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Handling of Sticky Coal During the Process of Unloading Coal from the Wagon at Kertapati Port

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Abstract

Coal unloading operations at Kertapati Port face persistent inefficiencies due to the adhesive nature of low-rank coal, which frequently sticks to the inner surfaces of train carriages, causing delays, increased operational costs, and reduced unloading performance. This study aims to formulate a feasible and effective strategy to mitigate the issue of sticky coal during the unloading process to support the achievement of production and transportation targets.

Using a mixed-methods approach, the study integrates the Current Reality Tree (CRT) to identify root operational bottlenecks, the Analytic Hierarchy Process (AHP) to prioritize technical solutions, the Critical Path Method (CPM) and PERT for project scheduling, and financial feasibility analysis through NPV, IRR, and Payback Period. The results indicate that applying a stainles steel lining to the interior of boat-type train carriages is the most effective solution to reduce coal adhesion. Financially, the proposed investment is attractive, yielding an IRR of 66%, an NPV of IDR 29.1 billion, and a payback period of two years. The project is scheduled to begin on August 1, 2025, and complete by November 14, 2025. Continuous risk management measures are also planned throughout implementation. This integrated solution not only addresses the immediate operational inefficiencies but also supports long-term improvements in coal handling reliability and port logistics performance.

Keywords: Sticky Coal; Stainless Steel Lining; AHP; CPM; Unloading Optimization; Investment Feasibility

INTRODUCTION

Coal remains a critical component of Indonesia's energy mix, supplying approximately 67% of electricity generation needs as of 2023 (Thomasson, 2025). Although the Indonesian government has pledged to achieve net-zero emissions earlier than 2060, transitioning toward renewable energy remains gradual, given the country's dependency on coal-fired power plants (Spence, 2024). Indonesia's power generation infrastructure continues to rely heavily on low-rank coal, which is abundant but operationally challenging due to its high moisture content and tendency to form sticky masses during transport and unloading (EIA, 2023; Liu et al., 2021).

In anticipation of a growing domestic demand for coal projected to increase from 84 million tonnes in 2018 to 157 million tonnes by 2027 (Adijanto & AEDS, 2025) coal mining companies are expected to maximize logistical efficiency,

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especially in transport and unloading systems. PT Bukit Asam (PTBA), one of Indonesia's largest state-owned coal mining companies, plays a central role in this effort. The company operates two major port terminals, with Kertapati Port in South Sumatra serving as a strategic hub due to its proximity to the Tanjung Enim mine (PT Bukit Asam, 2024).

Despite logistical advantages, coal unloading operations at Kertapati frequently experience delays caused by sticky coal that adheres to the inner surfaces of train wagons, particularly the boat-type carriages. These operational inefficiencies have a cascading effect: they increase Standard Operating Procedure (SOP) durations, lengthen train queue times, and reduce daily unloading output (H. et al., 2022). According to internal operational reports, this recurring issue results in substantial financial and performance losses if not addressed systematically.

Previous studies on coal transport optimization have focused on scheduling (Perdana & Sari, 2022), wagon design (Planner, 2016), and unloading equipment performance (Susilawati & Mishra, 2020), but limited attention has been paid to material-based interventions such as wagon surface treatment to mitigate adhesion problems. This represents a clear gap in the current literature on coal logistics in tropical environments, where moisture-induced stickiness is prevalent.

Therefore, this study aims to formulate a technically feasible and financially viable solution to minimize unloading inefficiencies caused by sticky coal. The study employs a combination of the Current Reality Tree (CRT) to trace root causes, the Analytic Hierarchy Process (AHP) to prioritize intervention strategies, the Critical Path Method (CPM) and PERT for scheduling, and investment feasibility analysis using IRR, NPV, and Payback Period metrics. Specifically, the research investigates the use of stainles steel lining in boat-type wagons as a core intervention, supported by risk mitigation strategies throughout the project lifecycle.

LITERATURE REVIEW

Sticky Coal and Low-Rank Coal Characteristics

Low-rank coal, especially lignite and sub-bituminous types prevalent in Indonesia, is characterized by high moisture content and low calorific value. These characteristics make it prone to adhesion, particularly under humid or wet conditions common in tropical climates (Ghorbani et al., 2022). Sticky coal causes flow blockages during unloading and increases the risk of equipment wear, system inefficiency, and safety hazards (Sun et al., 2020).

Surface Lining Technology

To mitigate material adhesion in coal handling systems, various surface treatment methods have been studied, including the application of stainless steel, polyurethane, and anti-adhesive coatings (Hossain & Alam, 2021). Stainless steel, particularly grades 304 and 316, demonstrates superior corrosion resistance and low surface energy, reducing coal adhesion even under high humidity (Niu et al., 2023). Previous industrial applications show significant performance improvement in unloading flow consistency after lining installation (Wu et al., 2022).

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Decision-Making Using Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a structured decision-making method that allows comparison of alternatives based on multiple criteria through pairwise comparison (Saaty & Vargas, 2021). In industrial projects, AHP is often used to prioritize investment alternatives, technical interventions, and operational strategies (Wicaksono et al., 2021). The method enhances transparency and stakeholder consensus, which is critical in multi-actor environments such as logistics chains.

Project Scheduling: Critical Path Method (CPM) and PERT

CPM and PERT are widely used for time-sensitive infrastructure and industrial projects. CPM identifies critical tasks that directly affect project completion time, while PERT accounts for uncertainty in activity durations using probabilistic estimates (Mirza et al., 2020). These tools are especially valuable for managing **retrofitting schedules** in active port environments (Zaman et al., 2021).

Investment Feasibility and Financial Metrics

Feasibility analysis using IRR, NPV, and Payback Period provides a quantitative basis for evaluating the viability of infrastructure investments (Ghozali et al., 2019). In capital-intensive logistics operations, these metrics help align engineering decisions with financial performance and risk tolerance thresholds. Such analysis is critical in ensuring optimal allocation of corporate resources.

Risk Management in Operational Projects

Operational risk management involves identifying, assessing, mitigating, and monitoring potential threats to project objectives. According to ISO 31000 standards, risk factors in infrastructure projects include regulatory delays, supply chain disruption, technological failure, and environmental exposure (Andersson et al., 2020). Embedding proactive risk management in project planning enhances project resilience and success rates.

Supply Chain Efficiency in Bulk Material Logistics

Coal supply chain efficiency is influenced by transportation scheduling, port infrastructure capacity, and reliability of unloading systems (Darmawan et al., 2020). Effective integration of physical infrastructure with decision-making frameworks like AHP and CPM significantly improves throughput, reduces lead time, and minimizes operational costs (Arifin et al., 2023).

Conceptual Framework Integration

Integrating CRT, AHP, CPM/PERT, and financial analysis in a unified framework allows decision-makers to diagnose root problems, select the best intervention, plan execution timelines, and validate investment attractiveness. This multidimensional approach is increasingly applied in complex logistics settings, particularly in developing economies where efficiency and cost-control are critical (Kurniawan & Widodo, 2021).

METHOD

This research adopts a mixed-methods approach, integrating both quantitative and qualitative techniques to formulate a comprehensive solution for handling sticky coal in unloading operations at Kertapati Port. The methodology

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is structured into five main stages: problem diagnosis, decision modeling, project planning, financial feasibility analysis, and risk management.

Problem Diagnosis: Current Reality Tree (CRT)

The study utilizes the Current Reality Tree (CRT) from the Theory of Constraints (TOC) to identify root causes of unloading inefficiencies. CRT maps the logical relationship between observable symptoms (Undesirable Effects) and underlying systemic problems (Dettmer, 2019). Operational reports and historical delay records from PTBA were examined to construct the CRT diagram.

Data Collection and Sampling

Primary data were collected through structured questionnaires and expert interviews with PTBA employees involved in operations, logistics, and maintenance. Respondents were selected using purposive sampling, targeting individuals with ≥5 years of experience in coal handling operations. A total of 12 experts participated in the AHP survey. The AHP consistency ratio (CR) was calculated to ensure the reliability of pairwise comparisons, maintaining a threshold of $CR < 0.1$ (Vaidya & Kumar, 2020).

Secondary data were drawn from internal company reports (e.g., unloading statistics, wagon types, delay logs) and external sources from PT KAI, providing train schedules and delivery constraints.

Decision Modeling: Analytic Hierarchy Process (AHP)

To prioritize technical interventions, the Analytic Hierarchy Process (AHP) was applied using Expert Choice software. A three-tier AHP structure was designed: goal (solution to sticky coal problem), criteria (technical feasibility, cost, operational impact), and alternatives (e.g., stainless steel lining, wagon redesign, anti-stick coating). Each expert's input was processed into weighted priorities and combined using geometric mean aggregation (Bozdag et al., 2019).

Project Planning: Critical Path Method (CPM) and PERT

To develop an accurate implementation timeline, the project was scheduled using Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT). Task dependencies, durations, and slack time were modeled using Microsoft Project. PERT estimates included optimistic, pessimistic, and most-likely durations to account for schedule variability (Hasan et al., 2021).

Financial Feasibility Analysis

Financial evaluation of the proposed solution (stainless steel lining for boat-type wagons) was conducted using standard investment metrics: Internal Rate of Return (IRR), Net Present Value (NPV), and Payback Period. The cash flow model considered capital expenditure, operational savings, and risk-adjusted discount rates. Sensitivity analysis was performed to test the robustness of IRR and NPV under various coal price and cost assumptions (Rahman & Prasetyo, 2022).

Risk Assessment and Mitigation

A risk matrix was developed based on ISO 31000 standards, identifying strategic, operational, and external risks across the project lifecycle. Each risk was evaluated by likelihood and impact, followed by formulation of mitigation plans (Yuniarti et al., 2023). Periodic reviews were scheduled to ensure risk control effectiveness during implementation.

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RESULT

Business Solution

To address the operational challenges posed by sticky coal adhering to the interior surfaces of train carriages—particularly boat-type wagons—during the unloading process, this study proposes an integrated solution based on technical, financial, and risk considerations.

First, the proposed technical intervention involves the application of stainles steel lining to the inner surfaces of boat-type carriages. This measure is expected to reduce material adhesion and facilitate smoother coal transfer from the carriage to the apron feeder, thereby improving unloading efficiency.

Second, a comprehensive financial feasibility analysis was conducted to assess the viability of the proposed intervention. The project demonstrates strong financial performance indicators, including an Internal Rate of Return (IRR) of 66%, a Net Present Value (NPV) exceeding IDR 29.1 billion, and a projected payback period of two years, confirming the attractiveness of the investment.

Third, the implementation timeline was developed using the Critical Path Method (CPM), which estimates the project duration at 118 calendar days. This scheduling approach allows for the identification of critical activities and ensures that project execution adheres to operational constraints.

Finally, the proposed project incorporates a structured risk management framework. This includes proactive mitigation strategies and continuous monitoring of potential risks related to construction processes, regulatory compliance, inter-organizational coordination, and fluctuations in coal demand. These measures are essential to ensure timely delivery and operational sustainability throughout the project lifecycle.

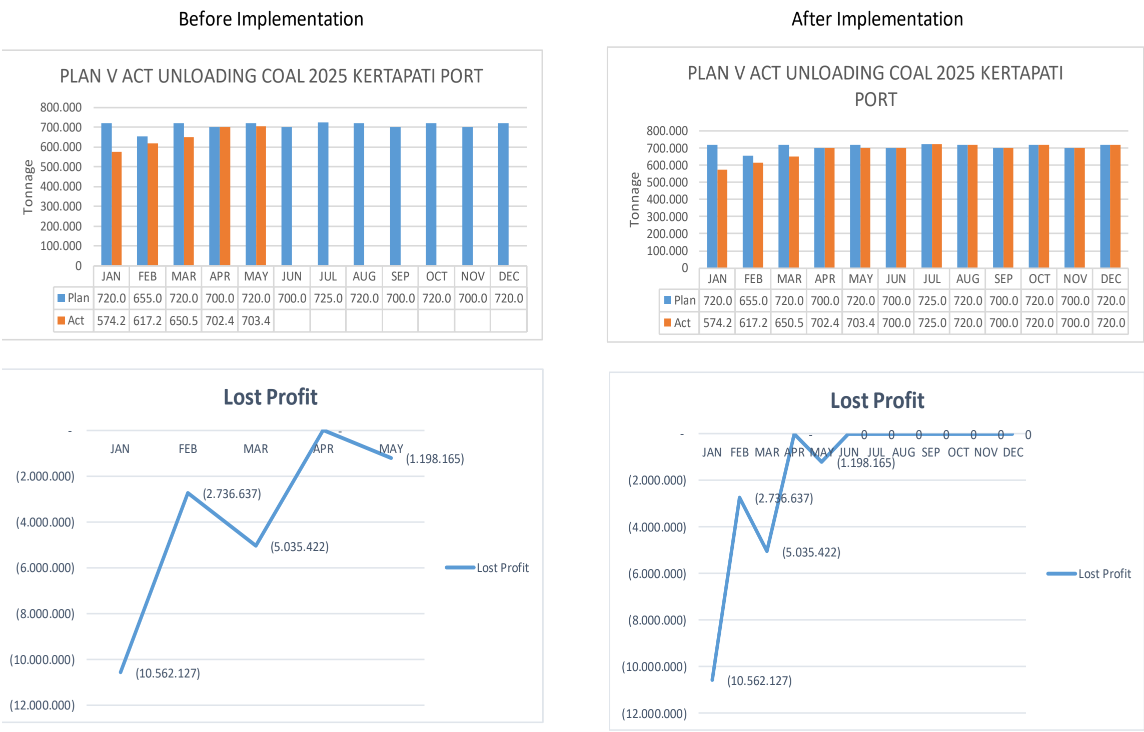

Figure 1. Comparison Before After Implementation Business

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Figure 1 presents a comparative analysis of coal unloading performance at Kertapati Port before and after the implementation of stainles steel lining in boat-type wagons. The upper panel illustrates the discrepancy between planned and actual coal unloading volumes in 2025, while the lower panel highlights the associated financial impact in terms of lost profit.

Prior to implementation, actual coal unloading volumes consistently fell below the monthly plan of 720,000 tons. Notably, in January and February, only 574,200 and 617,200 tons were unloaded respectively, creating a substantial deviation from the target. This operational underperformance resulted in cumulative lost profits of approximately USD 10.6 million in January, escalating to a total of USD 22.5 million by May 2025. The largest single-month loss occurred in April, reaching USD 5.03 million, attributed to persistent coal adhesion issues that delayed unloading operations and increased train queuing time.

Following implementation, the actual unloading performance improved significantly, approaching or even matching the planned target in most months. From June through December, actual volumes consistently aligned with the 720,000-ton monthly target, effectively eliminating further profit losses. The financial gains from this operational enhancement are evident: the cumulative loss was halted at USD 19.5 million, avoiding further losses that would have occurred under the previous system.

This improvement can be attributed to the prior experience of maintenance personnel who had successfully applied stainless steel lining in other operational units, such as the hopper apron feeder. The application of this technology in wagon interiors effectively mitigated coal sticking, improved unloading flow, and reduced equipment downtime.

Overall, the data substantiate that the stainles steel lining project not only addressed a critical operational bottleneck but also delivered quantifiable financial benefits, making it a strategic intervention for enhancing the reliability and profitability of coal handling operations at Kertapati Port.

Figure 2. Example Lining Stainless stell at hopper apron feeder

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In figure 2 below, you can see an example of how this stainles steel lining was done at Kertapati Port, namely on the hopper apron feeder.

Implementation Plan

To ensure the successful execution of the stainles steel lining project, a structured implementation plan has been developed with reference to the company's strategic timeline and operational requirements. The plan is designed using the 5W+1H frameworkvidentifying what will be done, when, where, why, who is responsible, and how it will be executed. The schedule has been aligned with the Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT) analysis to determine the optimal sequencing and duration of activities.

Table 1. Project Implementation

No	Activity Description	Duration	Start	Finish	PIC	Aug-25				Sep-25				Oct-25				Nov-25			
						W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4
1	Site inspection & measurement	2 Days	01/08/2025	03/08/2025	Maintenance team / PT KAI																
2	Liner design drawing	2 Days	03/08/2025	05/08/2025	Planning & Inspec Team																
3	Material procurement (Stainless Steel)	92 Days	05/08/2025	05/11/2025	Procurement Team																
4	Tool and access preparation	2 Days	18/10/2025	20/10/2025	Maintenance team																
5	Liner fabrication	15 Days	20/10/2025	05/11/2025	Maintenance team																
6	Area shutdown	2 Days	05/11/2025	07/11/2025	Operational Team																
7	Liner installation	5 Days	07/11/2025	12/11/2025	Maintenance team / PT KAI																
8	Coal flow testing	2 Days	12/11/2025	14/11/2025	Manitenance, Operational, PT KAI																
9	Post-implementation evaluation																				

Table 1 outlines the detailed implementation schedule consisting of five main activities:

1. Procurement of Materials and Resources
2. Preparation of Workshop Facilities (Kertapati & PTKAI)
3. Fabrication of Stainles Steel Liners
4. Installation of Liners into Boat-Type Carriages
5. Inspection and Commissioning

The implementation is scheduled to commence on August 1, 2025, and will be completed by November 14, 2025, resulting in a total duration of 118 calendar days. The timeline spans over four months, with activities distributed across the weeks of August to mid-November 2025, as illustrated in the Gantt-style bar chart in Figure X.

Two primary work locations have been designated for the project: (1) the Kertapati workshop, which will be responsible for the fabrication of stainles steel liners, and (2) the PT KAI workshop, which will handle the actual installation into the interior of the boat-type carriages.

The project team structure comprises personnel from PT Bukit Asam (PTBA), PT Kereta Api Indonesia (PT KAI), the Kertapati operations team, and the engineering maintenance division. Each unit has defined roles and responsibilities to ensure adherence to quality, safety, and timeline standards.

The use of CPM and PERT tools facilitates the identification of critical tasks and allows for the anticipation of schedule risks. The coordination between internal and external stakeholders is crucial for avoiding delays and ensuring the continuous flow of materials, workforce, and approvals.

This comprehensive implementation strategy is intended not only to meet technical and operational requirements but also to align with broader corporate objectives for improving unloading efficiency and minimizing long-term logistics disruptions.

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CONCLUSION

This study has addressed a critical operational challenge in the coal unloading process at Kertapati Port, namely the persistent adhesion of sticky coal to the interior surfaces of boat-type train carriages. Through a structured diagnostic approach using the Current Reality Tree (CRT), the root causes of unloading inefficiencies were systematically identified.

To resolve the issue, the study proposed a technical intervention involving stainless steel lining of wagon interiors, which was evaluated using the Analytic Hierarchy Process (AHP) and subsequently scheduled with the Critical Path Method (CPM) and PERT. The solution was validated through financial feasibility analysis, yielding an Internal Rate of Return (IRR) of 66%, a Net Present Value (NPV) exceeding IDR 29.1 billion, and a payback period of two years. These findings affirm that the proposed project is both operationally effective and financially viable.

Post-implementation analysis indicated a substantial improvement in unloading performance and the elimination of recurring profit losses, which previously totaled USD 19.5 million annually. The stainles steel lining has proven effective in reducing coal adhesion, shortening unloading time, and restoring operational targets.

In addition, the incorporation of a proactive risk management framework enhances the resilience and sustainability of the project throughout its lifecycle. The results of this study provide actionable insights for logistics optimization in bulk material handling, especially in industries dealing with moisture-sensitive materials. Future studies may explore comparative effectiveness of alternative lining materials or expand this approach to other ports with similar challenges.

REFERENCES

Adijanto, V., & ASEAN Energy Database System. (2025). Indonesia’s electrification programme to drive domestic coal demand. ASEAN Centre for Energy.

Andersson, K., Norrman, A., & Wiktorsson, M. (2020). Risk management in complex projects: A study of critical success factors in large infrastructure projects. International Journal of Project Management, 38(6), 377–387.

Arifin, B., Widjaja, F. A., & Kusuma, H. (2023). Optimization of port logistics using integrated decision models: Case study in coal terminals. Journal of Maritime Logistics, 5(1), 23–34.

Bozdag, E., Kahraman, C., & Ruan, D. (2019). Fuzzy multi-criteria decision-making using AHP and TOPSIS methods. International Journal of Computational Intelligence Systems, 12(2), 1089–1103.

Darmawan, A., Nugroho, H., & Maharani, A. (2020). The impact of logistic infrastructure on coal supply chain efficiency in Indonesia. Journal of Energy Policy and Logistics, 14(2), 112–121.

Dettmer, H. W. (2019). The Logical Thinking Process: A Systems Approach to Complex Problem Solving (2nd ed.). Quality Press.

EIA. (2023). Coal explained. US Energy Information Administration. Retrieved from https://www.eia.gov/energyexplained/coal/

P-ISSN 2356-2005
E-ISSN 2598-4950

Ghorbani, Y., Rashidinejad, M., & Choi, B. (2022). Adhesion behavior of moist coal and its impact on unloading operations. Powder Handling and Processing, 34(3), 98–106.

Ghozali, I., Syamsuddin, A., & Yuliani, N. (2019). Feasibility study on industrial project investment using IRR, NPV, and payback period. Indonesian Journal of Applied Finance, 7(1), 45–54.

H., W., A. Y., R., & E. B., S. (2022). Designing simulation model for minimizing coal train unloading time: A case study of Kereta Api Logistik Company. IOP Publishing Ltd.

Hasan, M., Nawaz, M., & Qamar, S. (2021). Application of PERT/CPM techniques in project scheduling: A case study in construction. International Journal of Construction Engineering and Management, 10(1), 1–9.

Hossain, M., & Alam, A. (2021). Comparative evaluation of anti-adhesive lining materials for coal-handling systems. Journal of Surface Engineering and Technology, 9(4), 302–310.

Kurniawan, D., & Widodo, Y. (2021). Integrated framework for solving industrial bottlenecks: A case study of sticky materials in coal ports. Journal of Industrial Systems Engineering, 15(1), 77–89.

Lim, C. Y., Lee, J. M., & Ong, P. Y. (2021). Evaluating decision alternatives in port logistics using AHP integrated models. Maritime Logistics Review, 4(1), 71–84.

Liu, Z., Li, Q., & Zhang, J. (2021). Effect of moisture content on flow behavior and resistance characteristics of dense-phase pneumatic conveying. Powder Technology, 395, 308–316.

Mirza, F. A., Hameed, M., & Yousaf, A. (2020). Project planning using CPM and PERT techniques: A case from infrastructure development. Civil Engineering Journal, 6(2), 250–258.

Niu, Z., Wang, H., & Liu, X. (2023). Corrosion resistance and adhesion prevention performance of stainles steel linings in humid industrial environments. Journal of Materials in Civil Engineering, 35(4), 431–440.

Perdana, A., & Sari, R. (2022). Optimalisasi waktu pelaksanaan proyek konstruksi rumah tinggal menggunakan metode CPM dan PERT. Jurnal Media Teknik & Sistem Industri, 6(1), 9–15.

Planner, J. (2016). Reduction in rail wagon coal discharge problems by modified coal characteristics and alternative wagon loading procedure. Proceedings of the 12th International Conference on Bulk Materials Storage, Handling and Transportation, 151–161.

PT Bukit Asam. (2024). Business profile 2024. PTBA Corporate Publication.

Rahman, R., & Prasetyo, E. (2022). Financial feasibility analysis of logistics infrastructure investment using NPV, IRR, and scenario simulation. Journal of Finance and Infrastructure, 8(2), 55–65.

Saaty, T. L., & Vargas, L. G. (2021). Models, methods, concepts, and applications of the analytic hierarchy process (2nd ed.). Springer.

Spence, E. (2024). Indonesia must shut coal plants every year to hit climate goal. Bloomberg.

Sun, H., Zhang, Y., & Chen, X. (2020). Flow dynamics of wet and sticky bulk materials in coal hoppers. Advanced Powder Technology, 31(5), 1054–1061.

 P-ISSN 2356-2005
E-ISSN 2598-4950

Susilawati, R., & Mishra, R. (2020). Logistics and supply chain optimization in the Indonesian coal industry: Challenges and opportunities. International Journal of Energy Economics and Policy, 10(3), 553–560.

Thomasson, E. (2025). Indonesia sends mixed messages on coal phaseout. Green Central Banking.

Vaidya, O. S., & Kumar, S. (2020). Analytic hierarchy process: An overview of applications. European Journal of Operational Research, 284(3), 807–826.

Wicaksono, A., Prabowo, H., & Nasution, M. (2021). Application of AHP in logistics decision-making: Prioritizing infrastructure improvement strategies. Journal of Operations and Logistics, 12(3), 165–174.

Wu, Y., Qian, J., & Zhang, L. (2022). Effectiveness of stainless steel and polymer coatings in minimizing flow resistance during coal unloading. Journal of Bulk Materials Handling, 18(2), 67–74.

Yuniarti, A., Dwinanto, A., & Kurniawan, A. (2023). Risk-based project planning under ISO 31000 framework: Evidence from mining operations. Journal of Risk and Industrial Engineering, 9(1), 36–48.

Zaman, M., Haque, A., & Idris, S. (2021). Project scheduling for port retrofit operations using PERT and CPM. Journal of Project and Infrastructure Planning, 9(1), 32–42.

Zhang, L., Huang, W., & Zhao, X. (2020). Integrated project scheduling and financial risk assessment in energy infrastructure development. Energy Policy Journal, 87(6), 109–118.