Technema: Journal of Intelligent Engineering and Computing
Vol 1 No 2 June 2026, Hal 353-370
ISSN: 3163-6020 (Print) ISSN: 3163-5997 (Electronic)
Open Access: https://sovereignresearch.org/technema

Occupational Safety Analysis of Coal Hauling Activities Using the Job Safety Analysis (JSA) Method at PT Lematang Coal Lestari

Wanda Elisa[1*], Aris Susilo[2], Rodiyah Nursani[3]
[1-3] Universitas Prabumulih, Indonesia
email: wandaelisa208@gmail.com[1]

Article Info :
Received:
13-06-2026
Revised:
20-06-2026
Accepted:
29-06-2026

Abstract

Coal hauling is a critical stage of mining operations with potential accident risks arising from heavy-equipment interaction, haul-road conditions, human factors, and the work environment. This study aims to analyze occupational safety in coal hauling activities using the Job Safety Analysis (JSA) method at PT Lematang Coal Lestari (LCL). An empirical descriptive-qualitative research design was employed, with data collected through field observations, interviews with operators, supervisors, and SHE personnel, and company documentation. The analysis involved mapping work stages, identifying potential hazards, assessing risk levels based on likelihood and severity, evaluating existing controls, and formulating additional control measures. The findings indicate that hazards were identified in the pre-start inspection, loading, hauling, dumping, and return stages, including vehicle collisions, vehicle rollover, slippery roads, dust, blind spots, excessive speed, and non-compliance with safety procedures. Existing controls include PPE use, daily inspections, toolbox meetings, haul-road maintenance, speed regulation, radio communication, safety signage, and field supervision. The findings demonstrate that JSA provides a structured framework for linking task-specific hazards with operational control measures. Consistent implementation of these controls and periodic JSA updates are required to maintain operational safety and strengthen risk management in coal hauling activities. Continuous monitoring of road conditions and worker compliance is also necessary to address changing operational risks.

Keywords: *Coal Hauling, Hazard Identification, Job Safety Analysis (JSA), Occupational Safety, Risk Control.*

INTRODUCTION

Mining activities constitute a complex chain of operations encompassing general investigation, exploration, feasibility studies, extraction, processing and refining, transportation, and post-mining activities, in which the intensive interaction of workers, mobile equipment, materials, and variable environmental conditions creates a persistent occupational safety challenge that must be addressed as an integral component of sustainable mining operations. The global development of mining toward increasingly intensive mechanization and productivity-oriented operations has strengthened the importance of occupational safety management because higher equipment utilization and continuous material movement can simultaneously increase workers' exposure to operational hazards. In Indonesia, the regulatory framework explicitly requires mining operations to incorporate occupational safety, health, and environmental protection into the implementation of good mining practices, as stipulated in Law No. 3 of 2020 on Mineral and Coal Mining and reinforced through the technical guidelines issued by the Ministry of Energy and Mineral Resources (Republik Indonesia, 2020; Kementerian Energi dan Sumber Daya Mineral Republik Indonesia, 2018). Occupational safety is also positioned within the broader national occupational health and safety management framework, which requires organizations to establish systematic mechanisms for controlling workplace hazards rather than relying solely on individual worker awareness or reactive accident prevention (Republik Indonesia, 1970; Republik Indonesia, 2003; Republik Indonesia, 2012). The operational significance of this framework becomes particularly evident in coal mining, where hauling activities involve continuous movement of heavy vehicles between mining fronts, stockpiles, and processing or loading facilities, creating repeated exposure to traffic interactions, road conditions, equipment movement, visibility limitations, and environmental disturbances. Previous mining safety research has demonstrated that occupational risks may emerge from interconnected combinations of human behavior, equipment conditions, work procedures, and workplace environments, indicating that safety performance cannot be adequately understood through a single hazard dimension (Akbar et al., 2024; Edmon & Fadhilah, 2021). This condition places coal hauling among the operational activities that require detailed task-level safety analysis because seemingly routine transportation processes may contain multiple sequential hazards whose consequences can escalate rapidly when preventive controls are insufficient.

One of the activities requiring particular attention is *hauling*, namely the transportation of coal from the mining *front* toward the *stockpile* or other designated facilities, because the activity combines heavy mobile equipment, repetitive vehicle movement, haul-road characteristics, extended operating periods, and changing weather and terrain conditions. Research specifically examining coal hauling and coal loading has identified potential hazards associated with operational processes and emphasized the need for appropriate controls across the sequence of activities rather than concentrating only on accident outcomes (Sainyakit & Djunaidi, 2023). Evidence from mining operations in South Sumatra likewise indicates that occupational safety risks remain distributed across different mining activities, demonstrating that the existence of an established safety system does not automatically eliminate operational exposure to hazardous conditions (Akbar et al., 2024). Studies conducted in other mining contexts further indicate that hazards associated with mobile equipment, work environments, and task execution require structured identification because risk can change according to the specific work stage and operational setting (Suparno et al., 2020; Putri et al., 2023). The repetitive nature of hauling can intensify exposure because workers and operators encounter similar operational conditions over extended periods, potentially increasing the probability of unsafe actions or unsafe conditions when procedures, supervision, communication, and hazard awareness are inconsistently implemented. From a safety-management perspective, this means that accident prevention requires an analytical approach capable of decomposing routine work into identifiable task sequences so that hazards can be connected directly to their causes and potential consequences. Such an approach is particularly relevant for PT Lematang Coal Lestari (LCL) in South Sumatra, where open-pit coal mining operations involve continuous hauling activities and therefore require systematic evaluation of safety risks at the level of actual work execution.

Previous studies have established Job Safety Analysis (JSA) as a practical task-oriented method for identifying hazards by breaking a job into sequential steps, assessing the risks associated with each step, and determining appropriate preventive or control measures before work is performed. Research applying JSA in occupational settings has shown that the method can facilitate the identification of accident and occupational-disease risks while simultaneously strengthening workers' awareness of hazards embedded within routine work procedures (Ishak et al., 2020; Ramadhana & Abdullah, 2020). Applications in mining have also demonstrated that JSA can be used to identify potential hazards in both underground and surface-related mining activities, supporting the development of more specific safety controls than generalized occupational safety policies (Putri et al., 2023; Kamaluddin et al., 2025). Comparable evidence from industrial, construction, logistics, offshore, and manufacturing environments indicates that JSA remains adaptable to different work characteristics, although its effectiveness depends on the degree to which task steps, hazard sources, worker practices, and control measures are represented accurately (Ikhsan & Hidayat, 2023; Maghfira et al., 2023; Muffi & Abdullah, 2024). The literature also suggests that JSA can be strengthened through integration with complementary risk-assessment approaches, particularly when organizations require not only hazard identification but also structured prioritization of risks and specification of control strategies (Djunaidi & Umami, 2024; Sa'adati & Widharto, 2023). This methodological development indicates a shift from viewing JSA merely as a procedural checklist toward using it as a decision-support instrument for understanding how hazards emerge within specific work sequences. Nevertheless, the diversity of industrial applications also reveals that findings obtained from one operational context cannot automatically be generalized to coal hauling because the configuration of mobile equipment, haul-road conditions, work organization, and environmental exposure differs substantially across sectors.

A critical limitation in the existing literature is that although numerous studies have applied JSA to mining and other high-risk industries, relatively fewer studies have focused specifically on the task-level safety characteristics of coal hauling within an operational context in which heavy vehicle movement is performed continuously and under changing field conditions. Existing research has predominantly examined broader mining safety conditions, underground mining, nickel mining, drilling, loading and unloading, or other specialized tasks, leaving an empirical gap concerning how individual coal-hauling work stages generate distinct hazards and how these hazards should be controlled within an integrated operational sequence (Sofia & Basuki, 2025; Sulistyo P. et al., 2023). Research on occupational safety in coal-mining operations has identified important risks, yet evaluations frequently emphasize general safety performance or particular mining areas rather than constructing a detailed task-based representation of hauling activities (Edmon & Fadhilah, 2021). The literature also demonstrates methodological variation, as JSA has been combined with HIRARC, HAZOPS, JHA, or other risk-assessment frameworks, which improves analytical breadth but can make it difficult to isolate the specific contribution of JSA as a task-decomposition method for coal-hauling operations (Lestari et al., 2024; Sofia & Basuki, 2025). Recent work has begun integrating JSA with quantitative or structured risk assessment to improve occupational safety decision-making, suggesting that task-level analysis remains an active area of methodological development rather than a fully resolved problem (Rinawiyanti et al., 2026). The unresolved issue is therefore not simply whether hazards exist, but how systematically they can be mapped across the actual sequence of hauling activities so that each hazard can be associated with a corresponding preventive measure that is operationally relevant. Addressing this gap is scientifically important because a context-specific understanding of task hazards can connect established safety-management principles with empirical evidence from real mining operations, while practically it can support more targeted interventions than generic safety recommendations.

PT Lematang Coal Lestari provides a relevant empirical setting for addressing this problem because its open-pit coal-mining activities involve routine hauling operations in which operators, transportation equipment, haul roads, coal material, and environmental conditions interact continuously. Although the company has implemented occupational health and safety practices and operational procedures, the existence of formal safety arrangements does not remove the need for periodic task-level examination because hazards can arise from deviations between prescribed procedures and actual field practices. Previous research on coal-mining and mining operations indicates that effective safety management requires continuous identification and evaluation of hazards arising from human, equipment, procedural, and environmental factors rather than assuming that compliance with established systems is sufficient to prevent accidents (Akbar et al., 2024; Amirudin et al., 2025). The recent emphasis on safety-attitude reinforcement also demonstrates that accident prevention extends beyond technical controls and requires attention to how safety practices are embedded within workers' operational behavior and organizational safety culture (Amirudin et al., 2025). Within this context, JSA offers a suitable analytical position because it enables the hauling process to be examined sequentially, allowing potential hazards, consequences, and preventive controls to be associated with specific work steps rather than treated as an undifferentiated list of risks. The analytical value of this approach is particularly relevant where routine hauling operations may involve recurring exposure that is difficult to recognize through general safety observation alone. A focused JSA-based assessment can therefore contribute empirical evidence on the structure of hazards within coal hauling while providing an operational basis for strengthening safety procedures and risk controls at PT LCL.

This study aims to analyze occupational safety in coal-hauling activities at PT Lematang Coal Lestari using the Job Safety Analysis method by systematically decomposing hauling operations into work stages, identifying potential hazards associated with each stage, evaluating the resulting occupational risks, and formulating appropriate control measures. The research is positioned within the task-based occupational safety literature by treating coal hauling not as a single operational activity but as a sequence of interconnected tasks in which different combinations of human, equipment, material, procedural, and environmental factors can generate distinct risks. Its theoretical contribution lies in strengthening the application of task-oriented safety analysis to coal-mining transportation activities and demonstrating how JSA can translate general occupational safety principles into a context-specific representation of operational hazards. Its methodological contribution lies in providing a structured framework for connecting individual hauling steps with potential hazards, risk consequences, and corresponding control actions, thereby supporting a more transparent assessment of where preventive measures should be prioritized. The study also seeks to bridge the gap between formal occupational safety requirements and empirical conditions encountered during actual coal-hauling operations. The resulting analysis is expected to provide evidence that can inform more targeted safety procedures, worker awareness, supervision, and operational controls at the company level. Ultimately, the study contributes to the development of a more systematic and context-sensitive approach to occupational safety management in coal-hauling operations within the broader field of intelligent engineering and computing.

RESEARCH METHODS

This study employed an empirical descriptive-qualitative field research design to analyze occupational safety risks associated with coal hauling activities at PT Lematang Coal Lestari (LCL), located in Gunung Raja Village, Rambang Dangku District, Muara Enim Regency, South Sumatra, approximately 130 km northwest of Palembang and 50 km west of Prabumulih. The research was conducted over two months in 2026 and focused on the operational sequence of transporting coal from the mining front to the stockpile. The empirical architecture of the study consisted of four interconnected components: the hauling work process as the analytical object, workers and operational supervisors as information sources, mining equipment and haul-road conditions as physical system components, and occupational safety procedures as the control framework. Primary data comprised the hauling route, work stages, mechanical equipment, haul-road conditions, potential hazards, personal protective equipment (PPE) use, unsafe actions, and unsafe conditions, while secondary data included the mining permit map, hauling SOP, occupational safety program, PPE inventory, working hours, records of near misses, dangerous incidents and property damage, and rainfall data. Field observations were conducted directly throughout the hauling process, while semi-structured interviews were performed with hauling operators, field supervisors, and SHE/OHS personnel to obtain operational information that could not be captured through observation alone. The implementation stage involved mapping the hauling sequence, decomposing the activity into identifiable work steps, documenting hazards and existing controls, and organizing the evidence into a JSA worksheet, consistent with the task-oriented structure of JSA-based occupational safety analysis (Ishak et al., 2020). The resulting empirical framework was designed to maintain traceability between observed work activities, identified hazards, risk characteristics, and proposed control measures, allowing the analysis to reflect actual field conditions rather than relying exclusively on predetermined theoretical assumptions.

The testing and analytical procedure was conducted by applying JSA to each identified stage of the coal hauling process, beginning with task decomposition, followed by hazard identification, risk assessment, evaluation of existing controls, and formulation of additional control measures. For each work step, potential hazards were identified from direct observations, interview findings, operational documents, and observed unsafe actions or unsafe conditions, after which the associated consequences and exposed workers were documented. Risk assessment considered two principal dimensions, namely likelihood of occurrence and severity of consequence, so that hazards could be categorized according to their relative level of occupational risk. The assessment results were compiled into a structured JSA matrix and examined descriptively to determine recurring hazard patterns, critical work stages, and discrepancies between prescribed procedures and observed practices, following the task-based application of JSA in mining environments (Putri et al., 2023). Validation was performed through triangulation of observation, interview, and documentary evidence, with information obtained from operators, supervisors, and SHE/OHS personnel compared against applicable company SOPs and occupational safety requirements. The analytical findings were further compared with established occupational safety provisions and previous JSA-based studies to assess the consistency of identified hazards and proposed controls, an approach that is relevant because JSA effectiveness depends on accurate representation of task conditions and appropriate linkage between hazards and control actions (Djunaidi & Umami, 2024; Sa'adati & Widharto, 2023). Performance was evaluated using the completeness of hazard identification across hauling work stages, the consistency of risk classification based on likelihood and severity, the adequacy of existing control measures, and the applicability of recommended controls to actual hauling operations, while the final output consisted of a validated JSA-based risk profile and prioritized recommendations for improving occupational safety at PT LCL.

RESULTS AND DISCUSSION

Characteristics of Coal Hauling Activities and Implementation of JSA at PT Lematang Coal Lestari

Coal hauling at PT Lematang Coal Lestari (LCL) represents a continuous operational sequence involving loading, material transportation, dumping, returning, and operational delays. The activity requires interaction among excavators, dump trucks, articulated dump trucks (ADT), road-maintenance equipment, operators, supervisors, and the physical hauling environment. Field observations showed that these interactions create safety exposure because heavy equipment operates repeatedly within a dynamic mining area where road geometry and surface conditions can change with mining development and weather. The empirical characteristics of the hauling system therefore provide an important basis for identifying hazards at the task level rather than evaluating occupational safety only from general site conditions. This approach is consistent with the JSA framework, which decomposes work into identifiable steps and associates each step with potential hazards and appropriate controls (Ishak et al., 2020). At PT LCL, the implementation of JSA was consequently oriented toward the actual sequence of hauling operations and the conditions encountered by operators during field activities.

The hauling route at the Gunung Raja site uses a two-way traffic configuration within a single road body, with loaded units traveling toward the stockpile and empty units returning toward the mining front. The observed configuration is summarized in Table 1, which shows a total road width of approximately 25 m, with each traffic lane measuring approximately 10–12 m.

Table 1. Hauling Route from the Mining Front to the Stockpile

No.	Parameter	Description
1	Route type	1 road body
2	Traffic direction	2 directions (2 lanes)
3	Total road width	±25 meters
4	Road characteristics	Non-permanent (dynamic), following the direction/distribution and contour of coal
5	Left lane	Loaded DT and ADT traveling toward stockpile
6	Right lane	Empty DT and ADT returning to the front
7	Left lane width	±10–12 meters
8	Right lane width	±10–12 meters
9	Remaining road width	Road shoulder and drainage

Source: Field data processing, 2026

The configuration indicates that traffic separation is achieved primarily through lane allocation rather than through physically separated carriageways. Such an arrangement requires consistent operator awareness because loaded and empty units travel in opposite directions on the same road body. The dynamic nature of the route also means that safety conditions cannot be considered permanently fixed, particularly when the mining front and coal distribution change. From a JSA perspective, these characteristics are relevant because road configuration, traffic direction, and vehicle interaction constitute task conditions that may alter the likelihood of collision or loss of control. The road width and lane arrangement are also consistent with the principle that haul roads should provide sufficient operating space for the dimensions and maneuvering requirements of the largest equipment used (Kementerian ESDM, 2018). The empirical configuration therefore indicates that traffic management and continuous road inspection are integral components of the safety controls applied to hauling activities.

The hauling cycle at PT LCL consists of loading, hauling, dumping, return, and delay, with each stage generating a distinct operational exposure. Table 2 presents the observed operational characteristics of these stages, including loading duration, hauling distance, vehicle speed, dumping duration, return time, and the causes of delay.

Table 2. Stages of Coal Hauling from the Mining Front to the Stockpile

No.	Stage	Activity	Operational Data
1	Loading	Excavator loads coal material into DT and ADT	Loading time 4–5 minutes; bucket passes 5–7 times; excavator bucket capacity ±5–6.5 m^3; Volvo A40G ADT capacity ±40

			tons (±25 m³); Volvo A40G passes 4–5 times
2	Hauling	Dump truck transports material from the mining front to the stockpile	Hauling distance 4–5 km; loaded speed ±40 km/h; travel time ±15 minutes 55 seconds
3	Dumping	Dump truck unloads material at the stockpile	Dumping time ±1 minute
4	Return	Dump truck returns empty to the front	Return time ±12 minutes 30 seconds; empty speed ±40 km/h
5	Delay	Waiting time during the hauling cycle	Rain; change shift; road maintenance; refueling; unit greasing; P2H; rest & meal; other operational constraints

Source: Field data processing, 2026

The data demonstrate that hauling is not a single homogeneous task but a sequence of interconnected activities with different forms of exposure and operational interaction. Loading requires coordination between the excavator and haul unit, while the hauling and return stages involve continuous vehicle movement and interaction with the road environment. Dumping introduces a separate exposure associated with vehicle positioning and surface stability, whereas delay creates conditions related to vehicle queuing, operator attention, and interaction with surrounding activities. The observed travel duration and repeated cycling also indicate that operators are exposed to the same road and traffic hazards over successive hauling cycles. Task decomposition is important under these circumstances because JSA identifies hazards according to specific work steps rather than treating the entire operation as one undifferentiated activity (Putri et al., 2023). The resulting analysis provides a more traceable relationship between operational characteristics, hazard sources, and safety controls.

The physical condition of the hauling road represents another important component of the empirical safety profile at PT LCL. Table 3 indicates that the hauling road is an unpaved road approximately 7–8 km long and 25 m wide, constructed from compacted soil and laterite aggregate, with grades of approximately 8–10% and curve radii of approximately 25–30 m.

Table 3. Hauling Road Conditions in the Mining Area

No.	Hauling Road Parameter	Description
1	Road name	PT LCL hauling road
2	Road function	Operational route for mobilizing haulage equipment from the mining front to the stockpile
3	Road type	Unpaved road
4	Road construction material	Compacted soil and laterite aggregate
5	Hauling road length	±7–8 km
6	Road width	±25 meters
7	Road system	Two lanes
8	Road gradient	±8–10%
9	Curve radius	±25–30 m
10	Drainage	Open drainage channel along the road
11	Condition during rain	Muddy and slippery
12	Condition without rain	Hard and dusty
13	Road maintenance	Routine grading and watering

Source: Field data processing, 2026

These characteristics demonstrate that road safety is strongly influenced by environmental conditions and routine maintenance. During rainfall, the muddy and slippery surface can reduce tire traction, whereas dry conditions increase dust generation and may reduce operator visibility. The combination of grades, curves, opposing traffic, and changing surface conditions can increase the consequences of inadequate speed control or insufficient following distance. Drainage therefore functions not merely as an infrastructure component but as a preventive control that helps maintain road stability and reduce water accumulation. The requirement to maintain haul roads according to safe operating conditions is consistent with the mining safety provisions established by the Ministry of Energy and Mineral Resources (Kementerian ESDM, 2018). Similar concerns regarding road conditions, environmental factors, and vehicle interaction have been identified as important contributors to occupational risk in mining operations (Akbar et al., 2024).

The mechanical equipment used in the hauling system also determines the nature of interaction among work tasks and potential hazards. Table 4 shows that the principal equipment consists of Tonly TL859R dump trucks, Volvo A40G ADTs, Sany SY500H excavators, and supporting equipment including motor graders, bulldozers, and water trucks.

Table 4. Mechanical Equipment Used for Hauling Operations

Equipment Type	Type/Model	Specification	Function
Dump Truck (DT)	Tonly TL859R	GVW ±66 tons; body capacity ±24 m³; engine power ±460 HP	Transports material from the mining front to the stockpile
Articulated Dump Truck (ADT)	Volvo A40G	Capacity ±40 tons (±24–26 m³); maximum speed ±57 km/h	Transports material under difficult or slippery road conditions
Excavator	Sany SY500H	Operating weight ±50–54 tons; bucket capacity ±5–6 m³; engine power ±298 kW	Loads material into DT and ADT
Motor Grader	–	Supporting equipment	Maintains the hauling road
Bulldozer	–	Supporting equipment	Maintains and repairs the hauling road

Source: Field data processing, 2026

The equipment configuration demonstrates that hauling safety depends on coordinated operation rather than the condition of individual machines alone. The excavator creates a direct interaction with DT and ADT during loading, while motor graders, bulldozers, and water trucks enter the traffic environment during road maintenance. The presence of equipment with different dimensions, capacities, and operating functions increases the need for communication and spatial separation between units. The operational role of the Volvo A40G under difficult or slippery road conditions is particularly relevant because road condition can alter the interaction between vehicle capability and environmental risk. JSA-based mining studies similarly emphasize the need to identify hazards according to the equipment and work sequence involved in each task (Kamaluddin et al., 2025). At PT LCL, this equipment structure supports the use of task-specific controls such as pre-start inspection, communication protocols, safe positioning, traffic management, and supervision.

The implementation of JSA at PT LCL was conducted by decomposing hauling activities into observable work steps and examining the potential hazards associated with each step. The loading stage was evaluated through the interaction between excavator movement, dump truck positioning, material transfer, operator visibility, and communication between equipment operators. The hauling-road component was examined through vehicle movement, road condition, traffic direction, weather exposure, speed, and interaction with other units. Field observations were complemented by interviews with hauling operators, field supervisors, and SHE personnel to capture operational conditions that were not always observable during a single work cycle. This task-oriented approach is consistent with previous applications of JSA that use work-step decomposition to connect hazards with specific preventive measures (Ikhsan & Hidayat, 2023). The empirical evidence indicates that the value of JSA at PT LCL lies in its ability to connect actual operational conditions with control requirements, allowing safety evaluation to remain responsive to changes in equipment movement, road conditions, weather, and worker behavior.

Risk Analysis of Coal Hauling Activities Using the Job Safety Analysis (JSA) Method at PT Lematang Coal Lestari

The JSA assessment identified that coal hauling at PT Lematang Coal Lestari involves interconnected hazards originating from road conditions, weather, equipment movement, maintenance activities, and human factors. The empirical findings indicate that the hazard profile is not concentrated in a single work stage because loading, hauling, dumping, return, and delay each expose workers to different combinations of mechanical and environmental risks. Table 5 summarizes the hazards identified through direct observation and interviews, showing that slippery roads, potholes, sharp curves, gradients, dust, dense traffic, and unsafe operator behavior represent recurring sources of exposure.

Table 5. Potential Hazards in Hauling Activities

Hazard Category	Potential Hazard	Impact
Road Conditions	Slippery and muddy roads during rain; potholes; sharp curves; uphill and downhill sections	Unit skidding; unit damage and accidents; collision risk; loss of vehicle control
Weather Conditions	Rain; dust during hot weather	Slippery roads and reduced visibility; respiratory disturbance and reduced operator visibility
Hauling Road Maintenance	Road not maintained periodically; increasing number of potholes on hauling road	Deterioration of road conditions and increased accident risk; disruption of operational continuity and accelerated unit damage
Vehicle Activities	Dense haulage equipment traffic	Risk of collisions between vehicles
Human Factors	Insufficient attention to road conditions; inappropriate vehicle speed	Potential occupational accidents; difficult vehicle control and potential rollover

Source: Field data processing, 2026

The pattern confirms that road and weather conditions interact with human behavior rather than functioning as isolated risk sources. Rain can transform a relatively stable unpaved surface into a slippery route, while dry conditions can generate dust that reduces visibility and increases respiratory exposure. Dense traffic further amplifies these conditions because reduced visibility or delayed operator responses can increase the probability of vehicle interaction. Similar findings have been reported in coal-hauling environments, where road characteristics, environmental conditions, and operational behavior constitute important hazard sources requiring systematic control (Sainyakit & Djunaidi, 2023). Mining risk assessments also demonstrate that variations in work conditions can produce different levels of occupational exposure even when the basic work task remains unchanged (Akbar et al., 2024). The JSA framework is therefore relevant because it enables these interacting hazards to be traced to specific work activities and corresponding control measures rather than being treated as generalized workplace risks.

The loading stage represents a critical interaction point because the excavator and haul unit operate within a restricted working area and must maintain coordinated positioning. Field observations identified hazards including bucket contact with the dump truck, falling coal material, improper truck positioning, blind spots, and inadequate communication between operators. These hazards can produce consequences ranging from equipment damage and struck-by incidents to serious injury when workers enter the operating envelope of mobile equipment. The observed controls consisted of maintaining a safe loading position, using radio communication or predetermined signals, complying with the loading SOP, conducting pre-start inspections, and maintaining appropriate PPE. Table 6 shows that the main PPE requirements were generally implemented, although inconsistent seatbelt and mask use remained evident among some workers.

.

Table 6. PPE Use among Hauling Workers in the Field

Position	Type of PPE	Usage Condition
Excavator Operator	Safety helmet, safety shoes, safety vest, gloves, and mask	Main PPE used; mask not consistently used
DT and ADT Driver	Safety helmet, safety shoes, safety vest, seatbelt, and mask	Helmet and shoes used; seatbelt not always used consistently; mask rarely used
Foreman/Supervisor	Safety helmet, safety shoes, safety vest, mask, and gloves	Main PPE used; mask used according to dust conditions

Source: Field data processing, 2026

The PPE findings indicate that the residual safety problem is primarily associated with behavioral consistency rather than the absence of prescribed protective equipment. Seatbelt compliance is particularly important because PPE cannot compensate for inadequate restraint during sudden deceleration, collision, or rollover events. In the JSA hierarchy, PPE functions as a final layer of protection and should therefore complement engineering, administrative, and operational controls. This interpretation is consistent with studies showing that JSA effectiveness depends not only on hazard identification but also on worker adherence to the control measures established for each task (Ramadhana & Abdullah, 2020). The findings also support the broader requirement for occupational safety management systems to integrate worker compliance, supervision, and continuous evaluation into daily operations (Republik Indonesia, 2012). Consequently, PPE observations at PT LCL should be interpreted as an indicator of control implementation quality rather than merely as evidence that protective equipment has been distributed.

The analysis further distinguished unsafe actions from unsafe conditions because both mechanisms contribute to accident potential but require different intervention strategies. Table 7 indicates that unsafe actions included incomplete PPE use, failure to use seatbelts, overspeeding, inadequate following distance, failure to reduce speed at curves and gradients, failure to use horns at blind spots, improper loading positions, non-compliance with designated traffic routes, failure to perform pre-start checks, and inadequate radio communication. Unsafe conditions included thick dust, slippery roads, potholes, unstable road shoulders, sharp curves without adequate warning devices, obstructed blind spots, uneven loading areas, unclear traffic signs, unrepaired equipment, and insufficient lighting.

Table 7. Unsafe Actions and Unsafe Conditions

Unsafe Action	Unsafe Condition
Not using complete PPE	Thick dust reducing visibility
Not using seatbelt while driving	Hauling road slippery due to rain
Driving above the speed limit (over speed)	Potholes or uneven road surfaces
Not maintaining a safe distance between vehicles	Narrow or unstable road shoulder
Not reducing speed at curves and uphill sections	Sharp curves without adequate convex mirrors or warning signs
Not sounding the horn at blind spots or curves	Blind spots obstructed by dust or material
Incorrect unit position during loading	Uneven or muddy loading area
Not following designated routes or ignoring traffic signs	Damaged or unclear traffic signs
Not conducting a pre-start check before operating the unit	Unit damage that has not been repaired

Source: Field data processing, 2026

This distinction is analytically important because unsafe actions can be addressed through supervision, training, communication, and behavioral reinforcement, whereas unsafe conditions require physical correction, maintenance, or modification of the work environment. The coexistence of both categories suggests that accident prevention at PT LCL cannot rely exclusively on worker discipline because environmental deficiencies may constrain safe performance. The relationship is particularly evident in cases where operators encounter dust, blind spots, damaged signs, or uneven surfaces while simultaneously being required to maintain speed and traffic discipline. Similar task-level identification of unsafe acts and unsafe conditions has been used in JSA-based studies to establish more specific control priorities (Novianti & Windriya, 2023). The findings also correspond with research on blind-spot hazards in mining areas, where limited visibility can become more consequential when combined with vehicle movement and inadequate traffic controls (Suparno et al., 2020). From an empirical risk perspective, the presence of both behavioral and environmental deficiencies indicates that JSA should be treated as a dynamic control instrument requiring periodic reassessment as operational conditions change.

The daily equipment inspection results provide additional evidence regarding the effectiveness of existing preventive controls. Table 8 records P2H results for DT and ADT units, with assessed components receiving condition values between 85% and 100%, including brakes, steering, tires, lighting systems, seatbelts, reverse alarms, fire extinguishers, first-aid equipment, and communication devices. Components classified as critical or high hazard, such as mirrors, wipers, engine oil, seatbelts, and braking-related systems, remained within the normal or serviceable category during the observed inspection.

Table 8. P2H (Daily Inspection and Maintenance) of DT/ADT Units

No.	Inspection Component	Hazard Code	Good/ Normal	Damaged/ Abnormal	Percentage (%)
1	Cabin Condition	A	✓	-	95
2	Seat Belt Function	A	✓	-	85
3	Mirror Condition	AA	✓	-	90
4	Windshield Condition	A	✓	-	80
5	Wiper	AA	✓	-	95
6	Front Lights	A	✓	-	95
7	Rear Lights	A	✓	-	85
8	Turn Signal	A	✓	-	90
9	Hazard Lights	A	✓	-	90
10	Horn	B	✓	-	95
11	Tire Pressure	A	✓	-	95
12	Front Left Tire	A	✓	-	85
13	Front Right Tire	A	✓	-	85
14	Rear Left Tire	A	✓	-	95
15	Rear Right Tire	A	✓	-	85
16	Spare Tire	A	✓	-	85
17	Engine Oil	AA	✓	-	100
18	Transmission Oil	C	✓	-	95
19	Hydraulic Oil	A	✓	-	95
20	Differential Oil	B	✓	-	95
21	Radiator Water	A	✓	-	100
22	Battery Water	A	✓	-	95
23	Fuel Level	C	✓	-	90
24	Foot Brake	A	✓	-	100
25	Right Brake	C	✓	-	95
26	Steering	C	✓	-	95
27	Back-Up Alarm	A	✓	-	100
28	Fire Extinguisher	A	✓	-	100

29	First-Aid Kit	AA	✓	-	100
30	Handy Talkie	AA	✓	-	100

Source: Data processing, 2026

The relatively high inspection values indicate that mechanical equipment was generally maintained in a condition suitable for operation, reducing the contribution of equipment failure to immediate accident exposure. However, the lower values recorded for several components demonstrate that serviceability should not be interpreted as the absence of residual risk. Components such as seatbelts, tires, and visibility-related equipment require continuous attention because small deficiencies may become consequential when vehicles operate at speed on gradients, curves, or wet surfaces. This finding supports the JSA principle that equipment condition must be evaluated as part of the work step because mechanical reliability and task exposure are closely connected (Sulistyo P. et al., 2023). It also reinforces the importance of preventive maintenance and inspection under the occupational safety requirements established by Indonesian legislation, particularly Law No. 1 of 1970 concerning occupational safety and Law No. 3 of 2020 concerning mineral and coal mining (Republik Indonesia, 1970; Republik Indonesia, 2020). The P2H evidence therefore indicates that PT LCL has established a meaningful preventive barrier, although inspection findings with values below 100% should remain subject to scheduled maintenance and verification.

Road inspection produced a comparable pattern, with the hauling route generally classified as operationally feasible while several physical parameters still required continuous monitoring. Table 9 shows that road width, gradient, cross slope, drainage, safety berms, traffic signs, watering, loading and dumping areas, and overall road condition obtained values ranging from 85% to 95%. The lowest values were associated with surface condition, potholes, and road lighting, indicating that these elements represent comparatively greater opportunities for deterioration within the observed road system.

Table 9. P2H (Daily Inspection and Maintenance) of the Hauling Road

No.	Inspection Component	Hazard Code	Good/ Normal	Damaged/ Abnormal	Percentage (%)	Description
1	Hauling road width	A	✓	-	95	Meets standard
2	Road gradient	A	✓	-	90	According to design
3	Cross slope/superelevation	B	✓	-	90	Good
4	Road surface condition	A	✓	-	85	Slightly uneven
5	Potholes	A	✓	-	85	Several small potholes
6	Slippery road	AA	✓	-	90	Does not interfere
7	Standing water	A	✓	-	90	Drainage functioning
8	Drainage/water channel	A	✓	-	95	Flowing properly
9	Safety berm	AA	✓	-	95	Height meets standard
10	Safety signs	A	✓	-	95	Complete
11	Delineator/road marker	B	✓	-	90	Installed
12	Convex mirror	B	✓	-	90	Functional
13	Road lighting	A	✓	-	85	Adequate
14	Road dust	B	✓	-	90	Controlled by water truck

15	Road watering	A	✓	-	95	Conducted routinely
16	Vegetation obstructing visibility	B	✓	-	95	None
17	Curve condition	A	✓	-	90	Safe
18	Intersection condition	A	✓	-	90	Safe
19	Loading area	A	✓	-	95	Good
20	Dumping area	A	✓	-	95	Good
21	Escape road	AA	✓	-	90	Ready for use
22	Bridge/culvert condition	A	✓	-	95	Suitable
23	Vehicle speed within limit	A	✓	-	95	Complied with
24	Grader activity	B	✓	-	90	Routine
25	Overall road condition	AA	✓	-	95	Operationally feasible

Source: Data processing, 2026

The results indicate that road maintenance constitutes a continuing control requirement rather than a one-time corrective measure because the hauling route is exposed to traffic loading and weather changes. Potholes, uneven surfaces, dust, and lighting limitations can progressively alter the risk profile even when the road remains generally suitable for operation. The combination of routine grading, watering, drainage maintenance, safety berm inspection, and traffic control therefore represents an important preventive system within the JSA framework. Previous research has shown that JSA-based assessment can provide a structured basis for prioritizing controls when hazards arise from interactions among equipment, work environment, and worker activities (Lestari et al., 2024). The findings at PT LCL also correspond with evidence from mining studies in which systematic JSA implementation improves the identification of task-specific hazards and supports more targeted safety interventions (Kamaluddin et al., 2025). At the management level, the results suggest that the effectiveness of JSA depends on maintaining consistency between documented controls and actual field conditions, particularly when road geometry, weather, traffic density, and equipment activity change during mining operations.

The integrated evidence from JSA, P2H, observations, and interviews indicates that the most important risk exposures at PT LCL arise from the interaction of mobile equipment, hauling-road conditions, and operator behavior. The hauling stage presents a particularly important exposure because vehicles repeatedly travel through gradients, curves, opposing traffic, and weather-dependent surface conditions, while loading and dumping introduce concentrated equipment-interaction hazards. Operator interviews further indicated that changing road conditions during rainfall and increased dust during dry periods are among the conditions that most directly affect operational safety. These findings are consistent with previous research demonstrating that occupational safety in mining requires integration of task analysis, hazard recognition, operational controls, and worker awareness rather than reliance on a single preventive measure (Amirudin et al., 2025). The JSA results also demonstrate that existing controls at PT LCL have established several effective barriers, but behavioral inconsistencies and changing environmental conditions create residual risks that require continuous supervision and reassessment. This interpretation is consistent with the requirements of Indonesian occupational safety and employment legislation, which place safety management within an ongoing organizational responsibility rather than a one-time compliance activity (Republik Indonesia, 2003).

Evaluation of Risk Control Effectiveness in Coal Hauling Activities

The evaluation of risk control effectiveness was conducted by comparing identified hazards with the controls observed during field activities, P2H inspections, interviews, and the JSA matrix. The assessment indicates that PT LCL has established multiple layers of control covering engineering, administrative, behavioral, and personal protection measures. Existing controls include pre-start inspection, toolbox meetings, road inspection, road maintenance, traffic signs, speed restrictions, radio communication, watering, PPE, and direct supervision by field supervisors and SHE personnel. The control structure reflects the principle that occupational risk should be addressed through measures that intervene at the source of exposure before relying on individual protective equipment. JSA provides an operational mechanism for connecting these measures with specific work steps, making it possible to evaluate whether the prescribed controls correspond to hazards actually encountered in the field (Djunaidi & Umami, 2024). The observed control system therefore demonstrates that JSA at PT LCL functions not only as a hazard-identification document but also as an operational reference for maintaining safety during repetitive hauling activities.

The loading stage demonstrates relatively strong control implementation because the principal hazards are associated with equipment interaction and can be directly addressed through positioning, communication, exclusion distance, and supervision. Operators were observed to position dump trucks within designated loading areas while excavator operators coordinated material loading through radio communication or established signals. Pre-start inspection and PPE use provided additional preventive and protective barriers against mechanical and operational hazards. However, blind spots and improper positioning remain relevant because the excavator bucket and dump truck operate within close proximity during repeated loading cycles. Research on JSA implementation has similarly demonstrated that equipment interaction requires explicit identification of movement zones, operator communication, and task-specific procedures to prevent struck-by and caught-between incidents (Ikhsan & Hidayat, 2023). The effectiveness of loading controls at PT LCL therefore depends on maintaining physical separation, communication discipline, and operator attention throughout each loading cycle rather than assuming that compliance at the beginning of a shift guarantees safe performance throughout the operation.

The hauling and return stages require greater attention because risk exposure continues throughout the movement of vehicles along a dynamic road network. Field evidence indicates that grading, watering, drainage maintenance, safety berms, traffic signs, convex mirrors, speed restrictions, and radio communication have been implemented as controls against road-related and traffic-related hazards. These measures address several major exposure mechanisms, including loss of traction, reduced visibility, vehicle interaction, and excessive speed. However, the effectiveness of these controls can decline when rainfall changes surface conditions, when dust accumulates during dry periods, or when operators fail to maintain prescribed speed and following distance. Studies of mining safety have identified road geometry, equipment interaction, environmental conditions, and worker behavior as interconnected determinants of accident risk in mining operations (Akbar et al., 2024). The findings indicate that road maintenance should therefore be integrated with real-time operational monitoring so that changes in road conditions can trigger immediate adjustments to traffic controls and work practices.

The dumping stage presents a different control profile because the dominant hazards are associated with vehicle stability, surface condition, material movement, and positioning near the dumping area. PT LCL has implemented safety berms, inspection of the dumping area, operator communication, PPE, and supervision as primary controls during material discharge. The P2H results show that the dumping area was assessed at 95%, while the safety berm received a 95% condition value, indicating that these physical controls were generally maintained in an operationally suitable condition. Nevertheless, the presence of a satisfactory inspection result does not eliminate the possibility of risk because ground conditions can change following rainfall, repeated vehicle loading, or stockpile development. Previous JSA-based research emphasizes that control measures must be evaluated against the actual task environment because a control that is adequate under one set of conditions may become insufficient when work conditions change (Sa'adati & Widharto, 2023). This finding supports the need for continuous inspection of dumping surfaces and berm integrity, particularly before operators initiate discharge activities.

The delay stage also requires attention because waiting periods create a different form of exposure that is not directly associated with material transportation. Field observations identified potential risks from close vehicle queues, reduced operator concentration, dust, noise, and interaction with other mobile equipment during periods of operational waiting. PT LCL addresses these conditions through queue management, minimum separation distances, radio communication, field supervision, PPE requirements, and restrictions on distracting activities while units remain within operational areas.

The control strategy is important because repeated waiting periods can influence operator alertness and may create opportunities for unsafe positioning or unnecessary interaction between vehicles. Research concerning occupational safety awareness indicates that consistent communication, worker involvement, and reinforcement of safe behavior are important components in sustaining safety controls during routine operational activities (Ramadhana & Abdullah, 2020). The empirical findings therefore indicate that delay management should be treated as part of the hauling safety system rather than as an operational issue separate from occupational risk management.

The overall evaluation indicates that the existing control system at PT LCL is generally functional but remains dependent on implementation consistency and adaptation to changing field conditions. The principal residual risks are associated with inconsistent seatbelt and mask use, potential overspeeding, road-surface deterioration, dust, blind spots, and changing conditions during rainfall. These findings demonstrate that the effectiveness of JSA cannot be determined solely from the existence of documented procedures because actual safety performance also depends on worker compliance and the condition of physical controls. The integration of JSA with HIRARC principles is relevant in this context because hazard identification, risk assessment, and control selection should form a continuous process rather than independent administrative activities (Sa'adati & Widharto, 2023). Previous studies have also shown that combining systematic hazard analysis with active safety-management interventions can strengthen worker safety awareness and reduce accident exposure in mining operations (Amirudin et al., 2025). At PT LCL, the findings support periodic revision of JSA whenever road geometry, equipment configuration, weather conditions, traffic patterns, or work procedures change, ensuring that the documented risk profile remains consistent with actual operational conditions.

Prioritized Safety Improvements Based on the JSA Findings

The JSA findings indicate that safety improvement at PT LCL should prioritize controls addressing the interaction between mobile equipment, hauling-road conditions, environmental changes, and operator behavior. The empirical evidence shows that the existing control system has reduced several immediate exposures, but residual risks remain in the form of inconsistent seatbelt use, incomplete mask use, potential overspeeding, blind spots, uneven road surfaces, potholes, dust, and changing conditions during rainfall. These findings indicate that safety improvement should focus on strengthening controls at the source of exposure rather than relying predominantly on PPE compliance. The task-based nature of JSA allows each improvement to be linked directly to the work stage, hazard source, exposed worker, and required control action (Ishak et al., 2020). A prioritized control strategy is therefore required to ensure that available safety resources are directed toward hazards with the greatest potential operational consequences.

The first priority concerns the hauling and return stages because these activities involve continuous vehicle movement over a 4–5 km operational route and repeated interaction between loaded and empty units. The primary improvements should include stricter speed monitoring, reinforcement of safe following distances, improved communication at blind spots and intersections, and immediate adjustment of operating speed when rainfall or reduced visibility affects road conditions. Road maintenance should also receive priority at locations where potholes, uneven surfaces, slippery sections, or inadequate visibility have been identified through P2H inspections. Mining safety research demonstrates that road geometry, vehicle movement, and environmental conditions can interact to increase accident probability when operational controls are not consistently implemented (Akbar et al., 2024).

Table 10. Recommended Safety Control Priorities for Coal Hauling Activities at PT LCL

No.	Work Stage	Main Hazard	Existing Control	Recommended Additional Control	Priority
1	Loading	Bucket–truck collision, falling material, blind spot	SOP, radio communication, safe positioning, PPE, supervision	Establish exclusion zone, reinforce loading-point communication, improve blind-spot monitoring	High

2	Hauling	Slippery road, potholes, dust, collision, overspeeding	Grading, watering, signs, speed limits, radio communication	Intensify road inspection, speed monitoring, corrective road maintenance, weather-based traffic control	Very High
3	Dumping	Rollover, unstable surface, material movement	Safety berm, area inspection, SOP, supervision	Pre-dumping ground verification, berm inspection, controlled positioning, stop-work authority	High
4	Return	Overspeeding, collision, dust, fatigue	Speed limits, signs, watering, radio communication	Strengthen speed enforcement, fatigue monitoring, following-distance control, communication at blind spots	Very High
5	Delay	Vehicle queues, close spacing, reduced concentration, dust	Queue management, radio communication, supervision	Dedicated waiting zones, minimum queue distance, operator alertness monitoring	Medium
6	All Stages	Unsafe action and PPE non-compliance	PPE, toolbox meeting, supervision	Behavioral safety observation, compliance feedback, periodic refresher training	High

Source: Field data processing, 2026

Table 10 shows that hauling and return should receive the highest control priority because the associated hazards occur during prolonged vehicle movement and can involve multiple units simultaneously. The recommendation to strengthen road inspection and speed control is supported by the observed P2H results, particularly the 85% values for road surface condition and potholes and the 85% value for road lighting. The control approach should incorporate weather-responsive measures, including temporary speed reduction, intensified watering or road treatment, and additional inspection after rainfall. Such an approach is consistent with the principle that mining safety controls must account for dynamic environmental and operational conditions rather than rely exclusively on fixed procedures (Kementerian ESDM, 2018). The use of dedicated monitoring mechanisms would also strengthen the traceability between identified hazards and corrective actions recorded in the JSA documentation.

Loading and dumping require targeted improvements because both stages involve concentrated interactions between mobile equipment and defined work areas. At the loading point, an exclusion zone around the excavator should be maintained so that personnel and equipment remain outside the bucket swing radius unless their presence is operationally necessary. Communication between excavator and truck operators should use standardized radio terminology or predetermined signals to minimize ambiguity during positioning and loading. At the dumping area, operators should verify ground stability, berm condition, and vehicle alignment before raising the dump body. Research applying JSA to mining activities indicates that task-specific controls are more effective when hazards are directly connected to equipment movement and worker positioning (Putri et al., 2023). These measures would strengthen existing administrative controls by introducing more explicit spatial and procedural barriers at high-interaction work points.

The observed unsafe actions indicate that behavioral controls should complement physical and administrative improvements. The most important behavioral targets are seatbelt compliance, adherence to speed restrictions, completion of pre-start checks, maintenance of safe following distances, correct use of communication devices, and compliance with designated traffic routes. Toolbox meetings can be used to communicate recent hazards and reinforce controls, while supervisors can conduct short behavioral observations during active hauling cycles to identify deviations before they result in incidents. Safety awareness programs are more sustainable when workers receive continuous reinforcement and feedback rather than relying only on formal training sessions (Ramadhana & Abdullah, 2020). The implementation of a simple observation-and-feedback mechanism would provide additional empirical evidence for evaluating whether JSA recommendations are being translated into actual operator behavior.

The control program should also incorporate a formal mechanism for updating the JSA when operational conditions change. Changes in hauling-road geometry, mining-front location, traffic density, equipment type, weather conditions, or work procedures can alter the hazard profile and may render existing JSA controls insufficient. A revised JSA should therefore be triggered after significant operational changes, serious near misses, dangerous incidents, road configuration changes, or the introduction of new equipment. This approach is consistent with the task-based risk assessment principle that hazard analysis should remain responsive to changes in work activities and conditions (Rinawiyanti et al., 2026). Continuous review would also improve consistency between field observations, P2H results, interview evidence, and the documented JSA matrix.

The final improvement priority is the integration of JSA with the broader occupational safety management system at PT LCL. JSA should not operate as an isolated document but should be connected with P2H, toolbox meetings, road inspections, maintenance records, incident and near-miss reporting, supervisor observations, and SHE evaluations. This integration would allow recurring hazards to be identified from multiple operational data sources and would provide a stronger basis for determining whether corrective actions have reduced exposure over time. The approach is aligned with the Indonesian occupational safety management framework, which requires systematic implementation and continuous improvement of occupational safety practices (Republik Indonesia, 2012). The empirical findings from PT LCL demonstrate that the effectiveness of JSA is determined not only by the completeness of hazard identification but also by the consistency with which identified controls are implemented, monitored, evaluated, and revised. A closed-loop safety process linking hazard identification → risk assessment → control implementation → field verification → corrective action → JSA revision would therefore provide a more robust safety architecture for coal hauling operations.

CONCLUSION

Based on the empirical findings, the JSA application at PT Lematang Coal Lestari demonstrates that each stage of coal hauling, including pre-start inspection, loading, hauling, dumping, and return, contains task-specific hazards associated with human factors, equipment conditions, haul-road characteristics, and the surrounding work environment. These hazards indicate that occupational safety in hauling operations depends on the interaction between operational practices and the conditions under which mobile equipment is operated. The risk assessment further indicates that risk levels vary across work stages, with loading and hauling presenting comparatively higher exposure because of heavy-equipment interaction, haul-road conditions, and operator behavior. The JSA framework provides a structured means of connecting individual work steps with potential consequences and appropriate control measures. Existing controls at PT LCL, including PPE use, pre-start inspection, toolbox meetings, haul-road maintenance, and supervision by field supervisors and SHE personnel, have contributed to reducing occupational risk. However, the persistence of unsafe actions and variable environmental conditions indicates that control effectiveness depends strongly on consistent implementation and continuous monitoring. These findings support the application of task-oriented safety analysis as an operational mechanism for strengthening hazard recognition and risk control in coal hauling activities.

Based on the identified risks, PT LCL should strengthen supervision of SOP compliance and PPE use through consistent field monitoring and corrective feedback. Periodic safety training and toolbox meetings should also be enhanced to improve workers' knowledge, practical skills, hazard awareness, and ability to implement appropriate risk controls. Particular attention should be directed toward operator compliance with seatbelt use, speed limits, communication procedures, pre-start inspections, and safe vehicle positioning during loading and hauling. Haul-road maintenance should be conducted routinely, including grading, watering, pothole repair, drainage maintenance, and inspection of road geometry, because road conditions directly influence vehicle stability and operator visibility. The company should also maintain systematic monitoring of weather-related changes, particularly rainfall and dry conditions that can alter road traction and visibility. The JSA documentation should be reviewed and updated periodically whenever changes occur in equipment, work sequences, haul-road conditions, operating procedures, or environmental conditions. Continuous integration of field observations, worker feedback, inspection records, and JSA revisions can support a more adaptive occupational safety system and sustain safer coal hauling operations at PT LCL.

REFERENCES

Akbar, I., Fadhilah, F., Anarta, R., & Saldy, T. G. (2024). Analysis of Occupational Safety Risk Levels in Mining Activities at PT Golden Great Borneo Lahat Regency, South Sumatra Province. *MOTIVECTION: Journal of Mechanical, Electrical and Industrial Engineering*, *6*(3), 235-248. https://doi.org/10.46574/motivection.v6i3.337

Amirudin, A., Triraharjo, J., Zulkarnaen, Z., Ramli, S., & Fikriansyah, D. (2025, November). Reducing Accident Frequency Rate (AFR) Using SMART Safety Method (Safety Management Attitude Reinforcement Techniques) at PT. Antareja Mahada Makmur Site XXX in 2024. In *2nd Halu Oleo International Conference on Public Health (HOICPH 2024)* (pp. 177-191). Atlantis Press. https://doi.org/10.2991/978-94-6463-890-5_18

Djunaidi, M., & Umami, H. (2024, December). Occupational health and safety analysis using job safety analysis and hazard identification risk assessment and risk control methods. In *E3S web of conferences* (Vol. 517, p. 15003). EDP Sciences. https://doi.org/10.1051/e3sconf/202451715003

Edmon, R., & Fadhilah, F. (2021). Evaluasi keselamatan dan kesehatan kerja pada penambangan batubara PT. Nusa Alam Lestari, Desa Salak, Kecamatan Talawi, Sawahlunto, Sumatera Barat. *Jurnal Bina Tambang, 6*(2). https://doi.org/10.24036/bt.v6i2.111701

Ikhsan, A., & Hidayat, R. (2023). Implementasi Job Safety Analysis untuk meminimalkan kecelakaan kerja di PT. X. *Jurnal Teknik Industri Universitas Bung Hatta, 10*(1), 49–60. https://ejurnal.bunghatta.ac.id/index.php/JTI-UBH/article/view/23492

Ishak, A., Buchari, Asfriyati, & Nainggolan, B. (2020, December). Risk analysis of occupational accidents and occupational diseases using the JSA (job safety analysis) method. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1003, No. 1, p. 012077). IOP Publishing. https://iopscience.iop.org/article/10.1088/1757-899X/1003/1/012077/meta

Kamaluddin, M., Nurfasiha, N., & Dzakir, L. (2025). Analisis Potensi Bahaya Menggunakan Job Safety Analysis (JSA) Dalam Kegiatan Penambangan Nikel Laterit di PT. Ceria Nugraha Indotama Kecamatan Wolo, Kabupaten Kolaka, Provinsi Sulawesi Tenggara. *Mining Science And Technology Journal*, *4*(2), 112 - 116. https://doi.org/10.54297/minetech-journal.v4i2.1237

Kementerian Energi dan Sumber Daya Mineral Republik Indonesia. (2018). *Keputusan Menteri Energi dan Sumber Daya Mineral Republik Indonesia Nomor 1827 K/30/MEM/2018 tentang pedoman pelaksanaan kaidah teknik pertambangan yang baik*.

Lestari, S. P., Selviana, & Suwarni, L. (2024). Risk analysis of work accidents in the loading and unloading process using Job Safety Analysis (JSA) and Hazard and Operability Study (HAZOPS) methods at PT Pelindo II (Persero) Branch Pontianak. *Indonesian Journal of Administration and Health Research, 1*(2). https://doi.org/10.54630/ijahr.v1i2.74

Maghfira, A., Pratama, A. H., & Paotonan, C. (2023). Analisis risiko kecelakaan kerja pada pekerjaan instalasi bangunan lepas pantai dengan menggunakan metode Job Safety Analysis. *SENSISTEK: Riset Sains dan Teknologi Kelautan,* *6*(2). https://doi.org/10.62012/sensistek.v6i2.31600

Muffi, K., & Abdullah, R. (2024). Job Safety Analysis (JSA) of Work Accidents on Wood Work Machines in the Construction Workshop. *CIVED*, *11*(1), 380-393. https://doi.org/10.24036/cived.v11i1.607.

Novianti, F., & Windriya, A. (2023). Hazard Analysis of Occupational Health and Safety (OHS) Using The JSA (Job Safety Analysis) Method in Grey Weaving 2 Warehouse PT XYZ. *Asian Journal of Logistics Management, 2*(1), 33-47. https://doi.org/10.14710/ajlm.2023.19038

Putri, A. G., Fadhillah, & Saldy, T. G. (2023). Implementasi Job Safety Analysis untuk keselamatan dan kesehatan kerja di tambang bawah tanah PT. Allied Indo Coal Jaya, Parambahan Kota Sawahlunto, Sumatera Barat. *Jurnal Bina Tambang, 8*(3), 92–100. https://ejournal.unp.ac.id/index.php/mining/article/view/126022/108501

Ramadhana, L., & Abdullah, R. (2020). Job Safety Analysis as an implementation of occupational safety and health awareness at PT. Mega Sejahtera Sugan, Jorong Sopang, Lima Puluh Kota Regency, West Sumatra. *Jurnal Bina Tambang, 5*(2). https://doi.org/10.24036/bt.v5i2.108003

Republik Indonesia. (1970). *Undang-Undang Republik Indonesia Nomor 1 Tahun 1970 tentang keselamatan kerja*.

Republik Indonesia. (2003). *Undang-Undang Republik Indonesia Nomor 13 Tahun 2003 tentang ketenagakerjaan*.

Republik Indonesia. (2012). *Peraturan Pemerintah Republik Indonesia Nomor 50 Tahun 2012 tentang penerapan sistem manajemen keselamatan dan kesehatan kerja*.

Republik Indonesia. (2020). *Undang-Undang Republik Indonesia Nomor 3 Tahun 2020 tentang perubahan atas Undang-Undang Nomor 4 Tahun 2009 tentang pertambangan mineral dan batubara*.

Rinawiyanti, E. D., Kusumo, A. H., Irawan, F. C., & Dewi, D. R. S. (2026). Integrating job safety analysis and risk assessment for occupational safety in task-based sulfur mining activities. *Jurnal Rekayasa Sistem Industri (JRSI)*, *15*(1), 93-105. https://repository.ubaya.ac.id/50681/

Sa'adati, N. A., & Widharto, Y. (2023). Analisis Identifikasi Bahaya Kecelakaan Kerja Menggunakan Job Safety Analysis (JSA) dengan Pendekatan Hazard Identification, Risk Assessment, and Risk Control (HIRARC) (Studi Kasus : CV. Laksana Karoseri). *Industrial Engineering Online Journal, 12*(3). Retrieved from https://ejournal3.undip.ac.id/index.php/ieoj/article/view/40273

Sainyakit, E. F. N., & Djunaidi, Z. (2023). Identifikasi potensi bahaya dan upaya pengendalian pada proses coal hauling dan coal loading di Indonesia. *Buletin Keslingmas, 42*(2). https://doi.org/10.31983/keslingmas.v42i2.9634

Sofia, S., & Basuki, M. (2025). Analysis of potential hazards using the Job Safety Analysis (JSA) and Job Hazard Analysis (JHA) methods in the nickel chain process in nickel mining. *Nusantara of Engineering, 8*(1), 36–44. https://doi.org/10.29407/noe.v8i01.23138

Sulistyo P, B., Hartadi, H., & Hendrawati, L. S. (2023). Analysis of Hazard Identification, Risk and Control in the Drilling Area of Rig Using Job Safety Analysis (JSA) Method in PT PTM, in Indonesia. *European Journal of Science, Innovation and Technology*, *3*(1), 85-94. Retrieved from https://ejsit-journal.com/index.php/ejsit/article/view/161

Suparno, F. A. D., Kuswardani, I. F., Anggraini, Y. I., & Febriany, S. R. (2020). Manajemen Risiko Kecelakaan Kerja Akibat Blindspot pada Disposal Area Menggunakan Analisis HIRARC. *Jurnal Teknologi Sumberdaya Mineral*, *1*(1), 31-42. https://doi.org/10.19184/jeneral.v1i1.22136