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Integrating HIRARC and Fault Tree Analysis (FTA) for Comprehensive Work Health and Safety Assessment in a Wood Industry Workshop

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ABSTRACT

The wood business is inherently dangerous, with workers frequently exposed to hazards such as mechanical breakdowns, chemical exposures, and ergonomic strains. Ensuring the safety and health of workers in such circumstances is critical. The objective of this study is to identify the potential risks associated with each occupation, determine the underlying causes of workplace accidents, and subsequently propose recommendations for enhancing safety. This study provides a thorough examination of occupational health and safety in a wood industry workshop, employing the HIRARC (Hazard Identification, Risk Assessment, and Risk Control) approach and the Fault Tree Analysis method (FTA). The investigation commences by methodically analysing potential dangers that may be present in the workshop, encompassing physical, chemical, fire, noise, ergonomic, electrical, and environmental threats. A comprehensive risk assessment is performed to evaluate the probability and magnitude of these dangers, with them being categorised based on their levels of risk. The findings emphasise areas of elevated risk, specifically the use of machinery, manual handling, and exposure to wood dust and chemicals. Next, risk management strategies are suggested to reduce the highlighted dangers, with the significance of engineering controls, administrative controls, and personal protective equipment (PPE) being highlighted. The measures include the installation of machine guards, improved ventilation systems, ergonomic workstation design, comprehensive safety training programmes, and regular maintenance schedules. The HIRARC method's systematic approach to identifying and addressing workplace dangers demonstrates its efficacy, ultimately resulting in a more secure work environment. The findings of this study are useful for industry practitioners and safety managers seeking to improve occupational health and safety standards in wood industry workshops. Future research directions include continual monitoring of existing safety measures and the use of enhanced safety technologies.

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1. Introduction

1.1 Malaysian Wood Industry

Malaysia's strength in the manufacturing sector has been significantly driven by the implementation of robust and forward-thinking Industrial Master Plans [1,18,28]. Through the New Industrial Master Plans (NIMP) 2030, Malaysia intends to transform the industry to greater heights, capitalizing on emerging global trends, supply chain disruptions, the current geopolitical landscape, digitalization, and environmental, social, and governance (ESG) considerations. The wood, paper, and furniture industries are listed among the 21 sectors in this plan. Based on the annual report [2], there are about 2,595 wood-related mills operating in Malaysia, with 2,013 located in Peninsular Malaysia, 283 in Sarawak, and 287 in Sabah. The total export of timber and timber products amounts to RM21.844 billion, with wooden furniture continuing to be the largest export in 2023.

Essentially, the industry comprises four sub-sectors: primary wood products, which include sawn timber, veneer, and panel products; secondary wood products, which include mouldings, builders' joinery, and carpentry (BJC); furniture; and pulp and paper products [1]. These diverse environments share common risks and hazards that can result in both minor and major injuries, as well as immediate effects or long-term health issues. Munang A *et al.,* [3] stated that inadequate job planning, insufficient safety training, a limited safety budget, and substandard accident investigations or evaluations all contribute to the high accident rate. According to a previous study by Nugraha *et al.,* [4], work accidents fall into two categories: those caused by the work environment and those caused by human causes. Their study also highlights that workplace accidents are mostly caused by risky behaviour (88%), unsafe conditions (10%), and unavoidable circumstances (2%).

According to a previous study by Sufa and Astuti [5], the types of work-related accidents that commonly occur include instances when hands are contacted by table saws, individuals are struck by grinding machines, fingers are caught or pinched by wood, feet are crushed by wood, and hands and feet are struck by hammers. According to the OSHA report [6], common health hazards in wood industry workshops include wood dust, particles, molds, noise, vibration, chemical exposure, and ergonomic factors. Wood dust is frequently found in workshops, primarily due to its generation during machine operations such as cutting, ripping, planning, and sanding. Skin disorders, asthma, nasal obstruction, and cancer are some of the health issues linked to exposure to wood dust.

According to Martin *et al*., [7], one of the causes of machine-related injuries occurs during the formatting of disc saws on surface planers and panel table saws. Without proper safeguards, the operators risk contacting hazardous parts, as blades and cutters may remain in motion even after machines are powered off. A favorable work environment always prioritizes the occupational health and safety of its employees. Occupational health and safety encompass a variety of measures and practices aimed at ensuring and protecting workers' welfare, with the goal of preventing work-related accidents and illnesses. The Occupational Safety and Health Act's (OSHA) mission is to ensure worker protection and prevent work-related injuries, illnesses, and deaths by setting and enforcing standards and providing training, outreach, education, and assistance.

According to the Occupational Safety and Health Act's (OSHA) [6], the OSHA 1994 regulations state that it is the employer's responsibility to ensure the safety and health of their workers and workplace. According to subsection 15 of OSHA, employers are responsible "to ensure, so far as is practicable, the safety, health, and welfare at work of all their employees." Subsection 17 of OSHA also stipulates that employers must conduct their operations in a way that, to the greatest extent possible, ensures no harm to other individuals. Thus, by complying with this provision, the employer must have a commitment to OSH planning, implementation, and evaluation to ensure all safety and health hazards in the organization have been addressed. OSHA [6] also concluded that those who are new on the job have a higher rate of injuries and illnesses than more experienced workers. According to previous research by Sahoo [8], one method that can be used to reduce possible hazards and continuously improve manufacturing operations is lean manufacturing (LM), which focuses on increasing value-added activities and decreasing waste. The lean management programme for Malaysia's wood-related businesses is arranged in large part by MTIB. A previous study conducted by Abu *et al.,* [9] stated that adopting green lean methods will, inadvertently, encourage many manufacturing companies to get proactive in developing greener procedures. Based on this issue, it is critical to create risk management procedures. Various risk assessment tools are being implemented in industries where applications' objectives differ, whether it is specifically for job analysis, as mentioned by Amin *et al.,* [10].

Risk management in occupational health and safety can be accomplished using a variety of methodologies, two of which include the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) and Fault Tree Analysis (FTA) techniques. The HIRARC approach is used to detect hazards, analyse them, and then implement risk management strategies, as mentioned in the previous study [11]. The HIRARC approach will be used for data processing and analysis to assess worker risk and safety in the wood industry workshop. The process of data processing and analysis involves identifying the factors that contribute to the most serious accidents in the wood industry workshop. In order to arrive at risk values that can be expressed as scores during the risk level assessment stage, data analysis starts by calculating the risk value derived from consequence rating findings, exposure, and probability. The suggested framework for risk management includes adding risk frequency to risk rating calculations, risk criteria parameters for risk likelihood and risk severity, new risk matrix dimensions and tools to evaluate the current control measure factors, and new risk categories with five levels that give more information and a long-lasting risk assessment method, as shown by Yusof *et al*., [12] previous research. According to Matondan *et al*., [13] study, assessments are conducted using criteria such as the probability, frequency, and potential severity of the related risks.

After identifying the highest risk value using the prior technique, the FTA method will be used for further investigation. This strategy examines the causes of accidents in order to identify the root causes of problems and predict the interaction of unfavorable events. This strategy employs top-down analysis to determine the relationships between failure events and their causes, as mentioned by Peeters *et al*., [14]. Previous research also stated that [15] the results of risk control techniques are expected to significantly minimize or eliminate the possibility of workplace accidents (zero accidents). Effective risk control techniques can also give employees a greater sense of safety and security. The goal of this study is to evaluate the safety and health of people working in wood-related industries. During the workshop, ergonomic risks and health concerns will be identified. To identify and quantify these potential dangers, the extended-point technique will be used. Based on this assessment, security measures will be advised to reduce employee health hazards.

2. Methodology

2.1 Hazard Identification Risk Assessment and Risk Control (HIRARC)

The quantitative data gathering method has been chosen for this study. Questionnaires were utilised to gather information on the present implementation of Hazard Identification, Risk Assessment, and Risk Control (HIRARC) at a wood industry workshop. One hundred and fifty (150) sets of questionnaires were disseminated by email and Google Form. According to R Aulia and Qurtubi [16], hazard identification, risk assessment, and risk control (HIRARC) involves managing work-related risks that may cause or contribute to accidents. The first step is to identify hazards, which is a systematic effort to identify and assess occupational safety and health concerns in the workplace, as described in a prior study [16]. Previous research by Setiyawan *et al.,* [17] said that hazard identification can be accomplished using a variety of methods, including direct on-site observation, interviews or discussions with relevant parties, and recording of previous work-related accidents inside the firm. As a result, this study relies on on-site observations, interviews, and a questionnaire survey. Additionally, HIRARC encompasses risks associated with both new and existing processes, enabling comprehensive risk identification and management. Those who have conducted risk assessments at work have observed improvements in their working methods, as per Ahmad *et al*., [19]. The Department of Occupational Safety and Health (DOSH) [20] offers guidelines on the methodology for conducting HIRARC. This guidance should be straightforward for small and medium industries to use and adaptable for all economic sectors, including manufacturing, construction, and others. Figure 1 illustrates the HIRARC procedure. DOSH [20] defines hazard identification as identifying critical operations tasks that pose significant risks to employee health and safety, as well as hazards associated with specific equipment, energy sources, working conditions, or activities. Hazards fall into three categories: health, safety, and environmental. Hazards can be discovered through seven sources: workplace inspection, accident investigation, knowledge exchange, injury/illness reports, safety audits, complaints and observations, and health and environmental monitoring.

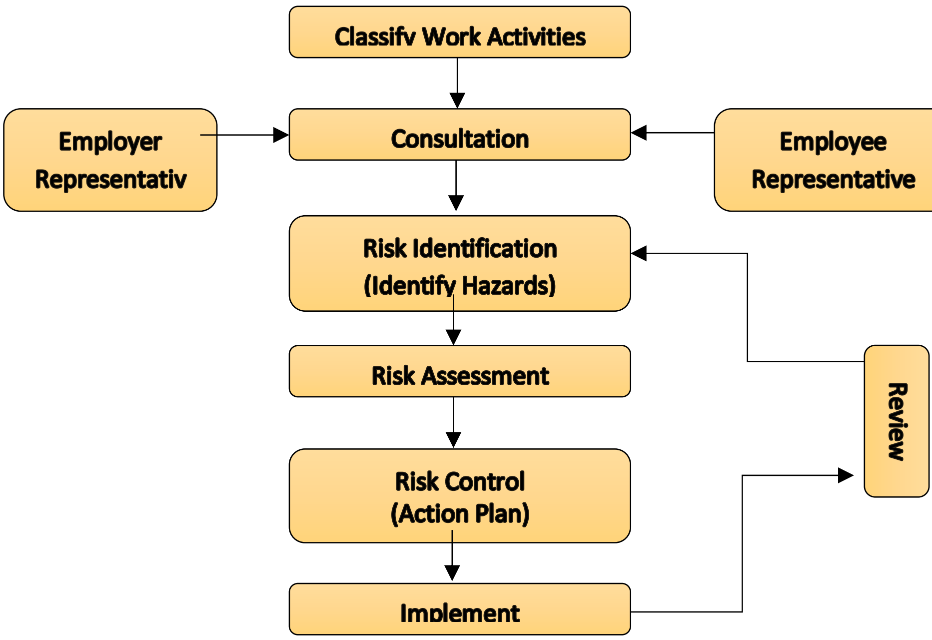

Fig. 1. Flow chart of HIRARC Process [20]

2.2 Risk Assessment Method

The second step is risk assessment, which entails assessing risk variables and estimating the level of risk. This assessment is typically conducted using a risk assessment matrix, which provides a structured approach to assessing and categorizing risks at various levels, as demonstrated in previous research [21,22], and it is also done to identify the risks that must be controlled, as stated in a study conducted by Kabul *et al*., [23]. According to Ahmad *et al*., [19], the measurement is made by analyzing the risk's severity and timing. In other words, risk assessment involves a detailed analysis of situations, procedures, and other potentially harmful workplace behaviors or dangers. Risk control decisions must be based on risk assessment results, which are provided in a risk matrix. According to Aulia [16], evaluating the size of a risk and determining its feasibility are steps in the risk assessment process. It could be used to assess the "likelihood" and "consequence" of a given hazardous event occurring or injuring a worker. If it is deemed high-risk and unsafe to deal with, appropriate steps may be taken to reduce the risk level that can be authorized as a safe workplace. According to Aulia [16], risk control is the eradication or inactivation of a danger in such a way that the hazard no longer poses a risk to workers who must access an area or work on equipment as part of their scheduled activity. Hazards should be controlled at the source (where the problem arises). The closer control is to the hazard's source, the more effective it is. This strategy is commonly referred to as implementing standard operation controls. If this strategy fails, it is often possible to manage risks along the worker's path, specifically between the machinery and the employee. This strategy is referred to as implementing administrative controls. Risk control involves conducting comparative tests and trials, or comparing them to standards, with the aim of reducing or preventing potential dangers. Risk assessment data, displayed in a matrix, are crucial for making risk control decisions. The methods used to assess recognized workplace hazards are described below. According to Edwards and Bowen [24], Table 1, Table 2, Table 3 and Table 4 show risk magnitude, severity, risk matrix, and risk ranking.

Table 1
Ranking of Likelihood Levels of an Occurrence [24]

Likelihood	Description	Rating
Almost Certain (AC)	Expected to occur in most circumstances	5
Likely (L)	Likely to occur in most circumstances	4
Possible (P)	Might occur at some time	3
Unlikely (U)	Could occur in certain circumstances	2
Rare (R)	May only occur in exceptional circumstances	1

Table 2
Ranking of Severity of an Impact [24]

Severity of an impact	Description	Rating
Severe (S)	Death occurs, toxic off- site release with detrimental effect, huge financial loss	5
Major (M)	Extensive injuries, loss of production capability, off-site release with no detrimental effect, major financial loss	4
Moderate (Mo)	Medical alert and light injuries, on site containment, requires outside assistance, high financial loss	3
Minor (Mi)	Minor injuries, rapid containment on site, medium financial loss	2
Insignificant (I)	No injuries, minor abrasion, Low financial loss	1

Table 3
Risk matrix develop using severity and likelihood parameters [24]

	Severity				
Likelihood	1	2	3	4	5
5	5	10	15	20	25
4	4	8	12	15	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5

Table 4
Risk ranking Categories [24]

Risk	Rating	Description	Hazards Mitigation Actions
20 - 25	E	Extreme	Extreme risks, immediate action required. Before the project commences or during project execution.
12-19	H	High	High risks. It will jeopardize project if not managed. Appropriate action implemented during project execution.
5-11	M	Medium	Medium risks. It will impact on time, quality, and cost of the project.
1-4	L	Low	Low risks. Acceptable project management risks monitor only.

2.3 Fault Tree Analysis (FTA)

This study utilized the Fault Tree Analysis approach, which analyses the fault tree to determine the root cause of the problem, as demonstrated in a previous study by Leimeister and Kolios [25]. The Fault Tree Analysis (FTA) method simplifies product failure analysis for human comprehension, particularly in company-created scenarios, as mentioned in a previous study [26]. This strategy involves creating graphical representations of issues to find root causes in a system, as stated in a study by Pratiwi *et al.*, [27]. According to Akyuz *et al.*, [26], the FTA clarifies probable failure occurrences, identifying risk sources before problems arise. On the other hand, Kang *et al.*, [29] stated that the FTA consists of two components: the event and the gate. Making FTAs follows this flow:

i) Recognize potential top events upon discovery.
ii) Identify the triggers for the top event to determine the initial contributor.
iii) The logic gate assignment determines whether two events occur simultaneously (AND) or one of the possible events (OR).
iv) Identify the second contributor and define logical symbols for event relationships that may cause the first-level contributor to fail.
v) The second contributor's logic gate responsibilities. Reduce or continue. Develop ways to improve the event mix and prevent high-level occurrences from recurring.

3. Result and Discussion

3.1 Respondent's Profile

The demographic profile of the respondents who participated in this study is shown in Figure 2. A total of 150 respondents were involved in this study. They consisted of 42.1% of female respondents and the remaining 57.9% of male respondents.

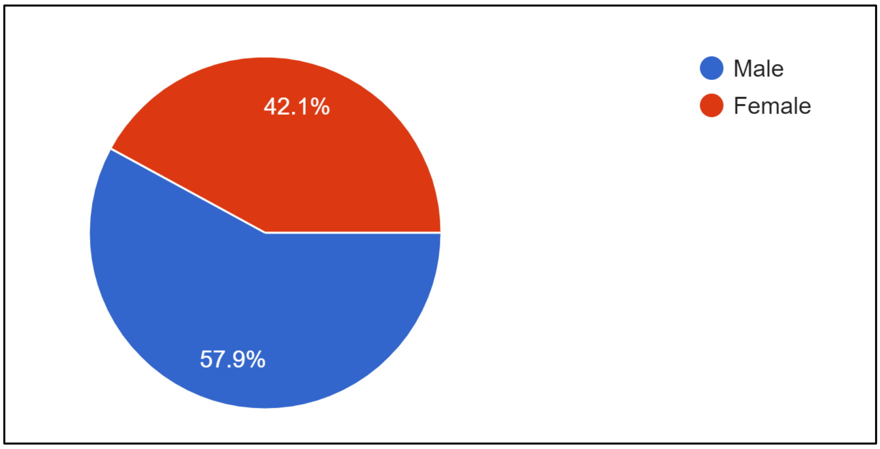

Fig. 2. Percentage of gender respondent

3.2 Analysis of Hazard Identification at the Work Industry Workshop

In this study, the HIRARC approach was used to identify hazards at several workstations, such as cutting, ripping, thickening, edge, drilling, sawmilling, and refinement. Hazard identification was carried out for each activity or work stage within each region, followed by risk assessment using likelihood and severity scale values. This phase included interviews for company owners and employees, as well as direct observations of workstations. To calculate the risk level for each action, the likelihood and severity numbers were multiplied together. The risk assessment was divided into four categories: low, moderate, high, and extreme. From the collected data, all possible hazards have been identified and evaluated for furniture processes at the work industry workshop, as shown in Table 5.

Table 5
Hazards Identification

No	Hazard	Risk
H1	Manual material handling is required when transporting wood from storage to cutting stations.	Backbone injury workers
H2	Using a table saw machine, wood is cut to size and design.	Exposure to fine dust is causing breathing difficulties.
H3	Kickback: Logs may have internal tensions or knots that can cause the saw blade to become stuck, potentially leading to kickback.	Injured worker
H4	Wood chips, splinters, or even larger bits of wood fly off as the saw blade slices through the log.	Can lead to injury for both the operator and bystanders.
H5	Band saw blades may shatter if they encounter unexpected knots, metal items embedded in the wood, or if they are worn out.	Injured worker
H6	Slips and falls: Logs can be heavy and difficult to move. Slipping or losing balance when moving logs on or around the bandsaw can result in falls or other injuries.	Injured worker
H7	Noise and vibration: Band saws emit high levels of sound and produce oscillations while in use.	Prolonged exposure to noise can cause hearing damage, and excessive vibrations can lead to fatigue or muscle strain for the operator.

H8	Manual material handling is required to move wood from the cutting workstation to the alignment workstation.	Injured worker
H9	The machine's surface becomes slippery due to the presence of wood on it.	Injured hand due to pinching
H10	An inattentive worker failed to properly adjust the wood to the required size.	Injured hand due to scratches
H11	The grinding machine is activated when wood on specified sections is being polished.	Headache due to machine noise
H12	There is a risk of hazardous adhesive content when applying glue during the assembly stage.	Can cause skin irritation and swivel head
H13	The flaming sandpaper machine is used to smooth the entire surface of the wood.	Exposure to fine dust is causing breathing difficulties.
H14	A flaming spray gun machine should be used when the entire surface of the wood is being painted.	Can cause skin irritation, eye irritation, swivel head, and respiratory disorders.
H15	Improper Guarding: If the band saw is not equipped with appropriate guards or safety features.	Injured worker

3.2 Analysis of Hazards Using Risk Assessment

According to the HIRARC evaluation, there is 1 (7%) hazard risk in the low category, 8 (53%) in the moderate category, 4 (27%) in the high category, and 2 (13%) in the extreme hazard category as ranked in Table 6. This percentage of the hazard category in the furniture process at the wood industry workshop has been simplified in Figure 3. According to the data gathered, exposure to fine dust was identified as a significant hazard during the cutting stage of furniture production. Jeroen *et al.,* [30] found that wood dust exposure is high among joinery workers and, to a lesser extent, furniture manufacturers, with regular hand tool use and cleaning being major sources of exposure. This exposure occurs when workers use a table saw to cut wood to size and design, as shown in Figure 4, as well as during the sanding process, which uses a flame sandpaper machine to smooth the entire surface of the wood.

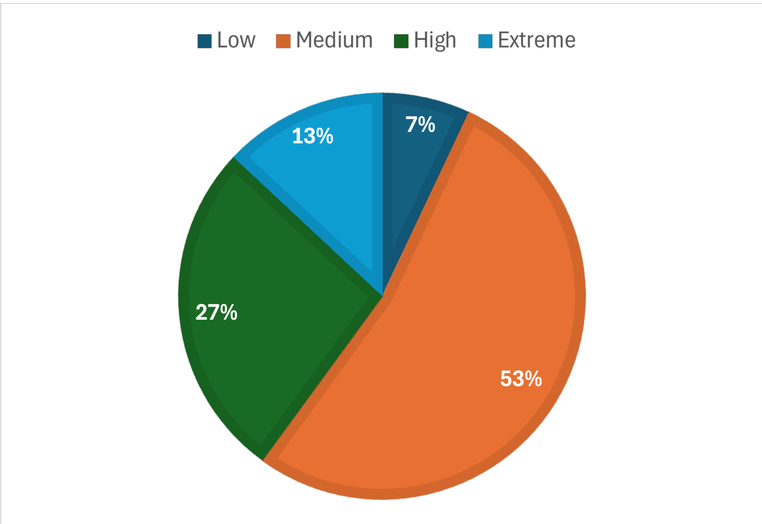

Fig. 3. Hazard category in wood industry workshop

Fig. 4. Sliding table saw and radial arm saw

Table 6
Risk Assessment

No.	Risk	Risk Assessment			
		Likelihood(L)	Severity (S)	Risk Level	Category
H1	Backbone injury workers	4 (Likely)	3(Moderate)	12	High
H2	Exposure to fine dust is causing breathing difficulties.	5 (Almost Certain)	5 (Severe)	25	Extreme
H3	Injured worker	2 (Unlikely)	2(Minor)	4	Medium
H4	Can lead to injury for both the operator and bystanders.	3 (Possible)	3(Moderate)	9	Medium
H5	Injured worker	1 (Rare)	1(Insignificant)	1	Low
H6	Injured worker	3 (Possible)	2(Minor)	6	Medium
H7	Prolonged exposure to noise can cause hearing damage, and excessive vibrations can lead to fatigue or muscle strain for the operator.	4 (Likely)	3(Moderate)	12	High
H8	Backbone injury workers	4 (Likely)	3(Moderate)	12	High
H9	Injured hand due to pinching	3 (Possible)	2(Minor)	6	Medium
H10	Injured hand due to scratches	3 (Possible)	2(Minor)	6	Medium
H11	Headache due to machine noise	3 (Possible)	3(Moderate)	9	Medium
H12	Can cause skin irritation and swivel head	3 (Possible)	2(Minor)	6	Medium
H13	Exposure to fine dust is causing breathing difficulties.	5(Almost Certain)	5 (Severe)	25	Extreme
H14	Can cause skin irritation, eye irritation, swivel head, and respiratory disorders.	4 (Likely)	3(Moderate)	12	High
H15	Injured worker	3 (Possible)	3(Moderate)	9	Medium

3.3 Analysis of Hazards Elimination through Risk Control

After identifying the various types and ranks of hazards, risk control is used to mitigate the sources of hazards at the workplace. Data were gathered from interviews, and mitigation measures for all identified hazards were implemented as stated in Table 7. The study identifies exposure to fine dust as one of the extreme hazards, and there are several potential elimination steps to consider, such as installing a dust collection system on the table saw. These tools frequently use a vacuum to capture dust right at the source before it becomes airborne. According to Jeroen *et al.*, [30], vacuum extraction on hand tools and other cleaning procedures dramatically lowered workplace exposures, although they may not be adequate to meet current occupational exposure limits. As a result, engineering and administrative control must both consider removing this hazard. For example, to capture dust at its source, install LEV systems in dust-producing areas such as cutting, sanding, and drilling stations.

Table 7
Risk Control

No	Hazard	Risk	Risk Control
H1	Manual material handling is required when transporting wood from storage to cutting stations.	Backbone injury workers	i) Establishing Standard Operating Procedures (SOP) for proper material handling and body placement provides administrative control. Use Personal Protective Equipment (PPE), including safety shoes and helmets. ii) In terms of engineering controls, it is recommended to provide workers with trolleys, carts, or pallet jacks to transport wood, thereby reducing the need for human lifting. Conveyor System: Install conveyor systems to automatically carry wood from storage to cutting stations.
H2	Using a table saw machine, wood is cut to size and design.	Exposure to fine dust is causing breathing difficulties.	i) Install a dust collection system on the table saw. These tools frequently use a vacuum to capture dust right at the source before it becomes airborne. ii) Workshop Ventilation: Make sure that the workshop has adequate ventilation. Good airflow can help to disperse dust particles and lower their concentration in the air. iii) Personal Protective Equipment (PPE): Use adequate PPE, such as a respirator or dust mask that filters out fine particles. Make sure the respirator is rated for tiny dust particles to ensure optimum protection. iv) Adopt safe work procedures to reduce dust formation. To prevent friction and dust formation, choose the appropriate blade type and make sure it is sharp. v) Design the workplace layout to reduce dust dispersion, such as keeping high-dust-generating equipment away from popular work areas.
H3	Kickback: Logs may have internal tensions or knots that can cause the saw blade to become stuck, potentially leading to kickback.	Injured worker	i) Place a riving knife or splitter behind the saw blade. This helps to keep the kerf (cut) from closing in and pinching the blade, which is a common source of kickback. ii) Proper blade maintenance for Keep the saw blade sharp and clean. A dull or unclean blade might produce more friction, increasing the risk of kickback.
H4	Wood chips, splinters, or even larger bits of wood fly off as the saw blade slices through the log.	Can lead to injury for both the operator and bystanders.	It is essential to use personal safety equipment (PPE) correctly. It is essential to always wear safety glasses or helmets to protect your eyes from flying objects. Wearing a face shield and safety glasses is recommended, especially when working with very soft or easily broken wood. Long sleeves and gloves will protect your skin from splinters and wood chips. Make

			sure your gloves are tight-fitting to avoid getting stuck in the equipment.
H5	Band saw blades may shatter if they encounter unexpected knots, metal items embedded in the wood, or if they are worn out.	Injured worker	Choose the suitable blade option. Select the proper blade for the type of wood and the cut you're making. Using the proper blade decreases the risk of splintering and ripping.
H6	Slips and falls: Logs can be heavy and difficult to move. Slipping or losing balance when moving logs on or around the bandsaw can result in falls or other injuries.	Injured worker	Clean floors in a regular manner to eliminate sawdust, wood chips, and other debris that might cause slippery situations. Install nonslip flooring or mats in areas where employees frequently walk or move heavy objects.
H7	Noise and vibration: Band saws emit high levels of sound and produce oscillations while in use.	Prolonged exposure to noise can cause hearing damage, and excessive vibrations can lead to fatigue or muscle strain for the operator	i) Provide all personnel with proper hearing protection, such as earplugs or earmuffs. Ensure that they are correctly fitted and utilized on a consistent basis. ii) Install soundproofing materials, such as acoustic panels or drapes, to absorb noise and lower sound levels in the workspace. iii) Maintain and service machinery on a regular basis to ensure they work smoothly and efficiently, lowering noise levels. iv) Workers who use vibrating tools and machines should be provided with anti-vibration gloves. These gloves can help to lessen the amount of vibration transmitted to the hands and arms.
H8	Manual material handling is required to move wood from the cutting workstation to the alignment workstation.	Backbone Injury worker, injuries such as strains, sprains, and other musculoskeletal disorders	i) Train employees in proper lifting techniques, such as bending at the knees, keeping the back straight, and keeping the load close to the body. ii) Install roller conveyors between workstations to ensure that wood moves smoothly and efficiently without the need for hand lifting.
H9	The machine's surface becomes slippery due to the presence of wood on it.	Injured hand due to pinching	i) Establish regular cleaning activities for machine surfaces to eliminate sawdust, wood chips, and other material that can cause slipping. ii) Maintain appropriate humidity levels in the workshop to avoid condensation on machine surfaces. Use dehumidifiers if necessary.
H10	An inattentive worker failed to properly adjust the wood to the required size.	Injured hand due to scratches	Provide comprehensive training on the proper use of equipment, measuring techniques, and the importance of accuracy when modifying wood to the desired size.
H11	The grinding machine is activated when wood on specified sections is being polished.	Headache due to machine noise	Implement administrative controls, such as rotating personnel, to restrict the length of time an individual is exposed to loud noises.
H12	There is a risk of hazardous adhesive content when applying glue during the assembly stage.	Can cause skin irritation and swivel head	Choose adhesives with low volatile organic compound (VOC) levels or those labelled as non-toxic. These are generally safer for employees and the environment.
H13	The flaming sandpaper machine is used to smooth the entire surface of the wood.	Exposure to fine dust is causing breathing difficulties.	Workers who apply adhesives should be given proper respiratory protection, such as N95 masks or respirators, especially in poorly ventilated spaces.

H14	A flaming spray gun machine should be used when the entire surface of the wood is being painted.	Can cause skin irritation, eye irritation, swivel head, and respiratory disorders.	i) Provide workers with safety eyewear or face shields to protect their eyes from spills and odors. ii) Provide workers with full instruction on how to use the spray gun machine safely, including startup and shutdown protocols, proper handling techniques, and emergency response.
H15	Improper Guarding: If the band saw is not equipped with appropriate guards or safety features.	Injured worker	Ensure that the band saw has appropriate guards that protect all moving parts, such as the blade, wheels, and driving systems. Guards should be robust, well-fitted, and hide the blade except at the point of operation.

3.4 Fault Tree Analysis (FTA)

After analysis was performed using the FTA (Fault Tree Analysis) approach, an HIRARC analysis identified the danger of exposure to fine dust while operating table saw machines at the cutting workstations. This investigation is based on people, tools, processes, and the physical setting of the workplace. Figure 5 illustrates the FTA for fine dust exposure during the operation of table saw machines. According to Figure 5, the major event is exposure to fine dust because of using a table saw machine when cutting wood to size and design, which is the top event in the error tree diagram. The FTA consists of nine intermediate events and fifteen basic events, all of which are linked by three "OR" logical gates. Potential hazards when using a table saw machine include respiratory problems caused by factors such as incorrect blade use, insufficient training, a lack of personal protective equipment (PPE) such as goggles, the absence of machine safety features, the absence of standardized work procedures, and the presence of dusty workbenches. To mitigate workplace health and safety hazards from FTA basic occurrences, several control measures are presented. Administrative control methods, such as table saw machine operating films, can address incorrect PPE and training. Provide adequate safety glasses and masks for employees to answer concerns about goggles not being available. Local exhaust ventilation (LEV) is suggested for workstation ventilation. LEV systems in cutting, sanding, and drilling stations gather dust at its source. When addressing the lack of safety measures on the machine, consider technical controls such as placing safety features on the equipment. In circumstances where standardized work practices are not available, administrative controls can be implemented by creating Standard Operating Practices (SOPs) for the use of table saw equipment. To address concerns with dusty workbenches, add dust collectors to table saw machines. These management techniques are intended to improve occupational safety and health for workers exposed to fine dust in furniture manufacturing.

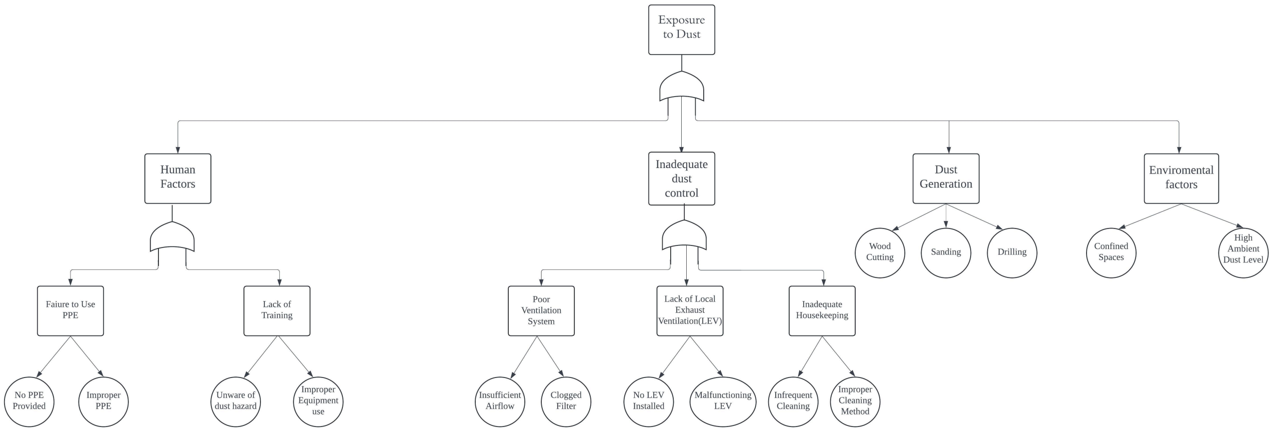

Fig. 5. FTA worker's exposed to fine dust

4.Conclusion

This study assessed the risks in the woodworking industry and proposed mitigation measures for each identified hazard. According to the data analysis, 15 risks have been identified during the stages of making furniture, such as cutting, ripping, thickening, edge, drilling, sawmilling, and finishing at the wood industry workshop. The next risk assessment found that there is 1 low risk, 8 medium risks, 4 high risks, and 2 extreme risks. Workers exposed to fine dust while using table saws to cut wood to the right size and shape face the highest level of risk, with a total value of 25. This risk has a likelihood level of 5 and a severity level of 5. The FTA was used to assess the risk of extreme accidents. The FTA is made up of 9 intermediate events and 15 basic events, all of which are connected by three "OR" logic gates. Factors such as inadequate PPE (goggles and safety mask), a lack of awareness about dust hazards, insufficient training, a poor ventilation system in the workplace, insufficient housekeeping, the absence of safety equipment on the machine, and the absence of standardized work procedures are among the 15 basic events identified. For occupational safety and health risk control, mitigation measures were proposed for each of the basic events outlined in the FTA involving workers exposed to fine dust, particularly during the cutting and sanding process. These control recommendations include a variety of administrative and engineering controls, such as installing local exhaust ventilation (LEV), adjusting work schedules to reduce workers' exposure to dust, providing educational videos on machine operation, obtaining enough PPE glasses and masks, adding safety features to the machines, developing Standard Operating Procedures (SOPs), and installing dust collectors on table saw machines.

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