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Analysis of Risk Management Implementation in the Cleaning Process of Coffee Roasting Machines at Manufacturing Industry Using Risk Identification and Matrix Approach

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A B S T R A C T

This study aims to identify and analyze occupational safety risks during the cleaning process of large-capacity coffee roasting machines at manufacturing industry. The method used is quantitative descriptive analysis with a risk assessment approach, using the SNI ISO 31000:2018 standard. Data were collected through interviews, direct observation, and literature studies. The results of the study indicate that the main risks include slipping, falling from a height, contact with sharp or hot objects, physical fatigue, and the risk of electrical contact. The risks with the highest severity are falling from a height and electrical contact, which are exacerbated by the lack of occupational safety facilities such as signs and personal protective equipment (PPE). Through a risk matrix and fishbone analysis, a mitigation strategy was designed in the form of installing safety facilities, implementing standard operational procedures, occupational health and safety (OHS) training, and routine inspections. The implementation of these steps is expected to create a safer work environment, increase efficiency, and support operational sustainability at manufacturing industry.

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1. INTRODUCTION

Manufacturing industry is a manufacturing company specializing in the production of food and beverages, with one of its main products being instant coffee. To maintain the quality and quantity of its production output, the company relies on large-capacity machines designed to operate optimally. Routine maintenance and regular cleaning before and after production are crucial steps that cannot be overlooked to ensure the efficiency and reliability of these machines. Preventive maintenance conducted regularly plays a vital role in preventing sudden disruptions, avoiding severe damage, and minimizing potential productivity losses for the company. An effective preventive maintenance (PM) strategy plays a crucial role in minimizing equipment failures and ensuring operational continuity (Basri et al., 2020). Research trends highlight that PM policies have evolved over the years, integrating advanced methodologies such as mathematical modeling, matrix formation, and critical analysis to enhance system reliability. In industrial settings, PM planning is often structured around cost, time, and failure considerations, aligning with risk management frameworks like ISO 31000:2018. Workplace safety remains a critical issue, particularly in developing countries where occupational exposure to hazards and injuries continues to rise (Dodoo & Al-Samarraie, 2021). A systematic review of workplace safety literature has identified construction as the industry with the highest number of workplace injuries and fatalities. These findings emphasize the need for stronger safety regulations and risk management frameworks to mitigate occupational hazards across various job contexts.

The cleaning process of the machines holds a crucial role in maintaining operational performance and meeting product hygiene standards. However, this activity is often accompanied by significant occupational safety risks, especially when it involves large and complex machinery. For example, in the United States, the United Kingdom, and Sweden, workplace injuries related to slips, trips, and falls account for between 20% and 40% of work-related injuries highlighting the high potential hazards that can impact operators. The use of Personal Protective Equipment (PPE) plays a crucial role in preventing occupational hazards and ensuring workplace safety (Mahmood et al., 2020). Similar to how PPE was vital in controlling COVID-19 transmission, its application in industrial settings, such as food manufacturing, is essential to minimize exposure to potential risks. Workers involved in operational processes, including equipment maintenance and cleaning, require adequate protective measures to prevent direct contact with hazardous substances and minimize health risks.

Risk management is a crucial element in ensuring workplace safety and operational sustainability (Mahmood et al., 2020). During the COVID-19 pandemic, effective PPE management was essential due to the high global demand and limited supply. Similarly, in industrial settings, structured risk management frameworks, such as ISO 31000:2018, are necessary to optimize the use of safety equipment, minimize occupational hazards, and ensure continuous operations. In practice, routine cleaning at manufacturing industry often involves working at heights, climbing up and down ladders, and using additional supporting tools. Despite this, the lack of safety facilities in the work area, such as warning signs or notice boards, remains one of the main challenges. This causes operators to work without adequate safety guidance. The presence of adequate safety facilities, such as warning signs, plays a critical role in reducing the potential for workplace accidents and creating a safer work environment.

Some of the main risks faced by operators include slipping, falling from heights, being exposed to sharp or hot objects, and electrical contact. These risks are often exacerbated by non-ergonomic machine designs or a lack of awareness of workplace safety importance. Therefore, an in-depth analysis of existing risks and identifying the need for additional safety facilities, such as warning signs and personal protective equipment (PPE), is urgently needed. By implementing a well-planned risk management strategy, it is expected that potential accidents can be minimized, thereby creating a safer work environment and supporting the sustainability of the company's operations. The most commonly identified hazards in Indonesia's manufacturing industry are physical hazards, with medium to high risk levels (Irfan, 2024) . The primary risk control measures applied are administrative controls, emphasizing the importance of structured safety management approaches to enhance workplace safety. The following image provides a concrete illustration of the challenges faced by operators during routine cleaning of large-capacity roasting machines. The image depicts operators working at heights without adequate safety equipment, emphasizing the need for improvements in workplace safety facilities in the area (Maharani et al., 2024).

Figure 1. Operator activities when cleaning the machine

Figure 1 shows one of the operator's activities while performing routine cleaning on the top of a large-capacity roasting machine. This process shows the challenges faced, such as working at heights without adequate safety equipment, as well as the lack of supporting facilities such as safety signs or additional handles in the work area. These conditions not only increase the risk of work accidents, but also highlight the urgent need for improved work safety governance in the company.

2. LITERATURE REVIEW

2.1 Risk management

Risk management is a strategic approach to identifying, analyzing, and managing various potential hazards that can affect workplace safety, operational sustainability, and efficiency across industries. ISO 31000:2018 serves as a fundamental guideline for implementing risk management within organizations, providing a structured framework to minimize uncertainties and establish a robust risk management program. In the manufacturing sector, such as at manufacturing industry, the application of risk management plays a crucial role in safeguarding worker safety, preventing financial and operational losses, and ensuring the smooth continuity of business processes (International Organization for Standardization, 2018) (Sitanggang, 2022).

A structured approach to risk management enables organizations to assess risks based on their severity and likelihood (Andry et al., 2024). Similar risk classification methods can be applied in food manufacturing industries to enhance risk mitigation strategies." Quantitative metrics play a crucial role in risk management by providing a structured approach to risk quantification and quality control (Prata et al., 2021). The use of statistical process control, including control charts, enables industries to monitor critical control points effectively and minimize defect rates. This risk-based approach aligns with the implementation of ISO 31000:2018 in operational risk management, particularly in industrial food processing where quality and safety assurance are essential. According to (Aisyah et al., 2023), risk management in the agroindustry supply chain, such as cocoa-based industries, plays a crucial role in balancing risks and ensuring operational sustainability. This principle aligns with the application of risk management in the food manufacturing industry, where risk mitigation efforts are necessary to enhance production efficiency and workplace safety. Therefore, the implementation of standards such as ISO 31000:2018 is essential for analyzing and controlling risks in the manufacturing sector, including operational processes such as the cleaning of industrial food processing machines.

Effective risk management can help the food and beverage industry to identify, evaluate and risk control and also to reduce the potential losses and to increase the overall success of the industry (Cristina et al., 2024). Through qualitative and quantitative analysis, research has identified key risks faced by shipping companies and evaluated the effectiveness of risk management strategies. Findings emphasize the significance of advanced technology, collaboration with maritime authorities, and a strong safety culture in improving company performance. The integration of risk management, capital structure, and product innovation is essential for sustaining financial performance in dynamic industrial environments (Judijanto et al., 2024). Managers and policymakers should adopt holistic approaches that balance risk mitigation with strategic investment to drive long-term profitability and competitiveness The research findings reinforce the importance of a structured approach to risk management in addressing maritime challenges and improving safety standards in the industry. Risk management is essential to identify and mitigate risks within the supply chain (Fan & Stevenson, 2018). A study on small and medium industry utilized the Supply Chain Operations Reference (SCOR) model and the House of Risk (HOR) method to determine mitigation priorities, the research identified 21 risk events and 19 risk agents affecting the supply chain, emphasizing the need for strategic risk mitigation (Nurwahidah & Nur, 2025).

The implementation of the House of Risk (HOR) and Interpretive Structural Modeling (ISM) methods provides a structured framework for risk mitigation in the manufacturing sector (Wakhyudi et al., 2024) By identifying key risk agents and prioritizing preventive actions, companies can enhance operational efficiency and minimize disruptions in production processes Risk management plays a crucial role in occupational health and safety (OHS) by systematically identifying, assessing, and controlling workplace hazards (Giovanni et al., 2023). The HIRARC method is widely used to classify risks based on their severity and likelihood, enabling industries to implement targeted mitigation strategies. This approach aligns with the application of ISO 31000:2018 in risk management, particularly in industrial operations such as equipment maintenance and cleaning processes.

Mining safety is closely linked to occupational safety and health management, which relies on effective risk management strategies (Tilc & Sari, 2023). A systematic literature review highlights that the Hazard Identification, Risk Assessment, and Determining Control (HIRADC) and Hazard Identification, Risk Assessment, and Risk Control (HIRARC) methods are widely applied in mining operations to identify hazards, assess risks, and implement control measures. Although initially designed for high-risk industries like mining, these structured approaches to risk identification and mitigation can also be applied in other industrial sectors, including manufacturing and food processing. The integration of these methods in industrial risk management allows organizations to proactively assess potential hazards, reduce workplace accidents, and enhance operational safety." The implementation of risk management strategies at PT Indofood has been effective in addressing various business risks (Rahmadanis et al., 2023). By integrating systematic risk management across divisions, the company has demonstrated resilience and adaptability in mitigating operational, financial, and environmental risks. Effective risk management in Indofood Sukses Makmur company enhances workplace safety and ensures sustainable operations (Rahmadanis et al., 2023).

The implementation of comprehensive risk control measures, including engineering improvements, administrative policies, and personal protective equipment, is essential for mitigating potential hazards and optimizing operational efficiency.

The House of Risk (HOR) approach is an effective methodology for identifying and evaluating risks in production systems (Arviana & Suseno, 2024). In Aleta Leather, this approach was applied in two phases—risk identification and risk evaluation—resulting in the identification of 18 risk agents, 7 risk events, and 19 preventative actions. These measures serve as key mitigation strategies to minimize operational risks and improve production efficiency. Effective risk management enables MSMEs to reduce business risks, enhance resilience, and seize future growth opportunities (Tilc & Sari, 2023). By systematically identifying and addressing financial, operational, and marketing risks, businesses can strengthen their market position, maintain consumer trust, and sustain long-term profitability Risk management in the manufacturing sector also aims to minimize negative impacts on workers, production equipment, and final outputs. Various studies indicate that ineffective risk management can lead to operational disruptions, financial losses, and serious workplace accidents. For instance, data shows that in countries like the United States, the United Kingdom, and Sweden, incidents of slipping, tripping, and falling account for up to 40% of workplace accidents (Aghnina., 2023). This highlights the importance of implementing comprehensive risk management to create a safer work environment.

2.2 Study on Risk Management Implementation at Manufacturing Industry

This study focuses on the cleaning activities of large-capacity coffee roasting machines at manufacturing industry, a manufacturing company in the food and beverage sector. Regular cleaning of these machines is crucial for maintaining operational performance and meeting product hygiene standards. However, these activities pose various potential hazards, such as: Hygiene control in the food industry plays a crucial role in minimizing microbiological risks and ensuring food safety from farm to fork (Holah et al., 2020). Proper contamination management, allergenic residue control, and pathogen prevention strategies are essential to maintaining high standards in food processing facilities. Risk analysis and management solutions help industries identify potential hazards and implement best practices to improve hygiene and safety protocols. Slipping and Falling, caused by slippery floors due to water or oil residues from cleaning. This hazard is often exacerbated by tools left carelessly around, creating additional obstacles for operators (Sitanggang, 2022). Falling from Heights, particularly when cleaning the upper parts of machines using unstable ladders or platforms. These activities are often conducted without adequate safety equipment, such as harnesses or additional handrails (Ririh, 2021). Electrical Contact Risks, occurring when machines are not fully powered off during the cleaning process. The use of liquid cleaning agents near active electrical panels increases the likelihood of significant accidents (Melati et al., 2024)

Physical Injuries, such as cuts from sharp objects or burns from hot surfaces, fatigue due to non-ergonomic working postures, and the risk of falling tools. These hazards often arise from a lack of preventive maintenance on machines and insufficient operator training (Sitanggang, 2022) These factors are compounded by the lack of safety facilities, such as warning signs and personal protective equipment (PPE), the non-ergonomic design of machines, and minimal training on safety procedures. Previous studies have shown that low awareness and insufficient training on workplace safety are among the primary causes of the high number of accidents in the manufacturing sector.

2.3 Research Gap

Researchers conducted a research gap analysis to identify gaps in previous research so that this study could address these shortcomings.

First, the study, "Analysis of Risk Management Implementation Based on SNI ISO 31000:2018" by Sitanggang (2022), only conducted a risk assessment based on ISO 31000:2018 but did not address these gaps. Second, the study, "Work Accident Risk Analysis Using the HIRARC Method and Fishbone Diagram on the PT DRA Production Floor" by Ririh (2021), focused solely on workplace accidents and neglected other risks.

Third, the study, "Optimizing Productivity and Risk Management in Production Systems Using the House of Risk Method" by Arviana & Suseno (2024), used the house of risk method but did not include a risk analysis tool that could complement this research.

Fourth, the study, "Effectiveness of Risk Management Implementation at PT. Indofood Sukses Makmur (Rahmadanis et al., 2023) only considered effectiveness with several risk categories.

Therefore, it can be concluded that this study complements several previous studies by identifying risks and using a matrix approach to identify all risks and implement strategies to maintain risk control.

2.4 Fishbone Diagram in Risk Analysis

This study employs the Fishbone Diagram to analyze the root causes of the identified risks. The Fishbone Diagram, also known as the cause-and-effect diagram, helps identify various risk factors by categorizing the main causes into several groups, such as human, machine, work methods, environment, and materials (Ririh, 2021). This approach enables researchers to gain a deeper understanding of cause-and-effect relationships, allowing them to design more targeted mitigation strategies.

3. RESEARCH METHOD

This study utilized a quantitative descriptive analysis method by applying a risk assessment approach to identify and evaluate potential risks requiring mitigation measures. The analysis process was conducted using tools such as Risk Maps. The necessary data were collected through literature reviews, interviews, and direct observations of activities during the coffee roasting process. The diagram below provides a visual representation of the step-by-step process carried out in this research (Figure 2).

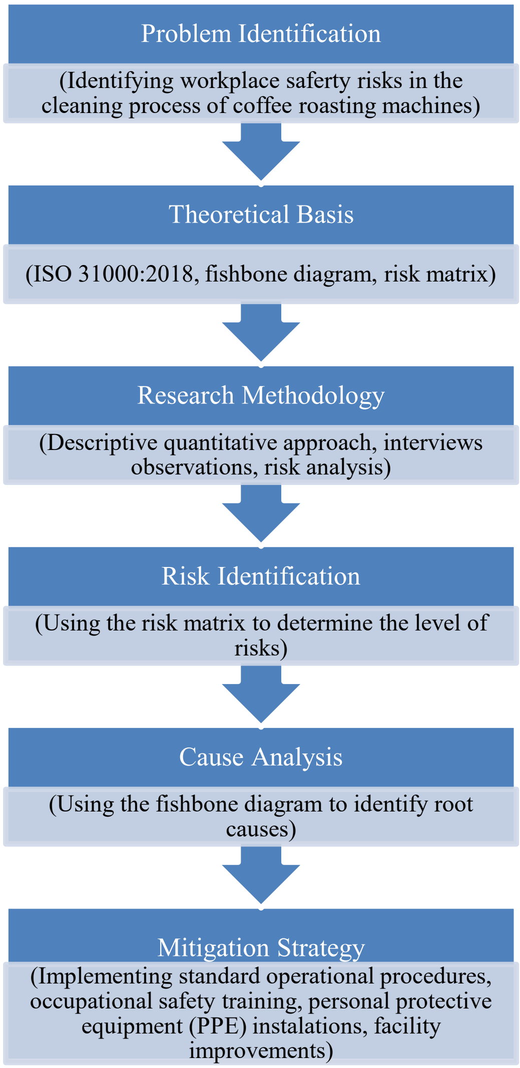

Figure 2. Framework of thinking

To clearly convey the research framework, the following diagram outlines the logical progression of this study. It starts with identifying workplace safety risks associated with the cleaning of coffee roasting machines at manufacturing industry. This is followed by establishing a theoretical foundation, applying research methodology, conducting risk assessment, analyzing root causes, and developing mitigation strategies. This structured approach enables a systematic evaluation of risks and the implementation of effective safety measures. Risk management is the process of identifying and managing risks while developing appropriate strategies for managing an organization's or company's resources (Sitanggang, 2022). A qualitative descriptive approach was chosen because it can comprehensively describe phenomena related to occupational risks during the machine cleaning process. With this approach, researchers can delve deeply into the issues encountered, including behaviors, processes, and risk factors that emerge during routine cleaning activities.

Risk Assessment Process

The study adheres to the stages of the risk management process outlined in international standards documented by the International Organization for Standardization (ISO 31000:2018). These stages are summarized in infographics following the guidelines found in the SNI ISO 31000:2018 document (accessed via https://bsn.go.id on May 20, 2022). This ISO 31000:2018 standard is designed to be implemented across various business sectors, whether small or large-scale. The standard outlines general steps in risk management processes. However, for detailed risk assessment techniques, the study refers to the ISO 31010:2018 document, which includes various technical methods for identifying, analyzing, and evaluating risks (Sitanggang, 2022).

The initial stage in the risk assessment process involves risk identification, carried out through interviews with stakeholders such as managers and occupational health and safety (OHS) experts at manufacturing industry. The information collected includes potential risks that occur during the cleaning process of coffee roasting machines. These analysis results are then reviewed and validated through discussion sessions with relevant managers and the OHS expert team. This step ensures that the proposed mitigation recommendations align with field conditions and can be implemented effectively. Documentation of these discussion and coordination activities is presented in the following photos.

Figure 3. Interview Activities with the Manager and the OHS Expert Team

In addition to interviews, risk identification is also supported by secondary data related to occupational safety. The identified risks are then documented in a risk register and analyzed using Gap Analysis by comparing actual conditions against the standards of SNI ISO 31000:2018. The results of this risk assessment are mapped in a Risk Map, which serves as the basis for designing appropriate mitigation measures. The risk analysis process involves determining the probability and impact levels of the identified risks, resulting in the overall risk level. This level illustrates the extent of potential risks that may affect the cleaning process of the coffee roasting machines at manufacturing industry. At this stage, the analysis is conducted both qualitatively and quantitatively to understand the characteristics of each risk and determine its level (level of risk). Subsequently, risks are mapped based on their characteristics and levels using a Risk Map. In this risk measurement, the indicators used include: Probability, which refers to the likelihood of an unwanted event occurring during the cleaning process. Impact, which refers to the consequences or effects if the risk occurs, whether it affects operator safety or work efficiency.

Fishbone diagram is a graphical technique used to systematically identify and analyze the root causes of specific events (Coccia, 2020). This approach has been widely applied in various fields, including risk management and technological innovation, to explore key factors contributing to a particular outcome. In the context of occupational safety, Fishbone Diagram can be utilized to classify potential hazards into categories such as human factors, machine issues, environmental conditions, and procedural deficiencies, facilitating a more structured risk analysis.bIn this study, the Fishbone Diagram is applied to identify and analyze risk factors in the cleaning process of roasting machines at manufacturing industry. Similar to its application in technological analysis, the Fishbone Diagram categorizes the root causes of hazards into human-related factors, equipment conditions, operational procedures, and environmental aspects. This structured visualization facilitates a more comprehensive approach to occupational health and safety risk assessment.

The results of this qualitative analysis are consistent with findings identified using the fishbone diagram, where various factors contributing to occupational safety risks are classified into main categories such as humans, machines, methods, environment, and materials. The cause-and-effect analysis using the fishbone diagram is useful for identifying the root causes of the problems encountered—in this case, understanding the causes and effects of workplace accident risks (Ririh, 2021). By understanding root causes through the fishbone approach, this study was able to develop a more focused risk matrix and mitigation measures that directly address the fundamental issues. This analysis provides a holistic overview of the interrelations among these factors, allowing the strategic recommendations produced to effectively improve workplace safety and operational efficiency at manufacturing industry.

Below is the cause-and-effect analysis of the cleaning process for coffee roasting machines using the fishbone diagram (Figure 4).

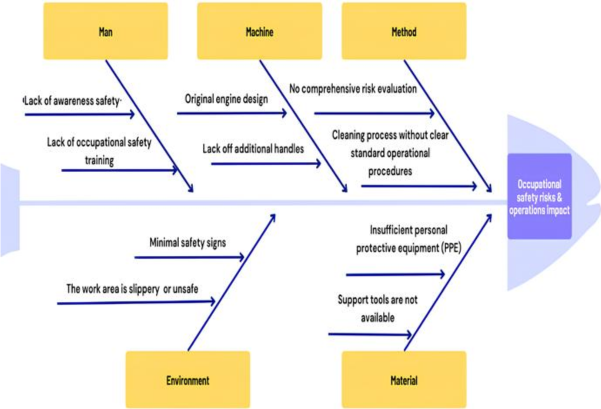

Figure 4. Fishbone diagram

Figure 4 illustrates the factors causing occupational safety risks when cleaning machines at manufacturing industry. This diagram includes five main categories: Human, Machine, Method, Environment, and Material, along with specific causes in each category. This diagram helps identify areas that need improvement to improve occupational safety.

4. RESULT AND DISCUSSION

In this discussion, the results of the analysis are presented based on data obtained through interview observations, as well as documentation related to the cleaning process of large-capacity coffee roasting machines at manufacturing industry. The discussion focuses on identifying work risks, their causal factors, and mitigation measures that can be applied to improve operational safety and efficiency. The analysis is carried out systematically to provide a comprehensive understanding of the problems faced and the proposed solutions. The following is a detailed presentation of the research results, covering the various risks identified and the suggested mitigation measures. Effective risk management serves as a reference for optimizing resource utilization within a company, ensuring sustainable business growth and operational efficiency (Muhammad et al., 2023). Research findings highlight that companies implementing structured risk management frameworks are more likely to achieve long-term profitability and resilience against uncertainties.

Table 1. Risk identification based on category and cause

No	Risk	Main Cause
1	Slipping and falling	- Slippery floor surface due to leftover water or cleaning oil. - Work tools placed carelessly in the machine area.
2	Falling from height	- Cleaning tasks involve high machine structures. - Use of unstable ladders or platforms.
3	Sprained or Injured Foot	- Repeated and hurried activity of climbing up and down machine stairs. - Foot position is not ergonomic or unstable.
4	Exposure to Sharp or Hot Objects Exposure to Sharp or Hot Objects	- Machine parts have sharp edges or hot surfaces after production. - Lack of proper use of Personal Protective Equipment (PPE).
5	Falling Tools or Machine Components	- Tools or machine parts falling during cleaning. - Operator's lack of attention when carrying or placing equipment.
6	Physical fatigue	- Cleaning large machines requires long working hours. - Non-ergonomic posture while cleaning.
7	Electrical contact risk	- Machine has not been ensured to be off. - Electricity is still active when using water or cleaning materials.

Traditional risk assessment methods, such as risk matrices, may have limitations in effectively ranking risks based on their true impact on project outcomes (Acebes et al., 2024). The use of Monte Carlo Simulation (MCS) provides a more structured quantitative analysis, modeling probability distributions to assess risks' potential impact on cost and duration. This approach enhances decision-making by allowing project managers to identify and prioritize critical risks based on specific project objectives. A quantitative risk assessment using Monte Carlo Simulation (MCS) provides project managers with a clearer understanding of each risk's absolute impact on project duration and cost (Acebes et al., 2024). By integrating simulation-basedmethodologies, organizations can improve risk management strategies and optimize decision-making processes in various industrial applications. The following is a risk table arranged based on risk categories and their causes (Table 1).

Based on the Table 1, four main categories are identified: Operational, Workplace Safety, Technical, and Environmental, each encompassing causes, impacts, and severity levels.

1. Operational Risks: Disruptions to workflow, such as lack of operator training, can reduce productivity.
2. Workplace Safety Risks: The absence of facilities such as safety signs and PPE increases the risk of operator injuries.
3. Technical Risks: Equipment malfunctions due to a lack of routine maintenance result in downtime and production delays.
4. Environmental Risks: Poor ventilation and lighting increase the likelihood of human error.

Risks with the Highest Impact and Likelihood:

1. Lack of Workplace Safety Facilities
    - Impact: Potential operator injuries, lost work hours, and operational disruptions.
    - Cause: Absence of warning signs or adequate PPE in the work area.
2. Cleaning Equipment Failure
    - Impact: High machine downtime and production schedule delays.
    - Cause: Lack of routine maintenance of equipment.
3. Human Error Due to Inadequate Training
    - Impact: Errors in cleaning procedures that can damage machines or cause accidents.
    - Cause: Insufficient training and unclear operational guidelines.

These risks are a priority for immediate mitigation as they can significantly affect safety, productivity, and the sustainability of operational processes at manufacturing industry. The next step involves designing mitigation strategies focused on the prioritized risks identified. This process includes mapping risks in a risk matrix to measure the severity level based on the combination of impact and likelihood. This matrix will serve as a key guide in determining mitigation actions tailored to the priority level of each risk.

Below is a table presenting the results of risk identification found during the coffee roasting machine cleaning process. The table includes risk categories, primary causes, and their potential impacts on operations, serving as a basis for further analysis in determining mitigation priorities.

Table 2. Identification risk

No	Risk	Main Cause	Impact
1	Slipping and falling	Slippery floor, tools placed carelessly	Minor to moderate injuries
2	Falling from height	High machine structure, unstable use of ladders/platforms	Severe to fatal injuries
3	Twisting or injuring foot	Rushing up and down stairs, unstable footing	Minor to moderate injuries
4	Contact with sharp/hot objects	Sharp or hot machine parts, lack of PPE usage	Cuts, burns
5	Dropped tools or components	Lack of attention when carrying/placing work tools	Head injuries, severe injuries
6	Physical fatigue	Repetitive cleaning activities, non-ergonomic posture	Reduced productivity, minor injuries
7	Electrical contact risk	Machines not fully powered off, active electricity during cleaning	Injuries from electric shock

Based on the risk identification results presented in the Risk Identification Table, the next step is to conduct a further analysis to assess the severity and likelihood of each risk. This assessment is organized in the form of a Risk Matrix, as shown in the following table, aiming to determine mitigation priorities to minimize the impact of risks on operations. The Risk Matrix is a tool used to measure the level of risk based on probability (likelihood of occurrence) and impact (severity of consequences).

Table 3. Risk matrix

Likelihood	Low (1)	Moderate (2)	High (3)	Very High (4)
Very Rare (1)	1 (Low)	2 (Low)	3 (Moderate)	4 (Moderate)
Rare (2)	2 (Low)	4 (Moderate)	6 (Moderate)	8 (High)
Likely (3)	3 (Moderate)	6 (Moderate)	9 (High)	12 (High)
Very Likely (4)	4 (Moderate)	8 (High)	12 (High)	16 (Very High)

Source: National Standardization Agency (2018)

Risk Level Description:
1-3: Low (acceptable, requires monitoring).
4-6: Moderate (requires control measures).
8-12: High (requires immediate control).
16: Very High (unacceptable risk, activity must be stopped).

The Risk Matrix helps in determining the level of risk by considering a combination of the probability of occurrence and its impact. To support this analysis, special criteria are used that measure the level of probability and impact, as presented in the following probability and impact table (Table 4).

Table 4. Probability (likelihood of happening)

Score	Description	Criteria
1	Very Rarely	Very unlikely to occur (1x/year)
2	Rarely	May occur but not often (1x/6 months)
3	Possible	Occurs quite frequently (1x/month)
4	Very Likely	Occurs frequently (1x/week or more)

The table above explains the risk probability criteria based on the likelihood of occurrence. Probability is measured in four levels, ranging from Very Rarely (with a very low likelihood, occurring only once a year) to Very Likely (occurring frequently, at least once a week or more). This assessment helps classify risks based on their frequency of occurrence.

Table 5. Impact (severity/consequences)

Score	Description	Criteria
1	Low	Minor injury, does not affect production
2	Moderate	Moderate injury, slight disruption to production
3	High	Severe injury, significant operational disruption
4	Very High	Fatal injury, total production halt

The table above describes the risk impact criteria based on the severity of the consequences. Impact is assessed in four levels, ranging from Low (causing only minor injuries with no effect on production) to Very High (resulting in fatal injuries and a total production halt). This assessment helps determine the urgency of mitigation based on the severity of the impact. These impact criteria, combined with probability, are used to measure the overall risk level. This assessment is crucial for prioritizing risk management, allowing mitigation efforts to focus on risks with the highest impact and probability. The overall risk level is summarized in the following Risk Assessment Table.

Table 6. Risk assessment

Risk	Probability (P)	Impact (D)	Risk Value (P x D)	Category
Slipping and falling	3 (Possible)	2 (Moderate)	6	Moderate
Falling from height	3 (Possible)	4 (Very High)	12	High
Twisted ankle or injury	2 (Rare)	2 (Moderate)	4	Moderate
Contact with sharp/hot object	2 (Rare)	3 (High)	6	Moderate
Falling tools or components	2 (Rare)	3 (High)	6	Moderate
Physical fatigue	3 (Possible)	2 (Moderate)	6	Moderate
Electrical contact risk	2 (Rare)	4 (Very High)	8	High

The table above presents a risk assessment based on probability (P) and impact (D), resulting in a risk value (P x D) and its category. The risks are classified into two main categories: Moderate and High, with risk values ranging from 4 to 12.

1. High Category includes risks with significant impacts on safety or operations, such as falling from height (value 12) and electrical contact risk (value 8). These risks require prioritized attention for mitigation.
2. Moderate Category covers risks with moderate impacts, such as slipping and falling, physical fatigue, or contact with sharp/hot objects (values 4-6). While these risks demand preventive measures, they have a lower urgency compared to high-category risks.

This assessment helps identify which risks need immediate attention to ensure workplace safety and efficiency. Based on the risk assessment results, the next step is to formulate a Risk Control Strategy to reduce the probability and impact levels of each identified risk. The following table presents the recommended control measures for each risk, tailored to its category and priority level.

Table 7. Risk control strategy

No	Risk	Control Strategy	Implementation
1	Slipping and Falling	- Place warning signs in slippery areas.	- Regularly inspect areas.
		- Use anti-slip mats.	- Implement 5S for work tools.
2	Falling from Height	- Provide stable work platforms and ladders with sturdy handrails.	- Use harnesses when working at heights.
		- Train operators in working at heights.	- Develop SOPs specifically for working at heights.
3	Twisted Ankle or Injury	- Use proper footwear (anti-slip, ergonomic).	- Inspect ladders or access paths.
		- Schedule work to avoid rushing.	- Educate workers on safe working postures.
4	Contact with Sharp/Hot Objects	- Ensure machines have cooled before cleaning.	- Use complete PPE (gloves, aprons).
		- Cover sharp machine parts.	- Create machine cleaning SOPs.
5	Falling Tools or Components	- Ensure work tools are securely stored in their designated places.	- Use safety belts when carrying tools.
		- Inspect tools before use.	- Develop SOPs for tool placement.
6	Physical Fatigue	- Schedule adequate rest periods during cleaning.	- Implement work rotation.
		- Provide ergonomic cleaning tools.	- Train workers on ergonomic practices.
7	Electrical Contact Risk	- Ensure machines are turned off and electricity is disconnected before cleaning.	- Use lockout-tagout (LOTO).
		- Avoid using water near electrical panels.	- Create SOPs for electrical safety.

The table above summarizes risk control strategies designed to reduce the probability and impact levels of each identified risk. These strategies include specific preventive and mitigation measures for each type of risk, such as: (1) Slipping and Falling: Reducing risks by placing warning signs, using anti-slip mats, and implementing 5S for work tools. (2) Falling from Height: Enhancing safety through the provision of stable platforms, the use of harnesses, and training for working at heights. (3) Twisted Ankle or Injury: Preventive measures include using ergonomic footwear, inspecting access paths, and educating workers on safe postures. (4) Contact with Sharp or Hot Objects: Minimizing risks by ensuring machines are cool before cleaning, using complete PPE, and following specific SOPs. (5) Falling Tools or Components: Ensuring safe storage of tools, using safety belts, and adhering to SOPs for tool placement.

1. Physical Fatigue: Reducing fatigue through work rotation, adequate rest schedules, and the provision of ergonomic cleaning tools.
2. Electrical Contact Risk: Ensuring safety through the use of a lockout-tagout (LOTO) system, which involves disconnecting or cutting off electrical energy sources on machines or equipment, followed by locking and tagging to warn of potential hazards. This includes turning off electricity before cleaning and following electrical safety SOPs (Melati et al., 2024)

This approach aims to prioritize workplace safety, maintain efficiency, and reduce negative impacts on company operations.
To ensure the effectiveness of the designed risk control strategies, further implementation steps need to be carried out, including:

- Installation of OHS Signs and Standard Operating Procedures (SOP): Ensuring clear and consistent safety guidelines.
- Training and Education: Increasing worker awareness and competency.
- Monitoring and Evaluation: Regularly assessing the effectiveness of strategies and compliance with SOPs.
- Follow-up and Continuous Improvement: Periodically refining systems based on evaluation results.

These steps aim to integrate the control strategies into daily operations, enhance worker awareness, ensure adherence to SOPs, and achieve system improvements through regular evaluations. This industry can take advantage of the results of this research by:

Implementation of OHS Signage Installation

As part of efforts to maintain occupational health and safety, OHS signage is installed in all areas with potential hazards to workers, such as machine cleaning areas, elevated workspaces, and areas near heat/electrical sources. These signs serve as safety warnings and guidelines, aiming to minimize accident risks and ensure a safer work environment.

Figure 5. Installation of occupational health and safety (OHS) signs

Implementation of Standard Operating Procedures (SOP)

SOP functions as a guideline for implementing work according to function and performance assessment. Optimal implementation of SOP is expected to increase employee productivity through active, effective and efficient work activities, which in turn can provide quality services (Pujianahum et al., 2024). (1) Cleaning SOP: Details steps for safe machine cleaning, including initial inspection, use of PPE, and specific risk controls. (2) LOTO Procedure: SOP to ensure the machine is completely turned off before cleaning. (3) Permit to Work (PTW): Work permit document for cleaning activities that have a high risk, such as working at heights or close to power sources.

Training and Education

• Occupational health and safety (OHS) training on: (a) Correct use of PPE, (b) Techniques for working in high risk areas, (c) Handling cleaning tools.

• Education regarding cleaning SOPs and risk management systems.

Monitoring and Evaluation

• Daily Inspection Checklist: Operator checks work area before and after cleaning.

• Periodic occupational health and safety (OHS) Audits: Ensure SOPs are adhered to and the work area remains safe.

• System Feedback: Operators can report problems or propose improvements via a special form.

Follow-up and Continuous Improvement

• Analyze work incidents and accidents that occur, then improve the system to prevent recurrence.

• Conduct regular reviews of the risk matrix and adjust control strategies if necessary.

With this risk management system, it is hoped that the potential for work accidents during routine cleaning at manufacturing industry can be minimized, while creating a safe and efficient work environment.

5. CONCLUSION

This research has identified and analyzed various occupational safety risks that occur during the cleaning process of large-capacity coffee roasting machines at manufacturing industry. Based on observations, interviews, documentation, and qualitative analysis, it was found that the main risks include slipping and falling, falling from heights, contact with sharp or hot objects, electrical contact risks, physical fatigue, and the falling of tools or components. These risks are caused by several factors, such as the lack of safety facilities (signage and personal protective equipment), minimal operator training, poorly designed machines that lack ergonomics, and suboptimal work procedures. Through fishbone analysis and risk assessment using a risk matrix, it was concluded that the highest severity risks are falling from heights and electrical contact risks. To address these, a risk control strategy was designed, including the installation of safety facilities, operator training, provision of ergonomic work equipment, and the implementation of SOPs such as lockout-tagout (LOTO) systems, Permit to Work, and routine inspections. Strategic recommendations from this research emphasize the importance of strengthening the safety culture at manufacturing industry through the following steps: (1) Improvement of safety facilities, such as installing signage, providing stable platforms, and ensuring the use of complete PPE. (2) OHS training and education, especially in the use of PPE, working in high-risk areas, and understanding cleaning SOPs. (3) Implementation of SOPs and regular supervision to ensure procedures are carried out safely and efficiently. (4) Ongoing evaluation and improvement based on audit results and incident analysis to ensure operator safety and operational continuity.

For further research, analysis can be added using other methods such as the house of risk, which has a more systematic approach and integrates quantitative risk analysis and prioritization of effective actions, or with the supply chain risk management method which also takes into account many condition factors.

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