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Analysis of Occupational Accident Sources in a Construction Project: A Case Study of the Pulokulon-Jambon Road Project

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Abstract

Occupational accidents remain a critical concern in road construction because construction activities involve heavy equipment, construction materials, changing workplace conditions, and continuous interaction between workers and machinery. This study aims to identify occupational accident types, accident sources, severity levels, and work-stage patterns in the Pulokulon–Jambon Road Improvement Project, Grobogan Regency, Central Java. A descriptive quantitative case-study design was employed, involving 15 project personnel selected through purposive sampling based on their direct involvement in construction activities. Primary data were collected through questionnaires and complemented by direct observations, semi-structured interviews, and project documentation. The data were analyzed descriptively using frequencies, percentages, and mean values to characterize accident occurrence across time, type, source, severity, and construction stages. The findings show that accidents occurred most frequently in the afternoon, accounting for 46.7% of recorded cases. Slipping was the dominant accident type at 33.3%, while slippery or uneven road-surface conditions represented the largest accident-source category at 33.3%. Construction materials and heavy equipment each contributed 26.7% of the identified accident sources, whereas work equipment accounted for 13.3%. Minor accidents dominated the severity distribution at 66.7%, followed by moderate cases at 26.7% and severe cases at 6.6%. The findings provide project-specific evidence supporting targeted OSH improvement through workplace-surface control, material organization, PPE compliance, safe work procedures, and heavy-equipment interaction management.

Keywords: *Accident Severity, Occupational Accident, Occupational Safety And Health, Road Construction, Work Accident Sources.*

INTRODUCTION

Infrastructure development depends on construction activities that shape transport connectivity, public facilities, and regional economic functions, making construction performance increasingly dependent on the ability to integrate productivity, quality, time, cost, and occupational safety into a coherent project-management framework. Within this setting, project success is not confined to the achievement of technical and economic targets because occupational safety and health (OSH) conditions determine whether construction activities can be delivered without exposing workers to preventable harm (Ramli, 2010). Road construction is particularly vulnerable to occupational accidents because work activities are performed within dynamic environments involving heavy equipment, construction materials, temporary work zones, traffic-related interfaces, and continuous changes in site conditions (Suma'mur, 2009). The International Labour Organization identifies construction as a high-hazard sector in which machinery, materials, elevated or open work areas, and changing operational conditions generate substantial occupational exposure (International Labour Organization, 2013). Indonesian construction practice has consequently developed within a safety-management orientation that places worker protection alongside the achievement of project objectives rather than treating safety as a separate operational concern (Widodo, 2015). Accident identification at the project level is therefore relevant to intelligent engineering and construction management because empirical patterns of incidents can reveal where engineering controls, supervision, and preventive practices require greater attention.

Occupational accidents are commonly associated with unsafe acts and unsafe conditions, yet their occurrence cannot be adequately explained by treating the immediate unsafe event as an independent cause because accidents emerge through interactions among workers, equipment, environmental conditions, and organizational arrangements. Heinrich et al. (1980) conceptualize accident occurrence through the relationship between unsafe acts and unsafe conditions, establishing an early foundation for examining accident causation beyond the visible injury event. Reason (1997) subsequently broadens this perspective by explaining how latent organizational conditions and weaknesses in safety systems can create pathways through which active failures eventually develop into accidents. The practical analysis of occupational safety also requires attention to immediate causes and controllable workplace conditions because effective prevention depends on identifying hazards at the point where work activities are actually performed (Reese, 2009). Indonesian evidence demonstrates that fatal construction accidents frequently involve interconnected causal factors rather than a single isolated mechanism, reinforcing the need for project-level investigation of how accident sources interact with construction activities (Bria et al., 2024). Such perspectives shift the analytical emphasis from attributing accidents primarily to individual worker behavior toward examining observable accident patterns and the conditions that facilitate their occurrence. This conceptual position provides a basis for classifying accident types, sources, and severity while maintaining a connection between empirical observations and broader occupational safety theory.

Despite the development of accident-causation theories and construction safety-management practices, the literature remains strongly oriented toward prospective risk identification and formal risk-control frameworks rather than concise empirical descriptions of accidents that have actually occurred during specific road construction projects. A systematic review of construction OSH research indicates that hazard identification, risk assessment, and risk-control procedures remain dominant approaches for understanding construction safety problems (Mei Dina & Purba, 2022). Road construction research using HIRADC similarly demonstrates that systematic identification of hazards can support the determination of appropriate control measures before occupational risks develop into more serious incidents (Marliana et al., 2024). Earthwork-related research further indicates that road construction activities generate distinctive hazard profiles because excavation, earthmoving, equipment operation, and changing site configurations produce different forms of worker exposure (Pongtuluran et al., 2024). Yet a risk-oriented framework does not automatically explain the empirical distribution of accident events, particularly when the research question concerns which accident types occur most frequently, what sources are most dominant, and how severe the resulting incidents are within one project. This creates a conceptual and empirical gap between identifying what *could* cause an accident and documenting what *actually* constitutes the accident pattern experienced by project personnel. The present study responds to this gap by focusing on descriptive evidence from the Pulokulon–Jambon Road Improvement Project rather than extending the analysis into a formal probabilistic or risk-ranking model.

The practical importance of this gap becomes more pronounced in road construction because occupational exposure changes as project stages progress, meaning that a hazard profile identified at one stage may not adequately represent conditions encountered during subsequent activities. Construction safety management must address environmental conditions, machinery and equipment, work procedures, and worker behavior because these dimensions can independently generate hazards while also amplifying one another during project execution (Djatmiko, 2016). Occupational safety is also inseparable from broader occupational-health considerations because workplace conditions influence the degree to which workers remain protected throughout repetitive, physically demanding, and changing construction operations (Kurniawidjaja, 2010). Recent Indonesian literature emphasizes that construction OSH management requires systematic attention to the relationship between workplace conditions, work processes, and risk-control practices rather than relying solely on individual compliance (Maddeppungeng et al., 2023). The Indonesian regulatory framework further establishes OSH management as a formal component of workplace governance, providing an institutional basis for controlling hazards during construction activities (Pemerintah Republik Indonesia, 2012). The unresolved issue is therefore not simply whether hazards exist, but whether project-specific accident evidence can identify the sources and severity patterns that deserve immediate managerial attention. A descriptive understanding of these patterns can support more targeted supervision, housekeeping, PPE compliance, work procedures, and interaction controls around construction equipment without requiring the research to claim a level of causal or predictive inference that its empirical design cannot support.

The present study is positioned as a descriptive quantitative case study of occupational accidents during the implementation of the Pulokulon–Jambon Road Improvement Project in Grobogan Regency, with the analytical focus placed on accident type, accident source, and accident severity. The study combines questionnaire data with field observations, interviews, and project documentation so that numerical distributions can be interpreted in relation to the actual working conditions encountered during project execution. Its analytical framework retains the distinction among environmental conditions, construction materials, work equipment, heavy equipment, and worker activities as potential sources of accident exposure, allowing the observed accident pattern to remain closely connected to specific construction contexts. The legal foundation for worker protection is established through Indonesia's occupational safety legislation, which provides the regulatory basis for preventing workplace accidents and protecting workers during occupational activities (Pemerintah Republik Indonesia, 1970). Labour protection within the construction employment context is also supported by national employment legislation, which places worker protection within the broader framework of employment relations and occupational obligations (Pemerintah Republik Indonesia, 2003). This positioning differentiates the study from research that primarily estimates risk levels because its central concern is the empirical configuration of accident events within a defined road-construction setting. The resulting evidence is intended to strengthen project-level OSH evaluation by connecting reported accidents with their observable sources and severity rather than reducing safety performance to generalized compliance indicators.

The objective of this study is to identify the types of occupational accidents occurring during the Pulokulon–Jambon Road Improvement Project and to analyze their severity categories based on evidence obtained from project personnel and field conditions. It also seeks to describe the principal sources associated with occupational accidents across the construction activities represented in the questionnaire and field observations. The study further examines how accident characteristics can be organized into a coherent project-level profile that supports interpretation of recurring exposure conditions. Its novelty is deliberately empirical rather than algorithmic, as the research does not introduce predictive models or computational procedures beyond the analytical requirements established by the study design. The methodological contribution lies in integrating quantitative accident distributions with contextual field evidence so that frequency, type, source, severity, and work-stage characteristics can be interpreted as interconnected components of the project's occupational safety profile. The study does not extend into formal risk quantification, accident-cost calculation, or technical road-design analysis. Its theoretical contribution is to reinforce a project-level understanding of accident occurrence in which observable incidents are interpreted in relation to their sources and working conditions, while its practical contribution is to provide contractors and project managers with focused evidence for evaluating and strengthening occupational safety practices in road construction.

RESEARCH METHODS

The study employed a quantitative descriptive approach as an empirical case study at the Pulokulon–Jambon Road Improvement Project in Pulokulon District, Grobogan Regency, Central Java, with the research architecture comprising questionnaire-based data collection, direct field observation, semi-structured interviews, and supporting project documentation. The primary instrument was a questionnaire administered to 15 project personnel selected through purposive sampling based on their direct involvement in and knowledge of construction activities, consistent with the need to obtain occupational safety information from personnel familiar with workplace conditions (Reese, 2009). The respondents consisted of one Site Engineer, one OSH Officer, one Field Foreman, one Field Implementer, one Quality Control officer, one Excavator Operator, one Vibro Roller Operator, two Dump Truck Operators, four Field Workers, and two Flagmen, as presented in Table 1. The questionnaire examined potential accident sources related to human factors, work equipment, heavy equipment, and working-environment conditions using a five-point Likert scale ranging from Strongly Agree (5) to Strongly Disagree (1). Direct observations documented PPE use, workplace conditions, equipment and heavy-equipment operations, work practices, and potential hazards, while semi-structured interviews with the OSH Officer, Field Foreman, and Field Implementer were conducted to clarify questionnaire responses and contextualize observed conditions within construction safety management (Djatmiko, 2016). Project accident reports, activity documentation, and other relevant records were incorporated as supporting secondary data, while field data collection was conducted from 25 October to 20 November 2025 within an overall research period extending from 20 October 2025 to August 2026.

Table 1. Respondents and Interview Informants

Position	Number	Role
Site Engineer	1	Respondent
OSH Officer	1	Respondent
Field Foreman	1	Respondent
Field Implementer	1	Respondent
Quality Control	1	Respondent
Excavator Operator	1	Respondent
Vibro Roller Operator	1	Respondent
Dump Truck Operator	2	Respondent
Field Worker	4	Respondent
Flagman	2	Respondent
Total	**15**	

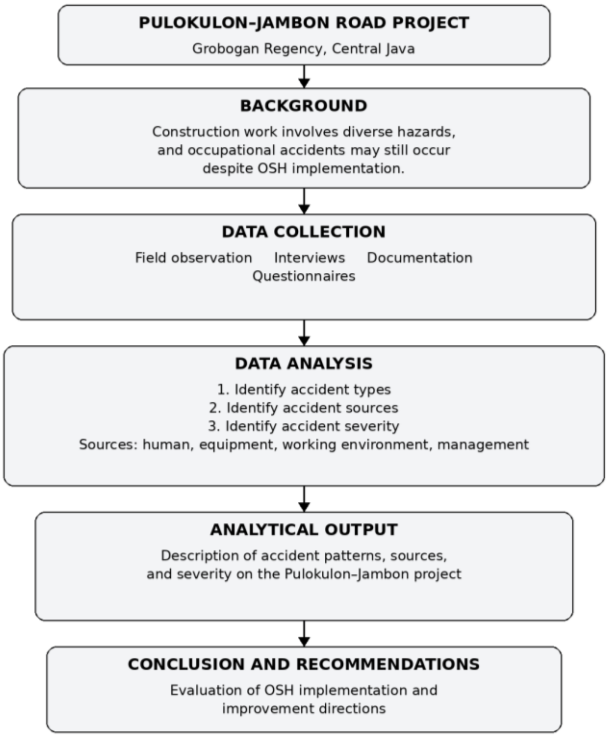

Figure 1. Research Process Framework

The analytical procedure began with validity and reliability testing of the questionnaire instrument before the responses were processed for the main descriptive analysis, ensuring that the measurement instrument was sufficiently appropriate and consistent for the study objectives. After instrument checking, questionnaire responses were coded and analyzed using frequencies, percentages, and mean values to describe the distribution of occupational accident indicators. The principal evaluation outputs comprised frequency and percentage distributions of accident time, accident type, accident source, and accident severity, supplemented by observations according to relevant construction activities and project stages. Mean values were used to rank questionnaire indicators where required, while no inferential statistical test was applied because the study was designed to provide a project-level descriptive assessment rather than statistical generalization. Quantitative findings were validated through comparison with field observations, semi-structured interviews, and project documentation, allowing numerical patterns to be interpreted against actual workplace conditions and construction practices, an approach consistent with systematic construction safety assessment that emphasizes identification and contextual evaluation of occupational hazards (Mei Dina & Purba, 2022). The final analysis was limited to occupational accident types, sources, and severity during project implementation and excluded accident-cost calculations, formal risk quantification, and technical road-design analysis, producing a reproducible descriptive profile of occupational accident patterns at the Pulokulon–Jambon Road Project.

RESULTS AND DISCUSSION

Accident Distribution and Types

The distribution of occupational accidents by time of occurrence indicates a non-uniform pattern across the working periods observed during the Pulokulon–Jambon Road Improvement Project. From the 15 recorded accident cases, the afternoon represented the highest proportion, followed by the evening and morning periods. The temporal distribution provides an initial indication of when workers were more frequently exposed to accident-producing conditions during project execution. The afternoon period coincided with several intensive construction operations, including concrete paving, material transportation, excavator operation, and compaction activities using vibro rollers. Hot working conditions and prolonged physical activities were also observed during these periods, creating workplace circumstances that may affect worker concentration and physical performance. Suma'mur (2014) emphasizes that occupational accident prevention is closely associated with the management of working conditions and the maintenance of safe work practices throughout occupational activities. The numerical distribution of the 15 reported cases according to the time of occurrence is presented in Table 2, while its graphical representation is shown in Figure 2.

Table 2. Distribution of Occupational Accidents by Time of Occurrence

Time of Occurrence	Number of Cases	Percentage
Morning	3	20.0%
Afternoon	7	46.7%
Evening	5	33.3%
Total	**15**	**100%**

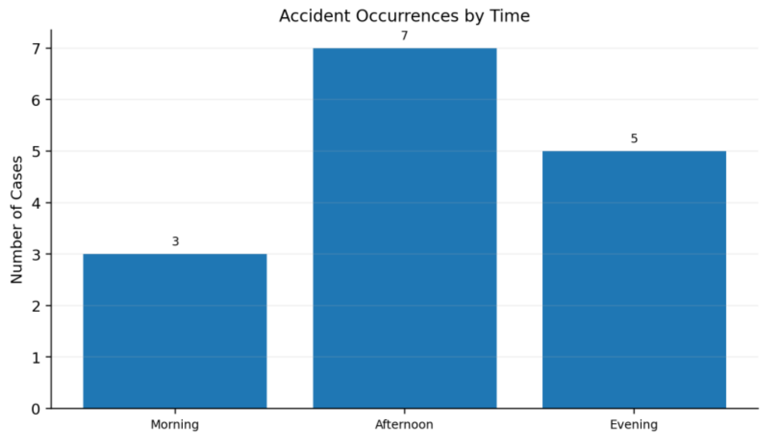

Figure 2. Distribution of Occupational Accidents by Time of Occurrence

Table 2 and Figure 2 show that the afternoon recorded the highest number of occupational accidents, with 7 cases or 46.7% of the total observations, followed by the evening with 5 cases (33.3%) and the morning with 3 cases (20.0%). The difference indicates that accident occurrence was concentrated in the later part of the working period rather than being evenly distributed across the observed time intervals. The afternoon concentration can be interpreted in relation to the simultaneous execution of paving, material transportation, earthwork, and compaction activities, which increases the number of workers, materials, and operating equipment interacting within the work area. The presence of heat and prolonged work exposure may also create conditions in which physical fatigue and reduced concentration become relevant contextual factors, although the present study does not establish these factors as statistically verified causes. The finding is consistent with the occupational-safety perspective that prevention requires continuous control of workplace conditions and worker performance rather than relying solely on responses after an accident has occurred. The temporal pattern therefore provides an important descriptive basis for strengthening supervision and safety monitoring during periods of intensive construction activity.

The distribution of occupational accidents by type further clarifies the nature of the incidents recorded during project implementation. Five accident categories were identified, comprising slipping, scratches caused by materials, being struck by materials, near misses involving heavy equipment, and being caught in work equipment. Slipping represented the most frequently reported category, indicating that interaction with work surfaces constituted a prominent form of accident exposure. Material-related incidents also accounted for a substantial proportion of cases, reflecting the extensive handling and movement of construction materials throughout road improvement activities. Heavy-equipment-related events appeared less frequently but remained relevant because workers and machinery operated within interconnected work zones. The distribution of these accident types provides a basis for distinguishing frequent routine exposures from less frequent equipment-related events. The detailed numerical distribution is presented in Table 3 and visualized in Figure 3.

Table 3. Distribution of Occupational Accidents by Type

Accident Type	Number of Cases	Percentage
Slipping	5	33.3%
Scratched by material	4	26.7%
Struck by material	3	20.0%
Near miss involving heavy equipment	2	13.3%
Caught in work equipment	1	6.7%
Total	**15**	**100%**

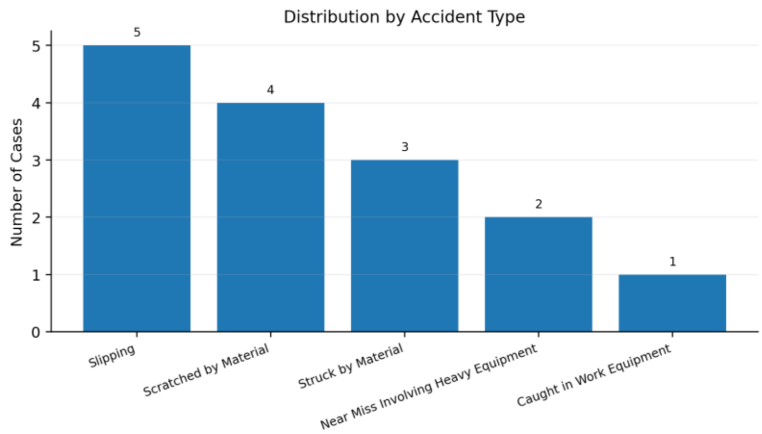

Figure 3. Distribution of Occupational Accidents by Type

Table 3 and Figure 2 demonstrate that slipping was the dominant accident type, accounting for 5 cases (33.3%), followed by scratches caused by materials with 4 cases (26.7%) and workers being struck by materials with 3 cases (20.0%). Near misses involving heavy equipment represented 2 cases (13.3%), whereas being caught in work equipment constituted 1 case (6.7%). The predominance of slipping suggests that routine work-surface conditions represented a more frequent exposure pathway than direct entrapment or contact with operating machinery. The International Labour Organization (2013) recognizes machinery, materials, work areas, and changing construction-site conditions as important sources of occupational exposure in construction, which corresponds to the range of accident types identified in this project. The relatively lower frequency of heavy-equipment incidents should not be interpreted as an indication of low safety significance because events involving moving equipment may carry consequences disproportionate to their frequency. The accident-type distribution therefore indicates that effective prevention needs to address everyday environmental and material-related exposures while maintaining strict controls over worker interaction with heavy equipment.

The relationship between accident types and construction activities indicates that the reported incidents were distributed across both manual and mechanized operations rather than being concentrated in a single work process. Slipping incidents were observed in activities involving ground preparation, drainage, formwork, concrete placement, and road paving, where workers were required to move across surfaces whose physical conditions changed during execution. Material-related injuries were similarly associated with reinforcing steel, formwork components, masonry, aggregate, and material transportation, indicating that handling, positioning, and movement of materials represented recurring exposure points. Heinrich et al. (1980) argue that accidents can develop through the interaction of unsafe acts and unsafe conditions, making the recurrence of these incidents relevant not only to individual worker behavior but also to the physical organization of work. The presence of near misses involving heavy equipment further demonstrates that the absence of a recorded injury does not necessarily indicate the absence of hazardous interaction within the construction environment. From an engineering-management perspective, the accident profile therefore reflects multiple interacting exposure pathways that require controls adapted to the characteristics of each construction activity. This interpretation supports examining the specific sources of accidents in greater detail, particularly environmental conditions, construction materials, heavy equipment, and work equipment.

The findings also indicate that the accident profile should be interpreted according to the frequency and operational context of incidents rather than solely according to their apparent severity. Frequent slipping and material-contact incidents may represent persistent weaknesses in everyday work conditions, including surface maintenance, material arrangement, movement routes, and worker positioning, even when individual events result in relatively limited physical consequences. Ishikawa (1985) emphasizes the importance of identifying process-related causes and controlling variation at the operational level, a perspective that can be applied to recurring safety problems in construction activities where similar conditions repeatedly generate exposure. The observed pattern suggests that accident prevention at the Pulokulon–Jambon project requires attention to the consistency of routine controls rather than interventions directed only at exceptional events. This includes maintaining safe walking surfaces, organizing construction materials, separating pedestrian and equipment movement where feasible, and reinforcing safe work procedures during activities involving tools and machinery. Such measures are particularly relevant because the descriptive evidence identifies repeated exposure across several stages of project implementation rather than an isolated cluster associated with one unusual event. The accident distribution therefore provides an empirical foundation for the subsequent analysis of accident sources and site conditions, where the relative contribution of environmental conditions, materials, heavy equipment, and work equipment can be examined more specifically.

Accident Sources and Site Conditions

The distribution of occupational accidents by source demonstrates that the reported incidents originated from four principal categories of exposure, namely road-surface conditions, construction materials, heavy equipment, and work equipment. These categories represent different dimensions of the construction environment and provide a more specific explanation of the accident types identified in the preceding analysis. Road-surface conditions constituted the largest source, while construction materials and heavy equipment contributed comparable proportions of the recorded cases. Work equipment accounted for the smallest proportion, although its occurrence remained relevant because it was associated with direct manual interaction during several construction activities. The classification of accident sources enables the observed incidents to be interpreted according to the physical and operational conditions surrounding workers rather than only according to the resulting injury. This approach is consistent with construction safety management, which requires attention to environmental, equipment, work-process, and human factors in controlling occupational hazards (Djatmiko, 2016). The distribution of the four accident-source categories is presented in Table 4 and illustrated in Figure 4.

Table 4. Distribution of Occupational Accidents by Source

Accident Source	Number of Cases	Percentage
Road surface condition	5	33.3%
Construction material	4	26.7%
Heavy equipment (excavator, vibro roller, dump truck)	4	26.7%
Work equipment	2	13.3%
Total	**15**	**100%**

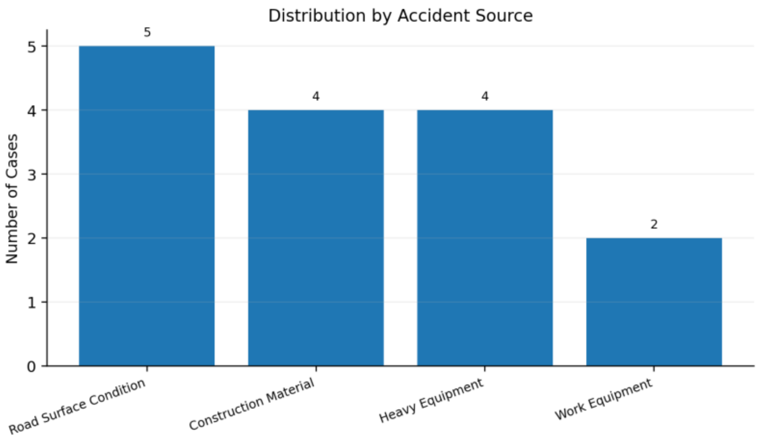

Figure 4. Distribution of Occupational Accidents by Source

Table 4 and Figure 4 show that road-surface conditions represented the largest accident source, accounting for 5 cases (33.3%), followed by construction materials and heavy equipment with 4 cases each (26.7%), while work equipment accounted for 2 cases (13.3%). The predominance of road-surface conditions is closely related to the physical characteristics of road construction, where workers repeatedly move across surfaces that may change because of excavation, drainage, paving, compaction, moisture, and material placement. Field observations associated the reported surface-related incidents with slippery, uneven, muddy, and wet areas, particularly during activities in which workers were required to maintain mobility within active work zones. Kurniawidjaja (2010) emphasizes that workplace conditions constitute an important dimension of occupational health and safety because physical characteristics of the work environment can influence workers' exposure to hazards. The concentration of incidents associated with road surfaces therefore indicates that housekeeping and surface-condition control represent important preventive dimensions for this project. The finding also demonstrates that accident prevention in road construction cannot rely exclusively on worker compliance because physical conditions created by ongoing construction activities can directly influence the likelihood of unsafe movement.

Construction materials constituted the second-largest accident source, with 4 cases or 26.7% of the recorded incidents. The materials involved in the observed activities included reinforcing steel, formwork boards, masonry, aggregate, and materials handled during loading and unloading operations. These materials generated different exposure mechanisms, ranging from scratches and impacts to injuries associated with lifting, carrying, positioning, and accidental material movement. The repeated occurrence of material-related incidents indicates that material handling should be considered a safety-critical component of routine construction operations rather than merely a logistical activity. The International Labour Organization (2013) identifies construction materials and their handling as important occupational hazards because workers frequently interact with materials while performing tasks within changing and congested work environments. Field observations further indicate that material-related exposure was present across reinforcing-steel work, formwork, paving, and transportation activities, suggesting that the source was distributed across several stages rather than restricted to one operation. Control measures therefore need to consider material storage, positioning, lifting techniques, loading and unloading procedures, and worker movement around material-handling areas.

Heavy equipment represented 4 accident cases (26.7%), equal to the contribution of construction materials, with the relevant equipment comprising excavators, vibro rollers, and dump trucks. The principal safety concern associated with this source was the interaction between workers and operating or moving equipment within shared construction areas. Field observations identified incidents involving proximity to excavators and other heavy equipment, while the absence of recorded run-over or bucket-entrapment cases does not eliminate the potential hazard associated with such interactions. Bria et al. (2024) demonstrate that construction accidents in Indonesia may involve multiple interacting causal factors, reinforcing the importance of examining equipment-related exposure within the broader configuration of site operations. The presence of heavy equipment alongside workers creates a dynamic risk environment in which visibility, communication, equipment movement, and spatial separation can influence the conditions under which an incident may occur. This source therefore requires control through clearly defined equipment operating zones, communication between operators and ground personnel, appropriate signaling, and supervision of worker movement around active machinery. The empirical findings indicate that heavy-equipment safety should be maintained even when the observed frequency is lower than that of surface-related incidents because the operational consequences of uncontrolled worker–equipment interaction may be substantial.

Work equipment accounted for 2 cases (13.3%), representing the smallest of the four identified accident-source categories. Despite its lower frequency, work equipment remained relevant because direct interaction with tools occurred repeatedly during manual construction activities such as land clearing, drainage, reinforcing-steel work, and formwork. The observed incidents included hand injuries associated with equipment use and contact with work materials, indicating that relatively simple tools can become accident sources when used in physically demanding or spatially constrained conditions. Reese (2009) emphasizes the importance of controlling immediate workplace causes through appropriate safety management because preventable conditions at the point of work can contribute directly to occupational incidents. The relatively small proportion of work-equipment-related cases should therefore be interpreted as a frequency finding rather than as evidence that these tools require less attention. Appropriate tool selection, inspection, handling procedures, worker competence, and PPE remain relevant controls for reducing direct-contact injuries during manual operations. The finding also demonstrates that the accident-source profile encompasses both large-scale mechanized hazards and smaller equipment-related exposures embedded within routine construction tasks.

The four accident-source categories collectively demonstrate that occupational accidents at the Pulokulon–Jambon Road Project were associated with a combination of environmental conditions, construction materials, heavy equipment, and work equipment rather than a single dominant mechanism. Road-surface conditions produced the highest observed frequency, but the combined contribution of construction materials and heavy equipment was also substantial, indicating that physical site conditions and operational interactions jointly shaped the accident profile. Heinrich et al. (1980) conceptualize accidents as resulting from interactions between unsafe acts and unsafe conditions, which supports interpreting the present findings beyond an attribution of accidents to individual worker behavior. Reason (1997) further emphasizes that accident pathways may involve latent weaknesses within organizational systems, making the observed physical conditions relevant to broader questions of work organization and safety control. The source distribution therefore indicates that effective prevention requires an integrated approach involving surface maintenance, material management, equipment segregation, safe work procedures, supervision, and worker awareness. This interpretation is also consistent with construction OSH research emphasizing systematic hazard identification and control across different work activities rather than isolated treatment of individual accident mechanisms (Magda et al., 2023). The empirical source profile consequently provides a basis for examining accident severity and work-stage patterns, where the consequences and recurrence of these sources can be interpreted in relation to specific construction activities.

Accident Severity

The severity distribution indicates that occupational accidents at the Pulokulon–Jambon Road Improvement Project were predominantly classified as minor incidents, while moderate and severe cases represented smaller proportions of the recorded accidents. This distribution provides an important basis for evaluating the consequences associated with the accident sources identified in the project because frequency alone does not adequately describe the potential impact of an incident. Minor accidents generally involved scratches, slipping without serious injury, minor impacts, or light muscle injuries, whereas moderate cases involved injuries requiring greater attention or medical treatment. Severe accidents occurred less frequently, but their presence indicates that the project still contained exposure conditions capable of producing substantial consequences. The distinction between accident frequency and accident consequence is important in construction safety because a low-frequency event may represent a critical hazard pathway that requires preventive control. Suma'mur (2009) emphasizes that occupational accident prevention should consider workplace conditions and the potential consequences of occupational exposure rather than relying only on the number of incidents recorded.

The observed distribution consisted of 10 minor accidents (66.7%), 4 moderate accidents (26.7%), and 1 severe accident (6.6%), as presented in Table 5. The predominance of minor cases suggests that the most frequently encountered accident mechanisms generally produced limited physical consequences, particularly those associated with routine movement, material contact, and manual work activities. Moderate accidents nevertheless accounted for more than one-quarter of the recorded cases, indicating that several workplace conditions had the capacity to produce injuries requiring more substantial intervention. The single severe case should not be regarded as negligible because severity represents the magnitude of potential consequence rather than merely the frequency of occurrence. Reason (1997) argues that organizational accidents can emerge through combinations of active failures and latent conditions, making low-frequency but high-consequence events relevant to the evaluation of safety controls. The severity distribution therefore needs to be interpreted alongside accident sources and work-stage observations to identify whether recurring exposure conditions also possess the potential to generate more serious outcomes.

Table 5. Distribution of Occupational Accidents by Severity

Accident Source	Number of Cases	Percentage
Road surface condition	5	33.3%
Construction material	4	26.7%
Heavy equipment (excavator, vibro roller, dump truck)	4	26.7%
Work equipment	2	13.3%
Total	**15**	**100%**

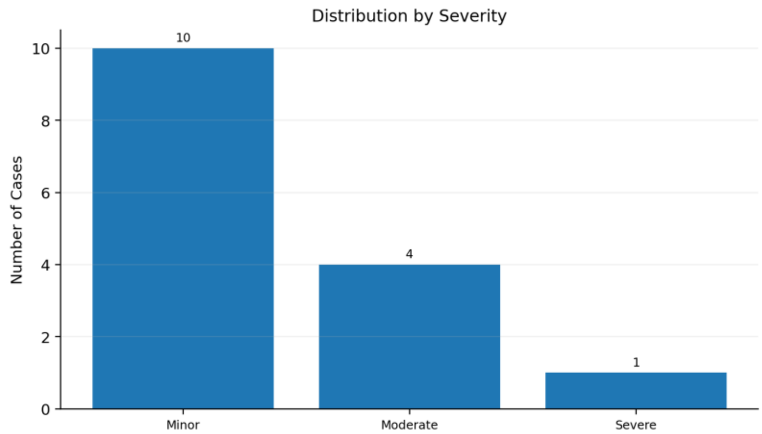

Figure 5. Distribution of Occupational Accidents by Severity

As shown in Table 5 and Figure 5, the 66.7% proportion of minor accidents represents the dominant severity profile, followed by moderate accidents at 26.7% and severe accidents at 6.6%. The concentration of minor cases is consistent with the accident types previously identified, particularly slipping, scratches from construction materials, and minor contact with equipment. However, the presence of moderate and severe cases demonstrates that the project safety profile cannot be assessed solely from the predominance of relatively low-consequence incidents. Reese (2009) emphasizes the importance of controlling immediate workplace causes through systematic safety management and supervision, which is particularly relevant when recurring minor incidents indicate persistent exposure conditions. The severity pattern also suggests that preventive measures should address both high-frequency routine hazards and less frequent mechanisms with potentially greater consequences. Figure 4 reinforces the numerical distribution by showing the substantial difference between minor incidents and the two higher-severity categories.

The relationship between severity and accident characteristics indicates that accident consequences were influenced by the type of interaction occurring during construction activities. Slipping and material-contact incidents appeared frequently among the recorded cases, while injuries associated with manual handling, work equipment, and heavy-equipment interaction also produced moderate or potentially more consequential outcomes. Suma'mur (2014) places accident prevention within systematic control of working conditions, suggesting that repeated exposure to seemingly routine hazards should remain an important target of preventive intervention. The field evidence indicates that accident severity was not determined simply by whether an activity involved heavy equipment, because manual activities such as reinforcing-steel handling and material transportation also produced moderate injuries. This finding supports an interpretation in which severity emerges from the interaction between the hazard source, worker position, task characteristics, and conditions present during execution. Such an interpretation is consistent with the broader accident-causation perspective that occupational incidents should be examined through interacting conditions rather than attributed exclusively to individual worker behavior.

The severity profile also has implications for the evaluation of occupational safety performance at the project level because frequent minor incidents can indicate weaknesses in everyday preventive controls. Persistent slipping, material contact, and manual-handling exposure may not immediately result in severe injury, yet their recurrence demonstrates that workers remain repeatedly exposed to preventable hazards. The International Labour Organization (2013) identifies construction as an activity characterized by changing work environments, machinery, materials, and work conditions that require systematic occupational safety control. The present findings reinforce the need to maintain basic preventive measures such as housekeeping, appropriate PPE, safe material arrangement, controlled movement areas, and task-specific supervision throughout project execution. The moderate and severe categories provide an additional warning that preventive programs should not be evaluated only from the absence of catastrophic accidents. A balanced interpretation of the severity distribution therefore requires simultaneous attention to incident frequency, injury consequence, and the workplace conditions that repeatedly generate exposure.

At the project level, the severity findings provide a descriptive baseline for connecting accident outcomes with the source and work-stage analyses presented in the subsequent sections. The dominance of minor incidents indicates that routine construction activities generated the largest share of recorded occupational accidents, while the moderate and severe categories identify less frequent but potentially more consequential exposure pathways. This distinction is particularly relevant for construction safety management because preventive priorities should consider both the recurrence of incidents and the possible consequences associated with their underlying mechanisms. Djatmiko (2016) identifies environmental conditions, machinery, work practices, and human factors as interconnected domains of occupational accident prevention, which corresponds to the multidimensional pattern observed in the project. The severity data therefore provide an important interpretive bridge between the overall accident profile and the more detailed examination of accident occurrence across individual construction stages. The next analysis examines these work-stage patterns to determine how specific activities contributed to the observed accident characteristics.

Work-Stage Accident Findings

The work-stage analysis provides a more detailed explanation of how occupational accident exposure varied according to the specific construction activities performed at the Pulokulon–Jambon Road Improvement Project. Rather than treating the 15 recorded accidents as a homogeneous group, the stage-based observations distinguish the physical conditions, materials, tools, and equipment encountered during each activity. The findings indicate that accident exposure was present from early land-clearing activities through excavation, drainage, reinforcement, formwork, concrete pouring, paving, material transportation, and heavy-equipment operations. This variation demonstrates that the accident profile was closely associated with task characteristics and the immediate conditions under which construction work was performed. Djatmiko (2016) identifies work environment, machinery, equipment, work practices, and human factors as interconnected elements in occupational accident prevention, providing a relevant basis for interpreting these stage-specific patterns. The following observations therefore extend the aggregate accident analysis by identifying the particular activities in which recurrent exposure was reported.

Table 6. Accident Observations During Land Clearing

Accident Type	Respondents Observing	Percentage	Dominant Severity
Slipping due to slippery ground surface	15	100%	Minor
Scratched by shrubs or sharp objects	15	100%	Moderate
Eyes exposed to dust or branches	13	87%	Minor
Hands injured while using work equipment	15	100%	Moderate
Struck by branches or clearing materials	13	87%	Minor

Table 6 shows that land clearing was characterized by repeated exposure to surface, vegetation, environmental, and work-equipment hazards. Slipping on slippery ground, scratches from shrubs or sharp objects, and hand injuries associated with work equipment were each reported by all 15 respondents, indicating that these conditions were consistently recognized during the activity. Eye exposure to dust or branches and contact with branches or clearing materials were also reported at 87%, suggesting that workers encountered multiple forms of physical exposure simultaneously. The combination of these hazards indicates that land clearing involved direct interaction between workers and an uncontrolled or rapidly changing work environment. Suma'mur (2014) emphasizes the importance of controlling workplace conditions as part of accident prevention, which is particularly relevant to activities where ground conditions and environmental obstacles can change during execution. The findings indicate that preventive attention during land clearing should emphasize surface management, vegetation clearance, PPE use, and safe handling of work equipment.

Table 7. Accident Observations During Earth Excavation

Accident Type	Ever Occurred	Percentage	Dominant Severity
Slipping into excavation area	7	47%	Moderate
Struck by soil collapse	0	0%	0
Hit by excavator bucket	0	0%	0
Hit by dump truck	0	0%	0
Caught by excavated material	0	0%	0

Table 7 presents a different exposure pattern during earth excavation, with 7 respondents (47%) reporting slipping into the excavation area while no respondents reported soil collapse, excavator-bucket impact, dump-truck impact, or entrapment by excavated material. The moderate dominant severity associated with slipping indicates that excavation access and worker movement represented the principal reported concern in this activity. The absence of reported cases for other mechanisms should be interpreted within the boundaries of the 15-person sample and the descriptive design rather than as evidence that these hazards were intrinsically absent from excavation work. Pongtuluran et al. (2024) demonstrate that earthwork hazards require activity-specific identification because excavation introduces particular risks associated with ground conditions, access, and equipment interaction. The comparatively narrow pattern observed here may reflect the work practices and controls implemented during the project period. Continued attention to excavation access, worker positioning, and separation from operating machinery remains relevant even when specific high-consequence events were not reported.

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Table 8. Accident Observations During Drainage Works

Accident Type	Ever Occurred	Percentage	Dominant Severity
Slipping in drainage channel	15	100%	Moderate
Hit by work equipment	15	100%	Moderate
Hands scratched by concrete material	14	93%	Minor/Moderate
Feet struck by masonry stone	14	93%	Minor
Falling into drainage channel	1	7%	Minor

Drainage activities exhibited one of the most pronounced patterns of recurrent exposure, as slipping within the drainage channel and contact with work equipment were reported by all respondents. Scratches from concrete materials and feet struck by masonry stones were also reported by 14 respondents, corresponding to 93% of the sample. These findings indicate that workers faced simultaneous risks from movement within confined or uneven areas and from direct contact with materials and tools. The occurrence of falling into the drainage channel was reported by only one respondent, showing that the frequency of a particular event can differ substantially from the broader exposure to the same work environment. Kurniawidjaja (2010) emphasizes the relationship between occupational health protection and workplace conditions, supporting the interpretation that drainage safety depends not only on individual behavior but also on the physical configuration of the work area. The drainage findings therefore highlight the importance of stable access, housekeeping, controlled tool movement, and worker positioning within drainage work zones.

Table 9. Accident Observations During Reinforcing-Steel Work

Accident Type	Ever Occurred	Percentage	Dominant Severity
Hands caught in formwork	5	33%	Minor
Stepped on nails	15	100%	Minor
Struck by formwork boards	10	67%	Minor
Slipping during installation	15	100%	Minor
Falling during formwork dismantling	5	33%	Minor

Table 10. Accident Observations During Formwork

Accident Type	Ever Occurred	Percentage	Dominant Severity
Hands caught in formwork	5	33%	Minor
Stepped on nails	15	100%	Minor
Struck by formwork boards	10	67%	Minor
Slipping during installation	15	100%	Minor
Falling during formwork dismantling	5	33%	Minor

The reinforcing-steel and formwork stages demonstrate the importance of repetitive manual interaction with construction materials as a source of occupational exposure. Table 9 shows universal reporting of hand scratches from rebar ends and muscle injuries from lifting rebar, while 87% of respondents reported hands being caught by reinforcing steel. Table 10 similarly shows universal reporting of stepping on nails and slipping during formwork installation, with contact from formwork boards reported by 67% of respondents. These patterns indicate that material geometry, manual handling, walking surfaces, and work positioning contributed more prominently than rare catastrophic mechanisms during these activities. Magda et al. (2023) emphasize that construction accident identification should consider hazards according to specific work activities, which is consistent with the distinct exposure patterns identified in reinforcing-steel and formwork operations. The results support preventive measures directed toward sharp-edge protection, appropriate lifting practices, material organization, housekeeping, and control of movement within formwork areas.

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Table 11. Accident Observations During Concrete Pouring

Accident Type	Ever Occurred	Percentage	Dominant Severity
Exposed to concrete-mix splashes	15	100%	Minor
Skin irritation from cement	0	0%	0
Slipping on wet concrete surface	13	87%	Minor
Caught by concrete-pouring hose	0	0%	0
Struck by pouring equipment	0	0%	0

Concrete pouring was dominated by direct exposure to concrete materials and wet working surfaces, as shown in Table 11. All 15 respondents reported exposure to concrete-mix splashes, while 13 respondents (87%) reported slipping on wet concrete surfaces. The absence of reported cement-related skin irritation, hose entrapment, and contact with pouring equipment indicates that these specific mechanisms were not identified among the observed cases. The contrast between universal material exposure and the absence of particular injury mechanisms demonstrates that exposure does not necessarily translate into recorded injury, although it remains relevant to preventive control. The International Labour Organization (2013) recognizes construction work as involving changing material, equipment, and workplace exposures that require systematic safety management. Concrete-pouring controls therefore need to address both the direct physical contact with construction materials and the temporary changes in surface conditions produced during the activity.

Table 12. Accident Observations During Road Paving

Accident Type	Ever Occurred	Percentage	Dominant Severity
Hit by stone fragments	15	100%	Moderate
Slipping in work area	15	100%	Moderate
Run over by compaction equipment	0	0%	0
Exposed to hot material (if asphalt is used)	0	0%	0
Injury during compaction process	15	100%	Minor

Table 12 indicates a strong concentration of exposure during road paving, with stone-fragment contact, slipping in the work area, and injury during compaction reported by all respondents. The dominant severity was moderate for stone-fragment contact and slipping, whereas compaction-related injury was classified as minor, indicating variation in consequence even within the same construction stage. No respondents reported being run over by compaction equipment or exposed to hot material, which limits the observed accident profile to the mechanisms actually identified by project personnel. The combination of material fragments, unstable work surfaces, and active compaction operations suggests that worker positioning and separation from operating equipment were important control considerations. Marliana et al. (2024) demonstrate the relevance of systematic hazard identification and control in road construction, particularly because work activities change as the roadway progresses through successive construction stages. The paving findings therefore reinforce the need for task-specific controls covering worker positioning, surface stability, material handling, and interaction with compaction equipment.

Table 13. Accident observations during material transport

Accident Type	Ever Occurred	Percentage	Dominant Severity
Hit by dump truck	0	0%	0
Material falling during loading/unloading	13	87%	Minor
Hands caught by material	0	0%	0
Injury while lifting material	15	100%	Moderate
Slipping while carrying material	7	47%	Moderate

Material transportation presented a combination of manual-handling and loading or unloading hazards, with injury while lifting materials reported by all 15 respondents. Material falling during loading or unloading was reported by 13 respondents (87%), while slipping while carrying materials was reported by 7 respondents (47%) and was associated with moderate severity. No respondents reported being hit by a dump truck or having their hands caught by materials, indicating that the dominant exposure in this activity was related more strongly to handling and movement than to direct vehicle contact. This pattern demonstrates that material transportation involves risks extending beyond vehicle operation because workers are simultaneously required to lift, carry, position, and receive construction materials. Lubis et al. (2025) emphasize integrated risk mitigation across occupational and environmental dimensions, which is relevant to material transport where worker movement, material stability, and site conditions interact. The findings support greater attention to manual-handling procedures, load stability, carrying routes, and coordination during loading and unloading operations.

Table 14. Accident Observations During Heavy-Equipment Operation

Accident Type	Ever Occurred	Percentage	Dominant Severity
Struck by excavator	10	67%	Minor
Run over by heavy equipment	0	0%	0
Caught by excavator bucket	0	0%	0
Hit by heavy equipment	7	47%	Minor
Struck by material from bucket	0	0%	0

Heavy-equipment operations reveal a distinct worker–machine interaction pattern, with 10 respondents (67%) reporting incidents involving being struck by an excavator and 7 respondents (47%) reporting being hit by heavy equipment. The dominant severity for these reported events was minor, while no respondents reported run-over incidents, entrapment by an excavator bucket, or being struck by material falling from a bucket. The relatively high reporting rate for excavator-related contact indicates that proximity to operating machinery remained an important exposure even though the most severe mechanisms were not recorded. Bria et al. (2024) demonstrate the significance of construction accident mechanisms involving equipment and unsafe work conditions in the Indonesian construction context, supporting closer examination of equipment-related exposure at project level. The absence of catastrophic equipment incidents should therefore be interpreted as a characteristic of the observed cases rather than evidence that worker–equipment interaction was adequately controlled in every situation. The findings reinforce the importance of defined equipment operating zones, communication between operators and ground workers, controlled access, and consistent supervision during heavy-equipment activities.

Taken together, Tables 6–14 demonstrate that accident exposure changed according to the construction stage rather than following a single uniform pattern throughout the project. Land clearing was characterized by environmental and tool-related exposure, drainage by slipping and material contact, reinforcing-steel and formwork activities by manual handling and sharp-material hazards, and concrete pouring and paving by wet surfaces and material interaction. Material transportation introduced substantial lifting-related exposure, while heavy-equipment operations were distinguished by worker–machine interaction. Heinrich et al. (1980) conceptualize accidents as arising from combinations of unsafe acts and unsafe conditions, and the present stage-specific findings illustrate how these elements can coexist within routine construction tasks. The recurring nature of several observations indicates that preventive control should be embedded within daily work procedures rather than applied only after an accident has occurred. The stage-based evidence consequently complements the aggregate findings on accident type, source, and severity by showing how specific work processes generated the conditions underlying the observed occupational accident profile.

CONCLUSION

This study demonstrates that occupational accidents at the Pulokulon–Jambon Road Improvement Project are closely associated with workplace surface conditions, construction materials, work equipment, and heavy-equipment activities. Among the 15 recorded cases, slipping was the most frequently identified accident type, while slippery or uneven road-surface conditions represented the largest accident-source category. Accidents were also identified across multiple construction stages, including land clearing, earth excavation, drainage, reinforcing-steel work, formwork, concrete pouring, road paving, material transport, and heavy-equipment operation. In terms of severity, minor accidents constituted the largest proportion, followed by moderate and severe cases with lower frequencies. This pattern indicates that routine exposure to unsafe working conditions remains an important component of occupational accident occurrence in road construction activities. Accident prevention should therefore emphasize workplace-surface control, material organization, PPE compliance, safe work procedures, and effective management of worker interactions with heavy equipment.

The primary contribution of this study is the provision of project-specific empirical evidence linking accident types, accident sources, severity levels, and work-stage observations within a road construction context. The descriptive approach, supported by questionnaires, field observations, interviews, and project documentation, enabled the identified accident patterns to be interpreted in relation to actual working conditions during project implementation. The findings provide a practical basis for strengthening supervision of routine workplace conditions, particularly in activities where repeated minor and moderate accident exposures were identified. The evidence can also serve as a reference for evaluating occupational safety practices in road construction projects with comparable operational characteristics. The study does not extend to statistical generalization, accident-cost estimation, or inferential risk modeling, keeping the conclusions consistent with the empirical scope and descriptive design of the research. Overall, the findings reinforce the importance of integrated occupational safety management that addresses environmental conditions, construction materials, work equipment, worker activities, and heavy-equipment operations across successive construction stages.

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