# Risk Mitigation of Workplace Accidents in Oil Palm Plantations by Using HIRADC and FTA Approaches (Case Study: PT. XYZ)

**Nur Rachmawati Sutriono Putri[1], Muhammad Nur[2*], Suherman[3], Nazaruddin[4], Muhammad Isnaini Hadiyul Umam[5]**
Industrial Engineering Study Program, Faculty of Science and Technology, Sultan Syarif Kasim State Islamic University of Riau, Pekanbaru
Email: [1]11950220075@students.uin-suska.ac.id, [2]muhammad.nur@uin-suska.ac.id, [3]suherman@gmail.com, [4]nazaruddin@gmail.com, [5]umar@gmail.com

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***Abstract***

This study addresses the mitigation of occupational accident risks in oil palm plantations using the Hazard Identification, Risk Assessment, and Determining Control (HIRADC) and Fault Tree Analysis (FTA) approaches. A case study was conducted at PT. XYZ with the aim of identifying potential hazards, assessing risk levels, and determining effective control measures to reduce workplace accidents. This study presents an integrated approach of HIRADC and FTA in the context of oil palm plantations, which successfully identified seven high-risk potential hazards and found their root causes. The application of risk controls based on this analysis has proven effective in significantly reducing the risk level. The HIRADC method was used to identify and assess the risk levels of various work activities in the plantation, while FTA was applied to analyze the root causes of workplace accidents in depth. The results of the study indicate that the main hazards in the plantation include the use of heavy equipment, contact with chemicals, and hazardous environmental conditions. This study applied the HIRADC and FTA approach to identify seven hazards categorized as high risk (Risk Score RS ≥ 8–9), such as being pricked by palm thorns, struck by fronds, and hit by harvesting tools. After implementing ISO 45001-based risk control measures, all risks were successfully reduced to medium (RS = 4–6) or low (RS ≤ 3), demonstrating the significant effectiveness of the method in reducing workplace accident potential in oil palm plantations.

***Keywords*:** FTA; HIRAD; Oil palm plantation; Risk mitigation; Workplace accidents

## 1. Introduction

The oil palm plantation industry plays a crucial role in the national economy, particularly in Indonesia, which is one of the world's leading producers. Despite its significant contribution to national income, this sector also faces serious challenges in terms of occupational safety. Workplace accidents in oil palm plantations can be fatal for workers and cause substantial losses for companies [1].

Workplace accidents do not occur by chance but are caused by specific factors that need to be investigated and identified [2]. These findings serve as a basis for corrective actions to address the root causes, enabling preventive measures in the future. According to the domino theory, the causes of accidents are classified into two main categories: unsafe acts and unsafe conditions, as well as unsafe interactions between humans and machinery. Modern occupational safety approaches aim to eliminate the root causes of workplace accidents. Unsafe behavior is a major contributor to workplace accidents, accounting for 80-85% of cases due to human factors [3]. Therefore, improving human behavior in the workplace is essential to reduce or even preventing workplace accidents, in addition to implement mechanical techniques and ensuring a safe working environment[4].

PT. XYZ holds a land-use permit (HGU) covering 4,235.58 hectares, divided into two regions and four divisions (afdelings). A region is a work area consisting of several divisions, while a division encompasses a work area of approximately 1,000 hectares (flat terrain) or 800 hectares (hilly terrain). PT. XYZ operates as an agribusiness company focusing on oil palm production. The company generates an average daily yield of 2.7 tons per division, making oil palm one of its primary products and operations.


**Figure 1. Workplace Accident Data for PT. XYZ Plantations (2020–2023)**
(Source: PT. XYZ, 2024)

In observations of the working environment in the oil palm plantation section of PT. XYZ, various tools with potential workplace accident risks were identified, including egreks, tojoks, dodos, gancus, machetes, axes, and wheelbarrows. PT. XYZ has yet to implement a Standard Operating Procedure (SOP) for Occupational Health and Safety (OHS). The government mandates that all organizations or companies implement an Occupational Health and Safety Management System (SMK3) in accordance with applicable regulations and standards. This requirement aims to enable companies to proactively improve occupational health and safety performance within the workplace, preventing accidents and negative health impacts, including occupational diseases [5].

Workplace accidents result in worker injuries, disrupting the harvest production process and reducing productivity. Each worker faces varying levels of risk, influenced by non-compliance with company regulations and unsafe working conditions [6]. To minimize these risks, companies should commit to protecting their workers by implementing OHS SOPs. The function of Standard Operating Procedures (SOPs) includes streamlining work units, serving as a legal basis in case of deviations, clearly identifying obstacles and making them easy to trace, guiding employees to maintain discipline, and providing a framework for carrying out routine tasks [7].

Survey results indicate that workplace accident cases at PT. XYZ from 2020 to 2023 involved 125 workers, ranging from minor to severe injuries, with the total number of incidents recorded as 39 cases in 2020, 24 cases in 2021, 35 cases in 2022, and 27 cases in 2023. Workplace accidents in PT. XYZ's oil palm plantations include incidents such as puncture wounds from thorns, being struck by fresh fruit bunches (FFB), being hit by fronds, injuries from egreks, and other types of accidents as detailed in the appendix.

In 2020, the number of workplace accidents at PT. XYZ reached 39 cases but decreased to 24 cases in 2021. However, the number rose again to 35 cases in 2022. Several factors contributed to this increase, including inadequate safety training for workers, a lack of understanding of the proper use of personal protective equipment (PPE), and unsafe work procedures. Unsafe environmental conditions, such as slippery terrain, uneven roads, or landslide-prone areas, also played a role. Additionally, extreme weather conditions, such as heavy rain or strong winds, impacted workplace safety.

**Table 1. Plantation Production Tonnage at PT. XYZ (2020–2023)**

| Year | Target Tonnage Production (Ton) | Tonnage Revenue Production (Ton) | Information |
|---|---|---|---|
| 2020 | 92,496.51 | 86,021.92 | Not Achieved |
| 2021 | 89,159.56 | 86,328.00 | Not Achieved |
| 2022 | 90,616.43 | 95,831.27 | Achieved |
| 2023 | 101,283.90 | 108,827.43 | Achieved |

(Sourece: PT. XYZ, 2024)

One recorded case of a workplace accident at PT. XYZ occurred on August 10, 2023, when a harvester sustained a laceration injury from an axe while clearing oil palm fronds. Immediate first aid was provided by coworkers and the foreman, after which the victim was taken to PT. XYZ's clinic for medical treatment. The impacts of workplace accidents at PT. XYZ include the inability to meet daily production targets due to a shortage of labor, unachieved tonnage or work quotas, reduced attendance premiums because of absenteeism, and the company needing to hire temporary workers to complete the work left by injured harvesters.

As shown in Grafik 1, PT. XYZ's production tonnage increased by only 0.36% from 2020 to 2021. This limited growth was influenced by workplace accidents, which were the highest among all recorded cases over the past four years at PT. XYZ. Several factors contributed to the failure to achieve production tonnage targets, including unmet output, ineffective working hours, extreme weather conditions, labor shortages, and a high rate of workplace accidents. One of the primary causes of these accidents was employees' lack of awareness regarding the importance of Personal Protective Equipment (PPE).

To address these issues comprehensively, detailed mitigation steps are necessary. These steps include identifying hazards, assessing risks, reducing risks, and understanding the root causes of workplace accidents. This approach is grounded in the application of the Hazard Identification Risk Assessment and Determining Control (HIRADC) and Fault Tree Analysis (FTA) methods. The HIRADC method is used to identify potential hazards, evaluate associated risks, and formulate controls to reduce or eliminate these risks. Meanwhile, the FTA method provides a systematic and structured analysis of the fundamental causes of workplace accidents, offering clearer insights into the most effective mitigation measures to implement [8]. By integrating these two methods, it is expected that the primary causes can be identified, and effective preventive measures can be applied to manage workplace accident risks. Based on this background, a study entitled "Risk Mitigation of Workplace Accidents in Oil Palm Plantations Using the Hazard Identification Risk Assessment and Determining Control (HIRADC) and Fault Tree Analysis (FTA) Approaches at PT. XYZ" is proposed.

## 2. Method

This research was conducted at PT. XYZ, an oil palm plantation located in Riau, focuses on the harvesting and loading divisions. The study utilized both primary data, obtained through observation and interviews with employees, and secondary data from company records (accident logs, equipment data, and production tonnage). Two main analytical approaches were applied: HIRADC (Hazard Identification, Risk Assessment, and Determining Control) and FTA (Fault Tree Analysis).

### 2.1. HIRADC Method

The HIRADC method is a structured approach used to identify workplace hazards, evaluate their risks, and determine appropriate control measures. The process involved the following steps:

1. **Hazard and Risk Identification**: Activities were analyzed through field observation and worker interviews to identify potential hazards such as tool-related injuries, falling fronds, and environmental dangers.

2. **Severity Assessment (S)**: Each identified hazard was rated on a scale of 1 to 5 based on the potential impact or injury severity it could cause.
3. **Likelihood/Frequency Assessment (L)**: The likelihood of each hazard occurring was similarly rated from 1 to 5 based on past incidents and observations.
4. **Risk Score (RS) and Risk Level (RL)**: A risk score was calculated using the formula RS = L × S. Risk levels were then categorized (Low, Medium, High, or Extreme) using a risk matrix.
5. **Determining Control Measures**: Based on the risk level, appropriate control strategies were chosen using the ISO 45001 hierarchy of controls:
    - Elimination
    - Substitution
    - Engineering Controls
    - Administrative Controls
    - Personal Protective Equipment (PPE)

The outcome of HIRADC guided the prioritization and implementation of controls to mitigate identified risks in activities such as harvesting, transporting, loading, and unloading oil palm Fresh Fruit Bunches.

### 2.1. FTA Method

The Fault Tree Analysis (FTA) method was applied to investigate the root causes of high-risk workplace accidents identified during HIRADC. FTA uses a top-down deductive approach structured as follows:

1. **Define the Top Event**: Each fault tree starts with a specific workplace accident (e.g., “Worker injured by machete”).
2. **Identify Immediate Causes**: Direct causes of the top event (e.g., unsafe tool use, poor positioning) are identified.
3. **Trace Root Causes**: The analysis breaks down contributing factors further, such as lack of training, defective tools, or inadequate supervision.
4. **Construct Logical Tree Diagrams**: Each path is mapped using logic gates (AND/OR) to show how multiple failures may combine to cause an accident.
5. **Determine Corrective Measures**: By understanding root causes, targeted interventions, like safety training, equipment redesign, and SOP development, are recommended.

### Data Collection

Data plays a crucial role in producing scientific and accountable research. Therefore, the data collected must be accurate and authentic, not fabricated. Data represents facts or figures that form the basis of analysis. In this study, data were obtained through both primary and secondary sources to develop a concrete dataset ready for processing and testing. Primary data was collected directly by the researcher without intermediaries, using methods such as observation and interviews. Observation involved directly observing the objects under study to gather relevant data. Interviews were conducted with harvesting employees, loading employees, and division assistants of PT. XYZ is to identify potential hazards and workplace accident risks. Secondary data, on the other hand, consisted of pre-existing information available within the company. This included records and documentation such as Workplace Accident Recapitulation Data, Work Equipment and Facility Data, and Production Tonnage Data.

### Data Processing

Once the data is collected, it will be processed in alignment with the literature studied earlier, utilizing the Hazard Identification Risk Assessment and Determining Control (HIRADC) method and Fault Tree Analysis (FTA). The outcomes of this data processing stage include:

1. Using HIRADC Methodology. After conducting observations and interviews to directly assess the condition of the subjects and gather information about the issues under investigation, the HIRADC method is applied. This method identifies potential hazards and risks, evaluates the severity and frequency of risks, assesses risk levels, and provides solutions and recommendations to address the identified risk levels.

a. Hazard and Risk Identification. Activities and observations are analyzed in detail to identify potential risks and hazards arising from these activities and field conditions.
b. Severity Assessment. The severity of the potential risks and hazards is assigned a value (1–5) based on how severe the injury or loss could be. This evaluation may also include the estimated number of lost workdays.
c. Frequency Assessment. The frequency of occurrence is evaluated (1–5) simultaneously with severity. This assessment is based on how often the hazard or risk might occur. It can be measured qualitatively, estimating the likelihood of a hazard occurring, or semi-qualitatively, by analyzing historical accident data, such as less than once in 10 years, three times in 10 years, etc.
d. Risk Value and Risk Level. The risk value is calculated by multiplying the severity value by the frequency value. The resulting risk level is then classified based on a risk mapping scale (low, medium, high, extreme).

2. Using FTA Methodology. The FTA method is used to identify risks contributing to failures through a top-down approach. This begins with an assumption of failure or loss at the top event, followed by breaking down the root causes leading to the top event. The process involves tracing back to fundamental causes (root causes) of failures or accidents to develop a structured understanding of the risks and their interdependencies.

## 3. Result and Discussion

### 3.1. Data Processing

Hazard Identification Risk Assessment and Determining Control (HIRADC)

At this stage, the process of hazard identification and risk assessment (Hazard Identification Risk Assessment Determining Control/HIRADC) will be conducted at PT. XYZ. The aim of this stage is to recognize potential sources of hazards in the workplace, assess the risk levels associated with them, and determine effective control measures. Through this approach, PT. XYZ is committed to creating a safe work environment that supports employee productivity while complying with applicable safety and health standards.

### 3.2. Hazard Identification

Hazard identification is the process of recognizing potential hazards that may arise within an organization or company. The primary goal of hazard identification is to identify and understand the various risks that may arise from work activities or the existing environment, as well as how these hazards can occur. This process involves mapping out various factors that can lead to accidents or damage, such as physical conditions, work tools, and environmental factors. Below is the hazard identification at PT. XYZ, as shown in Table 2.

**Table 2. Hazard Identification at PT. XYZ**

| No | Stages of Work | Work Process | Potential Danger |
|---|---|---|---|
| 1 | Oil Palm Frond Cutting | Cut the palm fronds before cutting the fruit using axes and machetes | Hit by palm fronds, scratched by palm frond thorns, hit by dodos, hit by machete and axe, eye stabbed by dodos handle |
| 2 | Cutting of Oil Palm Fresh Fruit Bunches | Harvesting oil palm fruit by cutting the fruit from the branches using tools such as dodos, tojok, axes and machetes. | Impaled by palm thorns, hit by a sledgehammer, hit by palm oil FFB, palm dust in eyes |

| | | | |
|---|---|---|---|
| 3 | Transportation of FFB to TPH (PlacePengumpulan Hasil) | Transporting TBS (Fresh Fruit Bunches) using wheelbarrows, motorized vehicles, or manually | Back pain due to overloading, falling and slipping at the market, being stabbed by a palm thorn, foot in a hole |
| 4 | Loading of oil palm FFB into dump trucks | The process of loading oil palm FFB from TPH using a tojok into the dump truck body | Hit by a corner, hit by oil palm fruit bunches, eyes hit by oil palm pollen, stabbed by oil palm thorns, caught in the door of a dump truck |
| 5 | Unloading of oil palm FFB on a pontoon (barge) | Unloading oil palm FFB and stacking them onto a pontoon (barge) | Impaled by a palm thorn, impaled by a corner |

## 3.3. Risk Assessment

The next step is to conduct a risk assessment of the potential hazards that have been identified. The following is a risk assessment that can be seen in the Table 3.

**Table 3. Risk Assessment**

| No. | Work activity | Potential danger | L | S | RS | RL |
|---|---|---|---|---|---|---|
| 1 | Palm Frond Cutting Process | Tertimpa pelepah sawit | 3 | 3 | 9 | High |
| | | Scratched by palm leaf thorns | 4 | 1 | 4 | Medium |
| | | Hit by a machete and an axe | 3 | 3 | 9 | High |
| | | Hit by dodos | 3 | 3 | 9 | High |
| | | Eyes pierced by dodos handle | 3 | 1 | 3 | Low |
| 2 | Cutting of Oil Palm Fresh Fruit Bunches | Impaled by palm thorn | 4 | 2 | 8 | High |
| | | Hit by a egrek | 3 | 3 | 9 | High |
| | | Hit by oil palm fruit bunches | 3 | 3 | 9 | High |
| | | Palm oil powder in eyes | 4 | 1 | 4 | Medium |
| 3 | Transportation of TBS to TPH | Back pain | 3 | 1 | 3 | Low |
| | | Fell and slipped at the market | 3 | 1 | 3 | Low |
| | | Feet go into the hole | 3 | 1 | 3 | Low |
| | | Impaled by palm thorn | 4 | 2 | 8 | High |
| 4 | Loading of oil palm FFB into dump trucks | Stabbed by a knife and a stick | 3 | 3 | 9 | High |
| | | Hit by oil palm fruit bunches | 3 | 3 | 9 | High |
| | | Palm oil powder in eyes | 4 | 1 | 4 | Medium |
| | | Impaled by palm thorn | 4 | 2 | 8 | High |
| | | Stuck in the dump truck door | 3 | 3 | 9 | High |
| 5 | Unloading of oil palm FFB on a pontoon (barge) | Impaled by palm thorn | 4 | 2 | 8 | High |
| | | Hit by a corner and a hook | 3 | 3 | 9 | High |

## 3.4. Control Measures (Determining Control)

The identified potential hazards can be managed by first determining a priority scale, which helps in selecting the appropriate risk control measures, known as the hierarchy of risk control. To reduce risks, efforts focus on minimizing the likelihood of hazards occurring and reducing the severity of the consequences resulting from high-risk activities [9]. Risk control measures are guided by the risk hierarchy according to ISO 45001, which consists of five levels of risk control: Elimination, Substitution, Engineering Controls, Administrative Controls, and Personal Protective Equipment (PPE) [10].

**Table 4. Hazard Risk Control for Palm Frond Cutting Process**

| No. | Potential Hazard | Hierarchical Control Solutions | Elimination | Substitution | Engineering Controls | Administrative Controls | PPE |
|---|---|---|---|---|---|---|---|
| 1 | Falling Palm Fronds | Ensure the work area is clear of fallen palm fronds and use protective equipment for vulnerable body parts. | ✕ | ✕ | Installation of automatic barriers to hold falling fronds, such as protective nets or supports. | Work area arrangement and inspection of palm fronds before cutting. | Helmets, body protectors, safety shoes. |
| 2 | Hit by Machete or Axe | Ensure machetes and axes are in good condition and used safely. | ✕ | ✕ | Use machetes and axes with ergonomic handle designs and sharp edge protectors. | Supervise the use of machetes and axes, and provide clear work instructions. | Protective gloves, safety shoes, leg guards. |
| 3 | Scratched by Palm Frond Thorns | Use protective equipment like sturdy gloves that resist thorn penetration. | ✕ | ✕ | Install automatic barriers to hold falling fronds, such as protective nets or supports. | Clear division of work areas to avoid injuries while clearing debris. | Protective gloves, body protectors, safety shoes. |
| 4 | Hit by Dodos | Use dodos with secure grips and ensure the tool is in good condition. | ✕ | ✕ | Redesign dodos with ergonomic grips and additional blade guards to prevent direct contact. | Clear task allocation to avoid crowding or accidents. | Protective gloves, body protectors, safety shoes. |
| 5 | Eyes Struck by Dodos Handle | Use dodos with handles equipped with guards or safer handle designs. | ✕ | ✕ | Redesign dodos handles with safer materials and ergonomic shapes to reduce eye injury risks. | Supervise and regulate proper tool usage by workers. | Safety goggles, face shields. |

**Table 5. Controlling the Risk of Hazards in the Oil Palm FFB Cutting Process**

| No. | Potential Hazard | Hierarchical Control Solutions | Elimination | Substitution | Engineering Controls | Administrative Controls | PPE |
|---|---|---|---|---|---|---|---|
| 1 | Hit by Falling Oil Palm FFB | Use safety helmets during the harvesting process. | ✕ | ✕ | Implement automatic harvesting systems for falling FFBs, such as conveyor systems or catching devices. | Identify hazardous zones and avoid them, ensuring safe walking paths within the plantation. | Safety helmet, body protector, safety shoes. |
| 2 | Hit by Egrek | Use egrek with secure grips and ensure the tool is in good condition. | ✕ | ✕ | Redesign egrek with ergonomic grips and additional blade guards to prevent direct contact. | Assign clear tasks to avoid crowding or accidents. | Protective gloves, body protector, safety shoes. |
| 3 | Eyes Exposed to Palm Dust | Use face shields or safety goggles to protect eyes from palm dust or debris. | ✕ | ✕ | Use cutting tools with an automatic dust-catching system or more effective protective devices. | Provide designated cutting areas far from other zones to reduce risks. | Safety goggles. |
| 4 | Pricked by Palm Thorns | Use protective equipment, such as sturdy gloves resistant to thorns. | ✕ | ✕ | Implement automatic harvesting systems for falling FFBs, such as conveyor systems or catching devices to avoid direct contact with thorns. | Use gloves made of materials like synthetic or genuine leather to resist thorn penetration. | Gloves, safety shoes. |

**Table 6. Controlling Hazard Risks in Transporting TBS to TPH**

| No. | Potential Hazard | Hierarchical Control Solutions | Elimination | Substitution | Engineering Controls | Administrative Controls | PPE |
|---|---|---|---|---|---|---|---|
| 1 | Back Pain | Use transportation tools with appropriate capacity, such as wheelbarrows or larger vehicles. | ✕ | ✕ | Design wheelbarrows or vehicles with automatic load distribution systems for better weight distribution. | Even distribution of loads and supervision to prevent overloading. | Protective back support belt, safety shoes. |
| 2 | Slipping in Carrying Path | Use safety shoes with non-slip soles. | ✕ | ✕ | Install wheelbarrows or vehicles with automatic braking systems to prevent shifting when stationary. | Ensure safer paths and carrying areas, with regular inspections of harvest point conditions. | Anti-slip safety shoes, knee protectors. |
| 3 | Foot Falling into Ground Hole | Use portable work platforms or cover boards for areas with holes. | ✕ | ✕ | Create movable work platforms for uneven ground areas. | Regular inspections of harvest and carrying areas, and closing off areas with holes. | Safety shoes. |
| 4 | Pricked by Palm Thorns | Use protective equipment, such as sturdy gloves resistant to thorns. | ✕ | ✕ | Implement automatic harvesting systems for FFB, such as conveyor belts or catching devices to avoid direct contact with palm thorns. | Use gloves made of synthetic or genuine leather to resist thorn penetration. | Gloves, safety shoes. |

**Table 7. Controlling the Risk of Hazards in the Process of Loading Palm Oil Fruit Bunches into Dump Trucks**

| No. | Potential Hazard | Hierarchical Control Solutions | Elimination | Substitution | Engineering Controls | Administrative Controls | PPE |
|---|---|---|---|---|---|---|---|
| 1 | Pricked by sharp tool | Use safety shoes with steel-toe material. | ✕ | ✕ | Equip tools with automatic protective covers for sharp parts when not in use. | Provide training on proper tool usage and maintenance, and inspect tools before use. | Protective gloves, safety shoes. |
| 2 | Hit by falling oil palm FFB | Use safety helmets during the harvesting process. | ✕ | ✕ | Implement an automatic harvesting system for FFB, such as conveyor belts or catching devices. | Identify and avoid hazardous zones, and use safe paths when moving within the plantation. | Safety helmet, body protector, safety shoes. |
| 3 | Eyes exposed to palm dust | Use face shields or safety glasses to protect eyes from dust or palm debris. | ✕ | ✕ | Use cutting tools equipped with automatic dust catchers or more effective protective devices. | Provide designated areas for cutting that are distant from other zones to reduce risks. | Safety glasses. |
| 4 | Pricked by palm thorns | Use protective body equipment, such as durable gloves resistant to thorns. | ✕ | ✕ | Use automatic harvesting systems for FFB, such as conveyor belts or catching devices to avoid direct contact. | Use gloves made of synthetic or genuine leather to resist thorn penetration. | Gloves, safety shoes. |
| 5 | Pinched by dump truck door | Use safety locks or warning signs. | ✕ | ✕ | Install hydraulic opening systems for truck doors to prevent sudden movements. | Display warnings such as “Caution! Do not stand near the truck door.” | Protective gloves, safety shoes. |

**Table 9. Controlling the Risk of Hazards in the Process of Unloading Oil Palm Fresh Fruit Bunches on Pontoons (Barges)**

| No. | Potential Hazard | Hierarchical Control Solutions | Elimination | Substitution | Engineering Controls | Administrative Controls | PPE |
|---|---|---|---|---|---|---|---|
| 1 | Pricked by palm thorns | Use protective body equipment, such as durable gloves resistant to thorns. | ✕ | ✕ | Implement an automatic harvesting system for oil palm FFB, such as conveyor belts or catching devices to avoid direct contact with palm thorns. | Use gloves made of synthetic or genuine leather to resist thorn penetration. | Gloves, safety shoes. |
| 2 | Pricked by sharp tool | Use safety shoes with steel-toe material. | ✕ | ✕ | Equip tools with automatic protective covers for sharp parts when not in use. | Provide training on proper and safe tool usage, and inspect tools before use. | Protective gloves, safety shoes. |

### 3.5. After Risk Control is Conducted in Each Process

The next step is to conduct brainstorming sessions to evaluate whether there is a reduction in the risk levels of the identified hazards. Through these sessions, comparisons can be made between the conditions before and after implementing the control solutions. The new risk assessment results show a significant reduction in the risk levels of all identified hazards. When control solutions are effectively applied to each activity, the overall risk level decreases from moderate to low. Similarly, hazards previously categorized as high risk have been reduced to moderate risk levels.

Based on the analysis conducted, seven hazards were identified as high-risk categories. These include: Pricked by palm thorns, Hit by falling palm fronds, Struck by falling oil palm fresh fruit bunches (FFB), Injured by machetes and axes, Pricked by sharp tools (e.g., spikes and gancu hooks), Hit by harvesting tools (e.g., dodos and egrek), and Trapped by dump truck tailgate doors. These hazards require special attention and effective control measures to reduce the risk levels and ensure worker safety.

### 3.6. Proposed Risk Control for Workplace Accidents Using the FTA (Fault Tree Analysis) Method

At this stage, risk control proposals are developed using the Fault Tree Analysis (FTA) method. This method is utilized to identify the root causes of each hazard that could lead to workplace accidents. FTA aids in analyzing the relationships between various causal factors and presents them in a logical tree diagram to determine effective control measures.

a. Fault Tree Analysis for Pricked by Palm Thorns. In this analysis, various factors contributing to workers being pricked by palm thorns are identified, including tool conditions, work methods, and the work environment. These factors are analyzed to design effective control measures.

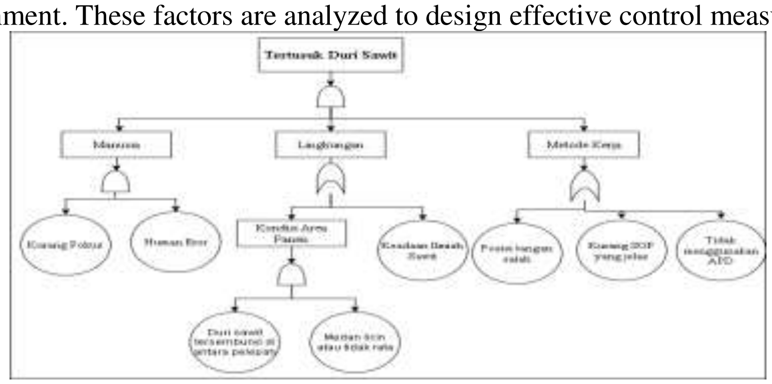


**Figure 2. Fault Tree Analysis for Pricked by Palm Thorns**

b. Fault Tree Analysis for Being Hit by Palm Fronds

This analysis aims to identify the root causes of workers being struck by palm fronds, focusing on safety factors during the cutting and felling of fronds, as well as workers' awareness of surrounding risks.

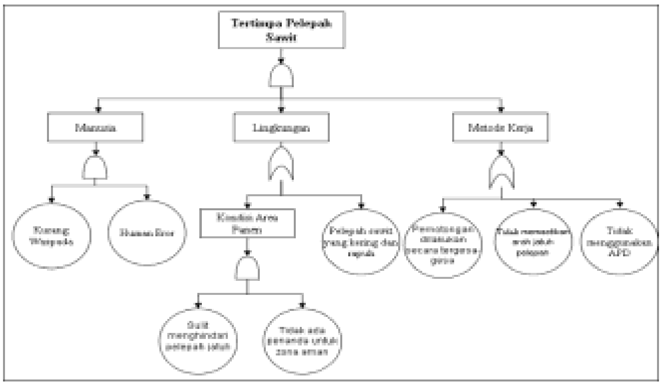


**Figure 3. Fault Tree Analysis for Being Struck by Palm Fronds**

c. Fault Tree Analysis for Being Struck by Palm Oil Fruit Bunches (FFB)
   Through this analysis, the main causes of workers being struck by FFBs are mapped, ranging from transportation techniques to work positioning arrangements, in order to significantly reduce this risk.

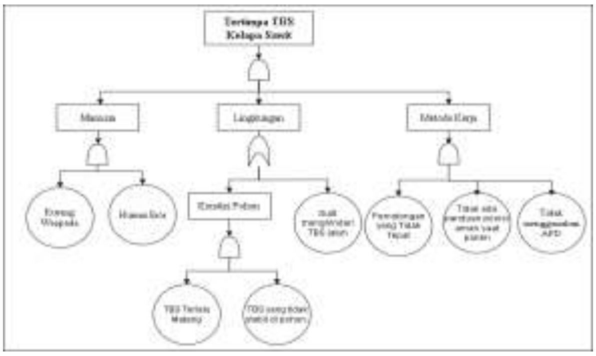


**Figure 4. Fault Tree Analysis for Being Struck by Palm Oil Fruit Bunches (FFB)**

d. Fault Tree Analysis for Injury from Machetes and Axes
   This analysis aims to identify the root causes of accidents caused by the use of machetes and axes in the workplace, as well as to pinpoint factors that increase the risk of injury to workers.

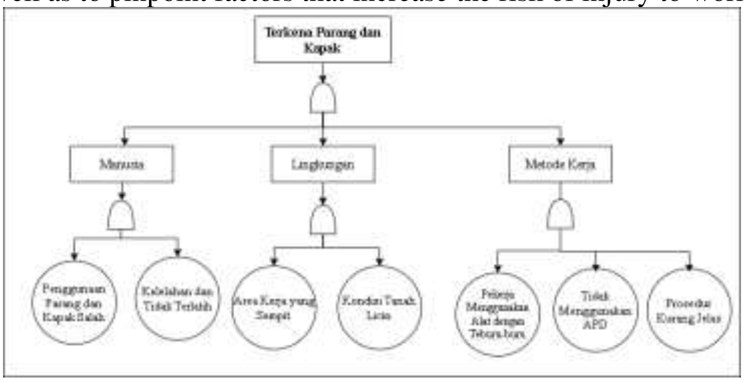


**Figure 5. Fault Tree Analysis for Injury from Machetes and Axes**

e. Fault Tree Analysis for Puncture from Tojok and Gancu
   This analysis aims to identify the root causes of accidents caused by punctures from the tojok or gancu, as well as to evaluate the factors that contribute to injuries among workers when using these tools.

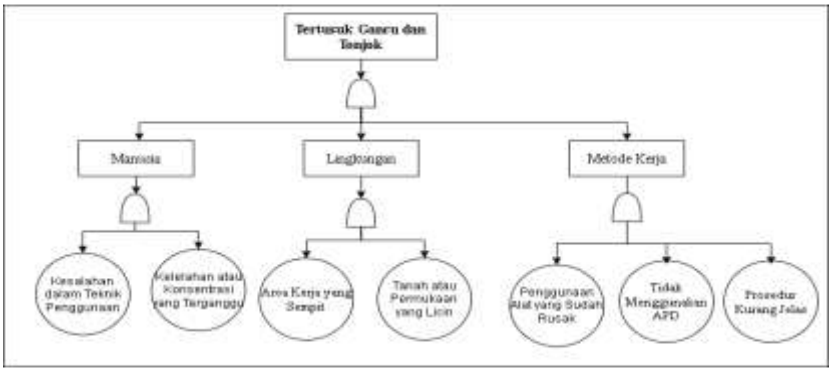


**Figure 6. Fault Tree Analysis for Puncture from Tojok and Gancu**

f. Fault Tree Analysis for Injury from Dodos and Egrek
   This analysis aims to identify the root causes of accidents resulting from injuries caused by dodos and egrek, as well as to find the underlying causes of injury risks in the use of these tools in the field.


**Figure 7. Fault Tree Analysis for Injury from Dodos and Egrek**

g. Fault Tree Analysis for Pinched by Dump Truck Tailgate
   This analysis aims to identify the root causes of accidents caused by workers being pinched by the dump truck tailgate, as well as to identify preventive measures that can be applied to reduce the risk of injury.

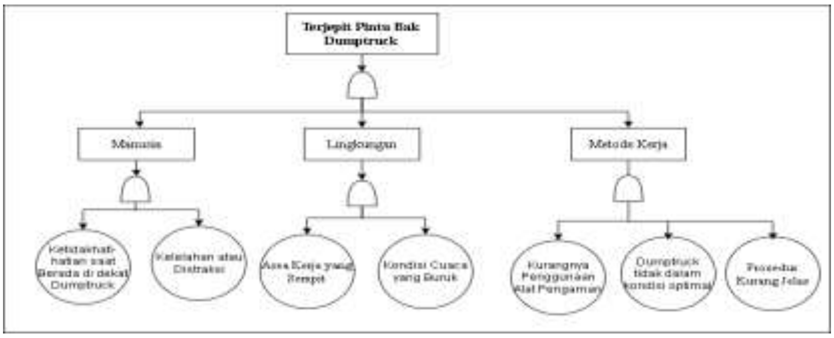


**Figure 8. Fault Tree Analysis Trapped in Dump Truck Door**

## 4. Conclusion

Based on the research conducted, the following conclusions can be drawn: (i)Risk Assessment Findings Using the HIRADC Approach: Seven potential workplace hazards were identified in the palm oil plantation of PT. XYZ, classified as high-risk. These hazards include injury from palm thorn punctures, falling palm fronds, falling Fresh Fruit Bunches (FFB), being struck by machetes and axes, punctured by tojok and gancu, injuries from dodos and egrek, and being pinched by the dump truck tailgate. The following are proposed improvements that can be implemented to reduce or eliminate these hazards: (a) Palm Thorn Puncture: (a) To reduce the risk of palm thorn punctures, it is essential to ensure that all workers use adequate personal protective equipment (PPE), such as thorn-resistant gloves. Regular training on proper PPE use is also necessary to ensure workers understand the importance of using PPE effectively. Human error and lack of focus are major contributors to this risk. Therefore, the company should conduct comprehensive training for workers, which should include information on the dangers of palm thorns, safe work practices, and correct PPE usage. This training should be conducted regularly, at least once a month. Additionally, implementing a work rotation system can help reduce fatigue, which contributes to decreased concentration. Daily supervision by field supervisors should also be conducted to provide direct feedback on unsafe work practices. The condition of the harvest area, such as hidden thorns among fronds, slippery terrain, and palm tree condition, requires intervention through workplace maintenance. Preventive actions include regular cleaning of pruned palm fronds to reduce the risk of workers unintentionally touching hidden thorns. Furthermore, harvest paths should be leveled and anti-slip materials used, particularly in high-sloped areas, to reduce the risk of slipping. Simple sensing tools, such as lightweight thorn detection sticks, can help workers identify potentially hazardous areas before transporting palm fruit bunches. A clear and standardized SOP must be designed and implemented for all processes in the palm plantation. This SOP should cover how to transport fruit bunches, proper hand positions when using tools, and correct use of tools like tojok and egrek. SOP documentation should be published in work areas in the form of visual guides that are easy for all workers to understand. Additionally, periodic evaluations of SOP implementation are required to ensure that field practices align with the established procedures. Work scenario simulations focusing on safe body and hand positions should also be incorporated into regular training. Using PPE, such as Kevlar gloves and anti-slip boots, should be mandatory for all field workers. To improve compliance, the company can provide high-quality PPE for free and ensure an adequate supply. Additionally, regular inspections and maintenance of tools like tojok and egrek should be part of the safety management program. Broken or dull tools must be repaired or replaced immediately to prevent accidents from using faulty equipment. As an additional measure, innovations such as polymer transport containers can be implemented to minimize direct contact with palm thorns. These containers should be designed ergonomically to facilitate safe transport without compromising worker safety.

(b) Falling Palm Fronds: To address the risk of falling palm fronds, it is crucial to improve safe cutting techniques in accordance with established procedures. Training workers on proper cutting techniques will help prevent this hazard. Additionally, regular monitoring of the work environment is necessary to ensure that the work area is free from hazards like falling palm fronds. Lack of worker awareness during harvesting activities is a major cause of accidents involving falling palm fronds. Therefore, the company should hold routine training to increase awareness of this danger. The training should include lessons on environmental observation techniques, identifying hazard zones, and safety procedures before cutting fronds. Scenario simulations of falling fronds can be conducted to train workers in quickly avoiding dangerous situations. Moreover, implementing a communication system using voice or visual signals among workers will help improve coordination, especially when cutting fronds. A work area without a clearly marked safe zone poses a significant risk. To address this, the company must implement a system of marking work zones using safety tape or visible signs. Before cutting begins, workers must mark the area where fronds will fall within a certain radius to ensure no other workers are in that area. Furthermore, the work environment should be periodically organized to avoid piling up dry fronds, which could create additional hazards like slipping or increasing the workload during removal. This organizing should be supervised by personnel qualified in safety management. Cutting techniques that do not consider the direction of falling fronds are a primary cause of accidents. Therefore, the company should develop and socialize an SOP for safe cutting techniques. The SOP should explain the optimal cutting angles to ensure the fronds fall in a controlled manner and do not harm workers. Additionally, using tools such as frond hooks or supports can help direct the fronds to a safe location. These tools also enhance worker control over the direction of the falling fronds, especially when working with tall or hard-to-reach trees. Regular inspections of these tools should be conducted to ensure their functionality. Appropriate PPE, such as safety helmets and anti-slip boots, must be applied to all workers involved in harvesting. The company must ensure that sufficient PPE is available and that workers wear it at all times while working. Additionally, field supervision by safety officers should be enhanced to ensure compliance with SOPs and PPE usage. This supervision will also provide direct evaluations of the implementation of taught cutting techniques and correct unsafe practices. Periodic evaluations of the effectiveness of these measures should be conducted to ensure continuous improvement in workplace safety.

Falling Fresh Fruit Bunches (FFB):

(c)To reduce the risk of falling FFB, an improvement is implementing safe FFB transport procedures. The use of appropriate transport equipment, such as trucks or transport vehicles that are strong and stable, can reduce the likelihood of accidents during FFB transportation. Workers should also be trained on safe transport methods, including how to properly load and manage the weight to prevent uncontrolled transportation and accidents. Intensive safety training should be a priority to prevent accidents caused by inattention or human error. This training should include recognizing signs of overripe or unstable FFB on trees at risk of falling. Workers should also be taught techniques for assessing the environment before starting the harvesting process, ensuring a safe position away from the risk of falling FFB. To enhance awareness, the company can provide a simple alarm system using whistles or visual signals, which workers can use to alert colleagues when FFB is about to be cut. A safe work environment is crucial for reducing the risk of injury. The company should ensure that only FFB with optimal ripeness is harvested to reduce the risk of overripe fruit falling by itself. Regular monitoring of tree conditions should be carried out by dedicated personnel to assess the stability of FFB. Additionally, work paths around harvest areas should be designed to be free from obstacles and equipped with signs indicating safe positions for workers. This step can minimize potential injuries from mispositioning or accidentally being under a tree at risk of falling fruit. The development and socialization of an SOP for FFB cutting is an important step in preventing accidents. This SOP should include guidelines for safe positions during harvesting, correct cutting techniques to prevent uncontrolled FFB falls, and steps to take if FFB begins to move. Tools such as extended poles with supports or collecting baskets should also be provided to ensure FFB does not fall directly onto the ground or workers. Workers should receive regular training on how to implement these SOPs, and field supervision should be conducted to ensure compliance with the procedures.Workers are required to use PPE designed to protect from falling FFB. Safety helmets with additional impact-absorbing protection should be standard equipment. Additionally, the company needs to provide transport vehicles with added safety features, such as load restraints made of mesh or strong tarpaulins, to ensure FFB does not fall during transport. Routine inspections of the transport equipment should be conducted to ensure structural integrity. This inspection should also cover transport paths to ensure there are no obstructions or terrain conditions that could increase accident risks.

(d) Pinched by Dump Truck Bed Door. To prevent accidents caused by being pinched by a dump truck bed door, the first step is to ensure the presence of a clear Standard Operating Procedure (SOP) regarding the operation of the bed door. Dump truck operators should be trained to open and close the bed door carefully and check for the presence of other workers around the vehicle before continuing their operations. Additionally, the use of communication tools, such as whistles or radios, will help operators coordinate with workers on the ground to avoid accidents. The first step is to implement safe work procedures for opening and closing the dump truck bed door. It is recommended that this process be carried out by more than one person to ensure proper control and reduce the risk of accidents. Alternatively, the use of automation technology, such as hydraulic systems or automatic hinges, could be a safer solution. This system allows the door to be opened and closed without direct human involvement, thus avoiding the potential for pinching that often occurs due to accidents or lack of coordination. Workers interacting with the dump truck door must be equipped with appropriate Personal Protective Equipment (PPE). The use of anti-slip safety shoes is crucial to prevent workers from falling or slipping when near the dump truck bed door. Additionally, upper body protection (such as vests or chest protectors) can help reduce the impact of injuries if pinched. This PPE must always be worn by any worker interacting with the dump truck, whether opening or closing the bed door. Workers must receive specialized training covering safe methods for opening and closing the dump truck bed door and how to act when near a moving door. This training should include the proper techniques for using safety tools and avoiding risky positions when close to the bed door. Additionally, workers need to be educated on the importance of maintaining a safe distance and always adhering to the established safety

procedures. Regular inspections of the dump truck's condition are essential to prevent potential accidents caused by equipment failure. Components related to the opening and closing of the bed door, such as hinges, hydraulic systems, and door locking mechanisms, should be inspected regularly to ensure everything is functioning properly. If damage or wear is found, immediate repairs or replacement of components should be carried out to prevent accidents that could harm workers.
The area around the dump truck bed door must be kept clean and free of obstacles or objects that could obstruct the door when it is opened or closed. Before opening the door, ensure that no objects block the door's movement. By maintaining cleanliness and orderliness in the work area, the likelihood of obstacles that could cause the door to malfunction is minimized.
Strict supervision is also needed to ensure that all safety procedures are correctly implemented. Supervisors should always monitor dump truck operations to ensure that workers are wearing protective equipment and following safe procedures when interacting with the dump truck bed door. With consistent supervision, the potential for accidents can be reduced, and workplace safety will be better ensured.

(ii) After conducting an analysis using Fault Tree Analysis, the root causes of potential hazards with the highest risk levels were identified. The root cause of the potential hazard of being punctured by palm thorns is the use of improper tools or negligence in using Personal Protective Equipment (PPE). The root cause of the potential hazard of being hit by palm fronds is unsafe cutting techniques or lack of supervision of the working environment's conditions. The root cause of the potential hazard of being hit by Fresh Fruit Bunches (FFB) of palm oil is unsafe transportation processes of FFB, and insufficient attention to FFB placement or transportation. The root cause of the potential hazard of being struck by machetes and axes is the improper use of tools or lack of attention to the positions of other workers nearby during work, as well as insufficient training in using the tools. The root cause of the potential hazard of being punctured by a tojok (palm harvesting tool) and gancu (hook) is negligence in storing tools in safe places, careless tool usage, or workers not understanding the correct usage of the tools. The root cause of the potential hazard of being struck by a dodos or egrek (palm harvesting tools) is unsafe working techniques, such as swinging these tools without ensuring that the surrounding area is clear of other workers. Poor tool conditions can also worsen this risk. The root cause of the potential hazard of being pinched by the dump truck bed door is a lack of attention or communication between workers during the transportation and closure process of the bed door. The heavy bed door and the lack of safety mechanisms also contribute to this risk.

## References


[1] A. S. Istisya, H. M. Denny, And Y. Setyaningsih, "Potential Hazards And Associated Causal Factors In The Occupational Environment Of Palm Oil Workers," *Indones J Occup Saf Heal*, Vol. 13, No. 1, Pp. 116–123, 2024.

[2] J. Zhang, J. Fu, H. Hao, G. Fu, F. Nie, And W. Zhang, "Root Causes Of Coal Mine Accidents: Characteristics Of Safety Culture Deficiencies Based On Accident Statistics," *Process Safety And Environmental Protection*, Vol. 136, Pp. 78–91, 2020.

[3] T. Lis And K. Nowacki, "Modern Trends In Occupational Safety Management," *New Trends In Production Engineering*, Vol. 2, No. 2, Pp. 126–138, Dec. 2019, Doi: 10.2478/Ntpe-2019-0078.

[4] W. N. Eka Rini, B. Aswin, And F. Hidayati, "Analisis Risiko Dan Determinan Kejadian Kecelakaan Kerja Di Pabrik Minyak Kelapa Sawit," *Jurnal Riset Hesti Medan Akper Kesdam I/Bb Medan*, Vol. 6, No. 2, P. 162, Dec. 2021, Doi: 10.34008/Jurhesti.V6i2.248.

[5] A. Purwanto *Et Al.*, "Mewujudkan Green Industry Dengan Pelatihan Iso 14001:2015 Sistem Manajemen Lingkungan Pada Industri Chemical Di Tangerang," 2021.

[6] S. A. Wekoye, W. N. Moturi, And S. Makindi, "Factors Influencing Non-Compliance To Occupational Safety And Health Practices In The Informal Non-Food Manufacturing Sector In Kampala City, Uganda," 2020.

[7] Orienta Zubaidah, I.F Romadhoni, Lilis Sulandari, And Niken Purwidiani, "Analisis Penerapan Standar Operasional Prosedur (Sop) Pengolahan Makanan Banquet Di Hot Kitchen Hotel Aria

Centra Surabaya," *Journal Of Creative Student Research*, Vol. 1, No. 4, Pp. 421–444, Jul. 2023, Doi: 10.55606/Jcsrpolitama.V1i4.2327.

[8] M. S. Ab Rahim, G. Reniers, M. Yang, And S. Bajpai, "Risk Assessment Methods For Process Safety, Process Security And Resilience In The Chemical Process Industry: A Thorough Literature Review," *J Loss Prev Process Ind*, P. 105274, 2024.

[9] A. Mawardani And C. K. Herbawani, "Analisa Penerapan Hiradc Di Tempat Kerja Sebagai Upaya Pengendalian Risiko: A Literature Review," *Prepotif : Jurnal Kesehatan Masyarakat*, Vol. 6, No. 1, Pp. 316–322, Jan. 2022, Doi: 10.31004/Prepotif.V6i1.2941.

[10] T. Ihsan, A. Safitri, And D. P. Dharossa, "Analisis Risiko Potensi Bahaya Dan Pengendaliannya Dengan Metode Hiradc Pada Pt. Igasar Kota Padang Sumatera Barat," *Jurnal Serambi Engineering*, Vol. 5, No. 2, Apr. 2020, Doi: 10.32672/Jse.V5i2.1957.