dispatching, balanced allocation of excavators and forklifts, and optimized internal transport routes. These interventions aim to reduce delays, eliminate redundant activities, and stabilize the workflow.

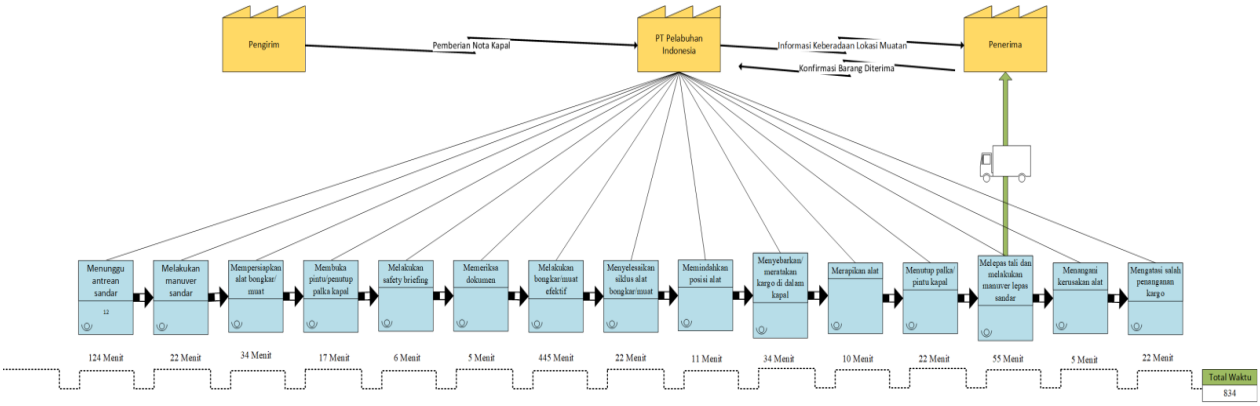

Figure 3. Future State Map of PT. Pelindo's loading and unloading process

Comparative analysis between the CSM and FSM shows significant projected improvements: a **30–32% reduction** in total unloading cycle time, a **24% decrease** in non-value-added activities, and a **15–20% increase** in overall operational productivity. These results underscore the effectiveness of Lean and VSM tools in diagnosing systemic inefficiencies and designing practical, low-cost solutions.

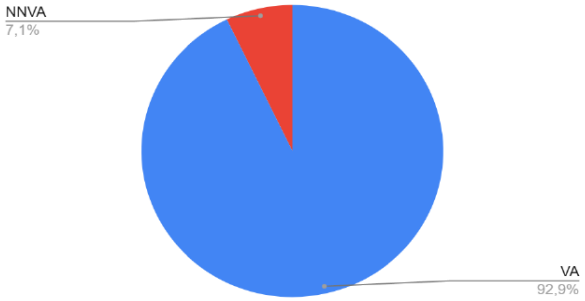

Figure 2. Percentage of Value Added, Non-Value Added, and Necessary Non-Value Added categories at FSM

The discussed findings are consistent with global studies on dry bulk terminals, where waiting and equipment imbalance frequently emerge as the primary inhibitors of operational performance. By applying Lean-based approaches, this study demonstrates that substantial efficiency gains can be achieved without

major investment in new infrastructure. Instead, process standardization, workflow redesign, and improved coordination serve as the core drivers of improvement.

CONCLUSION

This study concluded that the main waste in the coal loading and unloading process at the Port of Cirebon is waiting, overprocessing, and idle time. This waste is caused by equipment imbalance, unstandardized work procedures, and unsynchronized operational schedules. The application of Lean and Value Stream Mapping has proven effective in mapping workflows and identifying waste sources. The proposed Future State Map can improve the efficiency of the loading and unloading process through standardized procedures, redistribution of heavy equipment, improved coordination, and operator training. This model has the potential to increase loading and unloading productivity by up to 20%.

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