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Hazard Identification, Risk Assessment and Control for Basic Electronics and Embedded System Design Lab (Case Study: Fablab President University, Indonesia)

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A B S T R A C T

Basic Electronics and Embedded System laboratories are vital for technical education but pose understudied occupational hazards. Basic Electronics and Embedded System laboratories play a critical role in technical education; however, they also present significant yet often underexplored occupational hazards, such as electrical shock from exposed conductors and short circuits during circuit assembly. This study systematically identifies, assesses, and controls risks in the Basic Electronics and Embedded System Design Laboratory at Fablab President University using direct observation, interviews, and documentation review. It identified 18 hazards across 8 activities, categorized into 6 types: electrical (most dominant, 7 occurrences), mechanical, fire/explosion, extreme temperature, noise/vibration, and natural hazards especially from energized circuits and high-voltage work. A 4×4 risk matrix revealed 5 High Risk and 2 Extreme Risk scenarios (max value 12 from short circuits), with incidental inspections proving inadequate. Applying the hierarchy of controls LOTO, insulated tools, RCDs, barriers, layout improvements, and training—reduced average risk from 9 to 4.29, eliminating all high/extreme levels. These findings validate proactive HIRAC for enhancing OHS, offering a replicable model for electronics labs.

Laboratorium Elektronika Dasar dan Sistem Tertanam sangat penting untuk pendidikan teknik tetapi memiliki bahaya kerja yang kurang dipelajari. Laboratorium Elektronika Dasar dan Sistem Tertanam memainkan peran penting dalam pendidikan teknik; namun, laboratorium ini juga menghadirkan bahaya kerja yang signifikan namun seringkali kurang dieksplorasi, seperti sengatan listrik dari konduktor yang terbuka dan korsleting selama perakitan sirkuit. Studi ini secara sistematis mengidentifikasi, menilai, dan mengendalikan risiko di Laboratorium Desain Elektronika Dasar dan Sistem Tertanam di Fablab President University menggunakan observasi langsung, wawancara, dan tinjauan dokumentasi. Studi ini mengidentifikasi 18 bahaya di 8 aktivitas, yang dikategorikan menjadi 6 jenis: listrik (paling dominan, 7 kejadian), mekanik, kebakaran/ledakan, suhu ekstrem, kebisingan/getaran, dan bahaya alam terutama dari sirkuit yang bertegangan dan pekerjaan tegangan tinggi. Matriks risiko 4×4 mengungkapkan 5 skenario Risiko Tinggi dan 2 skenario Risiko Ekstrem (nilai maksimum 12 dari korsleting), dengan inspeksi insidental terbukti tidak memadai. Penerapan hierarki pengendalian (Hyper-to-Tag/LOOT), peralatan berinsulasi, RCD (Residual Current Device), penghalang, perbaikan tata letak, dan pelatihan—mengurangi risiko rata-rata dari 9 menjadi 4,29, menghilangkan semua tingkat risiko tinggi/ekstrem. Temuan ini memvalidasi HIRAC (Hazard Identification and Risk Assessment) proaktif untuk meningkatkan K3 (Keselamatan dan Kesehatan Kerja), menawarkan model yang dapat direplikasi untuk laboratorium elektronik.

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1. Introduction

In the digital era, knowledge is a critical asset, particularly as advancements in embedded systems and Internet of Things (IoT) technologies drive innovation across industries (Padilla, Espinal, Cordova-Garcia, & Schibelius, 2025; Rajagopalan et al., 2024). The growing integration of IoT in daily life has heightened the demand for robust technical understanding and practical expertise in embedded systems. Notably, the convergence of embedded systems and IoT underpins smart infrastructure, industrial automation, and intelligent devices, reshaping both technological capabilities and educational frameworks (Padilla et al., 2025). To respond to these shifts, the development of hard skills in electrical and embedded systems engineering has become indispensable for future professionals (Kapilan, Vidhya, & Gao, 2021; Wahyudi, Budiyanto, Widiastuti, Hatta, & Bakar, 2024) Modern curricula emphasize competencies such as circuit design, microcontroller programming, sensor integration, and system troubleshooting foundational elements of IoT and Industry 4.0 skill sets (Kapilan et al., 2021) Laboratory-based learning, supported by physical and increasingly virtual labs, is essential for equipping students with these critical technical skills.

High-quality laboratory facilities are important and therefore fundamental in engineering education. For instance, an embedded system lab typically provides resources such as PCB fabrication tools, microcontroller testbeds, programmable logic devices, and measurement instruments (Kapilan et al., 2021; Wahyudi et al., 2024) These real-world environments foster experiential learning, bridging the gap between theoretical knowledge and practical application. Nevertheless, laboratories inherently present a range of potential hazards, including electrical shock, component burns, physical injuries from equipment, and exposure to hazardous materials (Kapilan et al., 2021; Ridasta, 2020; Wahyudi et al., 2024).

The operation of an electronics or embedded systems laboratory demands rigorous attention to Occupational Health and Safety (OHS) in line with global best practices and national regulations. The adoption and continuous improvement of OHS management systems is recognized as essential for minimizing risks and ensuring safety in engineering educational settings (Rizbudiani & Jaedun, 2021).

In Indonesia, the implementation of OHS in academic institutions is governed by regulations such as Government Regulation No. 50/2012 concerning Occupational Safety and Health Management Systems (SMK3) and is further reinforced by standards like ISO 45001 and LAM TEKNIK accreditation requirements (Husna, Naomi Tosani, & Neny Afridayanti, 2022) ("Peraturan LAM Teknik Nomor 6 Tahun 2025," 2025). In addition, the use of standardized K3L (OHS, Environment, and Security) instruments and comprehensive risk assessment tools is critical for hazard identification and control (Ridasta, 2020; Rizbudiani & Jaedun, 2021; Wahyudi et al., 2024).

The implementation of Occupational Health, Safety, and Environment (K3L) management systems, particularly through the Occupational Health and Safety Management System (SMK3), has become an essential framework in ensuring safe and controlled working environments in educational laboratories. In Indonesia, SMK3 is regulated under Government Regulation No. 50 of 2012 and aims to systematically prevent workplace accidents and occupational diseases while ensuring compliance with national safety standards (Pemerintah Republik Indonesia, 2012). At the international level, ISO 45001 further strengthens this framework by providing a structured approach for organizations to identify hazards, assess risks, and implement effective control measures to continuously improve occupational health and safety performance (International Organization for Standardization, 2018).

Within this framework, Hazard Identification, Risk Assessment, and Control (HIRAC) serves as a core tool to systematically recognize potential hazards, evaluate associated risks, and determine appropriate control measures. Previous studies have highlighted that HIRAC is an essential component of risk-based occupational safety management, enabling organizations to proactively reduce hazards and improve safety outcomes (Abad, Lafuente, & Vilajosana, 2013; Jilcha & Kitaw, 2017).

Importantly, structured hazard identification, risk assessment, and control (HIRAC) frameworks have already been implemented in the Environmental Chemistry Laboratory of President University, where they proved effective in systematically recognizing and prioritizing hazards and refining laboratory safety practices (Manik et al., 2024). However, such a comprehensive HIRAC assessment has not yet been conducted for electronics and embedded systems laboratories at the university, despite their unique risk profiles and essential educational role. This study presents a hazard identification, risk assessment, and control (HIRAC) framework for a basic electronics and embedded system design laboratory at Fablab President University, aiming to strengthen OHS practices based on current standards, empirical evidence, and recommended guidelines.

2. Methods

2.1. Study design and setting

This study was conducted at the Basic Electronics and Embedded System Design Laboratory (Fablab) at President University. The laboratory activities observed involve practical experiments related to electronics assembly, soldering, programming embedded systems, and testing Internet of Things (IoT) devices. The research aimed to identify and analyze potential hazards, assess associated risks, and propose control measures to prevent accidents and ensure occupational health and safety.

2.2. Hazard identification

Hazard identification was conducted through a combination of direct observation, semi-structured interviews, and document review in laboratory activities at Fablab President University in September 2025. Direct observation was carried out using a structured observation checklist based on HIRAC principles and standard laboratory safety guidelines to systematically identify potential hazards during practical activities. These activities included soldering, wiring, operating oscilloscopes, handling electrical circuits, and working with microcontrollers.

Semi-structured interviews were conducted with laboratory assistants and students using an interview guide designed to explore their experiences, perceived risks, and safety practices during laboratory sessions. This approach allowed for in-depth insights into routine activities and potential hazards that may not be directly observable.

In addition, document reviews were performed on relevant laboratory records, including previous incident reports, standard operating procedures (SOPs), safety manuals, and equipment usage guidelines. These documents were analyzed to support hazard identification and ensure consistency with established safety standards.

Common hazards identified include electrical shock, burns from soldering irons, inhalation of soldering fumes, fire hazards, and mechanical injuries from cutting tools. The overall identification process was guided by HIRAC procedures and supported by multiple data sources to enhance the accuracy and reliability of hazard detection.

Hazard identification was conducted through direct observation at laboratory activities in September 2025, interviews with laboratory assistants and students, and documentation reviews from the Fablab President University. This process aimed to identify all possible hazards during practical activities related to electronics and embedded system design, such as soldering, wiring, using oscilloscopes, handling electrical circuits, and working with microcontrollers. Common hazards identified include electrical shock, burns from soldering irons, inhalation of soldering fumes, fire hazards, and mechanical injuries from cutting tools. The identification process was guided by HIRAC procedures and referenced reliable data sources from previous laboratory records and standard safety guidelines to ensure the accuracy of hazard detection.

2.3. Risk assessment

Risk assessment was conducted using a 4×4 risk matrix based on likelihood (L) and severity (S). Likelihood represents the probability of hazard occurrence, ranging from 1 (rare) to 4 (frequent), while severity represents the impact level of consequences, ranging from 1 (minor injury or negligible damage) to 4 (catastrophic injury or fatality). The risk value (R) was calculated using the equation $R = L \times S$. Risk levels were classified into three categories: low (1–3), medium (4–6), and high (8–16), which were used to prioritize control measures.

Risk assessment was performed using the Hazard Identification, Risk Assessment, and Control (HIRAC) methodology aligned with the ISO 45001:2018 Occupational Health and Safety Management System standard (ISO, 2018). Each identified hazard was evaluated based on its likelihood of occurrence and the severity of potential consequences, using a 4×4 risk matrix as shown in Table 2.

Risk = Likelihood × Severity.................. (eq. 1)

The likelihood scale ranged from frequent (1) to remote (4), while the severity scale ranged from minor injury or damage (1) to catastrophic injury or fatality (4) (Ristic, 2013; Salahuddin Araibi et al., 2024), as shown in Table 1. Based on this scoring system, risk values range from 1 to 12 and are categorized into four levels: low risk (1–3), moderate risk (4–6), high risk (7–9), and extreme risk (10–12). These categories were used to prioritize hazard control measures and to support decision-making in determining appropriate mitigation strategies. This risk assessment approach is consistent with risk-based thinking principles outlined in ISO 45001, which emphasize systematic hazard evaluation and control to improve occupational health and safety performance (International Organization for Standardization, 2018). Risk levels were categorized as low, medium, and high to determine the urgency of intervention and prioritization of control actions. The assessment process involved the following steps: (a) identification of hazards related to laboratory activities such as soldering, wiring, or working with live circuits; (b) evaluation of the likelihood of each hazard occurring and its potential severity; (c) calculation of the risk value using the matrix; and (d) classification of each risk level based on the risk score to prioritize safety measures.

Table 1. Detail information the Likelihood scale and Severity scale (Ristic, 2013)

Likelihood Scale			Severity Scale		
Scale	Name	Description	Scale	Name	Description
1	Frequent	Can occur several times in a year	1	Minor	Low-level or negligible injuries
2	Occasional	Can occur several times in 1 or 2 years	2	Moderate	Minor bodily injuries
3	Uncommon	Can occur several times in 2 or 5 years	3	Major	Permanent loss of body functions
4	Remote	Can occur once in 5 or 30 years	4	Catastrophic	Death or serious bodily injuries

Table 2. Risk assessment level (Ristic, 201*3 Modifi*ed)

	Minor	Moderate	Major	Catastrophic
Frequent	1	2	3	4
Occasional	2	4	6	8
Uncommon	3	6	9	12
Remote	4	8	12	15

Hazards categorized as high risk required immediate control actions such as engineering modifications, substitution, or strict administrative procedures. Meanwhile, medium risks were controlled through training, supervision, and use of proper PPE, while low risks were monitored regularly to ensure continued compliance and effectiveness of existing controls (Morris & Cannady, 2019) To support the prioritization process, a Pareto analysis was applied to identify the most significant hazards that contribute to the majority of overall laboratory risk, following the 80/20 rule (Spasojević-Brkić, Perišić, Veljković, Misita, & Damjanović, 2022). This systematic approach ensures that both electrical and non-electrical risks in the Basic Electronics and Embedded System Design Laboratory are properly evaluated, managed, and continuously improved in accordance with international safety standards.

2.4. Control

Control strategies were developed with reference to the hierarchy of controls framework, including elimination, substitution, engineering controls, administrative controls, and personal protective equipment (PPE) as shown in Figure 1. (Morris & Cannady, 2019).

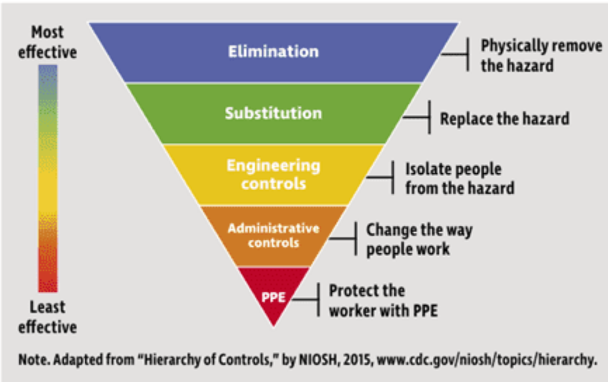

Figure 1. Hierarchy of controls (Morris & Cannady, 2019)

For example, electrical hazards were mitigated by isolating power sources and installing surge protectors, while ergonomic risks during soldering were reduced through adjustable workstations and breaks. Training and supervision protocols were also reviewed and recommended to enhance safety awareness among laboratory users.

2.5. Data collection and analysis

Data collection was conducted through direct observations during active laboratory sessions, semi-structured interviews with laboratory staff and students, and document reviews. Observations were guided using a structured checklist based on HIRAC principles and standard laboratory safety guidelines. Interviews were conducted using an interview guide to explore participants' experiences, perceived risks, and safety practices. Supporting documents, including standard operating procedures (SOPs), safety manuals, and previous incident records, were also reviewed to ensure comprehensive hazard identification.

All collected data were compiled into a hazard identification and risk assessment (HIRAC) table. Risk assessment was performed by assigning likelihood (L) and severity (S) scores to each identified hazard, with risk values calculated using the formula L × S. The resulting risk levels were used to prioritize hazards and determine appropriate control measures.

Proposed control measures were developed based on the hierarchy of controls. The effectiveness of these measures was evaluated by reassessing likelihood and severity values to obtain residual risk levels, enabling comparison between initial and post-control risks.

3. Results

The results of the hazard identification, as shown in Table 3, indicate the presence of 8 activity factors consisting of 6 internal activities working with live electrical circuits, handling high-voltage equipment, soldering and using hot tools, using power tools and drilling equipment, and operating motors, power supplies, and generators and 2 external factors, namely earthquakes and riots/fire-related events. From these activities, a total of 6 types of hazards were identified, including electrical hazards, mechanical hazards, fire and explosion hazards, extreme temperature hazards, noise and vibration hazards, and natural hazards. In total, 18 potential hazards were documented across all activities, with electrical hazards being the most frequent (7 occurrences), followed by noise and vibration hazards (4 occurrences), and extreme temperature, mechanical, and fire/explosion hazards (3 occurrences each). Natural hazards were the least frequent, with 1 occurrence. These findings highlight that electrical-related activities contribute the highest risk in the laboratory, emphasizing the need for strengthened safety controls and preventive measures.

Risk assessment was performed on each identified hazard using quantitative parameters of likelihood, severity, and risk value in Table 4. Based on the risk assessment table, laboratory activities are associated with various hazard potentials such as electrical risks, fire and explosion hazards, mechanical hazards, noise and vibration, extreme temperature, and even social hazards. The likelihood (L) of each hazard generally ranges from 1 to 3, with most hazards being managed through

routine incidental inspections. Maximum severity (S) values fall mostly within category 3 or 4, and risk values range from low (2) to extreme (12). The highest risks are found in activities involving short circuits, fire, and riots, while tasks such as soldering or handling moving components generally pose low to moderate risk levels.

Table 3. Hazard identification

No	Activity	Type of Hazard	Hazard Potential
1	Working with live electrical circuits	Electrical Hazard	Direct contact with energized wires or terminals
2	Handling high-voltage equipment	Fire and Explosion Hazard	Short circuit
3	Soldering and using hot tools	Fire and Explosion Hazard	Faulty wiring
		Fire and Explosion Hazard	Improper handling
		Extreme Temperature Hazard	Exposure to hot soldering iron
		Extreme Temperature Hazard	Molten solder
		Extreme Temperature Hazard	Toxic fumes
4	Using power tools & drilling equipment	Mechanical Hazard	Damaged cables
		Electrical Hazard	Sparks
		Mechanical Hazard	Flying debris
		Electrical Hazard	Direct contact with energized wires or terminals
		Noise and Vibration Hazard	Moving component
		Noise and Vibration Hazard	Drill and tools
5	Operating motors, power supply, generators	Mechanical Hazard	Rotating Parts
		Mechanical Hazard	Moving component
		Electrical Hazard	High-current electricity
		Noise and Vibration Hazard	Rotating Parts
		Noise and Vibration Hazard	Moving component
6	Earthquake	Natural Hazard	Structural collapse, falling electrical equipment, or short circuit leading to injury or fire.
7	Fire	Fire Hazard	Burns, smoke exposure, equipment, and property damage.
8	Riots	Social Hazard	Damage to laboratory facilities or injury to personnel due to riots or vandalism.

Risk assessment was performed on each identified hazard using quantitative parameters of likelihood, severity, and risk value in Table 5. Based on the risk assessment table, laboratory activities are associated with various hazard potentials such as electrical risks, fire and explosion hazards, mechanical hazards, noise and vibration, extreme temperature, and even social hazards. The likelihood (L) of each hazard generally ranges from 1 to 3, with most hazards being managed through routine incidental inspections. Maximum severity (S) values fall mostly within category 3 or 4, and risk values range from low (2) to extreme (12). The highest risks are found in activities involving short circuits, fire, and riots, while tasks such as soldering or handling moving components generally pose low to moderate risk levels.

Table 4. Risk assessment

No	Activity	Type of Hazard	Hazard Potential	L	Avg (L)	Current Control	S	Risk Value	Risk Level
1	Working with live electrical circuits	Electrical Hazard	Direct contact with energized wires or terminals	2	2	Incidental inspection	4	8	High
2	Handling high-voltage equipment	Fire and Explosion Hazard	Short circuit	3	3	Incidental inspection	4	12	Extreme
3	Soldering and using hot tools	Fire and Explosion Hazard	Faulty wiring	2	2	Incidental inspection	2	4	Medium
		Fire and Explosion Hazard	Improper handling	2	2	Incidental inspection	4	8	High
		Extreme Temperature Hazard	Exposure to hot soldering iron	1	1	Incidental inspection	3	3	Low
		Extreme Temperature Hazard	Molten solder	2	2	Incidental inspection	2	4	Medium
		Extreme Temperature Hazard	Toxic fumes	1	1	Incidental inspection	2	2	Low
4	Using power tools & drilling equipment	Mechanical Hazard	Damaged cables	2	2	Incidental inspection	3	6	Medium
		Electrical Hazard	Sparks	2	2	Incidental inspection	2	4	Medium
		Mechanical Hazard	Flying debris	1	1	Incidental inspection	2	2	Low
		Electrical Hazard	Direct contact with energized wires or terminals	2	2	Incidental inspection	4	8	High
		Noise and Vibration Hazard	Moving component	2	2	Incidental inspection	3	6	High
		Noise and Vibration Hazard	Drill and tools	1	1	Incidental inspection	2	2	Low
5	Operating motors, power supply, generators	Mechanical Hazard	Rotating Parts	2	2	Incidental inspection	2	4	Medium
		Mechanical Hazard	Moving component	3	3	Incidental inspection	2	6	Medium
		Electrical Hazard	High-current electricity	1	1	Incidental inspection	3	3	Low
		Noise and Vibration Hazard	Rotating Parts	2	2	Incidental inspection	2	4	Medium
		Noise and Vibration Hazard	Moving component	2	2	Incidental inspection	1	2	Low
6	Earthquake	Natural Hazard	Structural collapse, falling electrical equipment, or short circuit leading to injury or fire.	3	3	Incidental inspection	3	9	High
7	Fire	Fire Hazard	Burns, smoke exposure,Equipment and property damage	3	3	Incidental inspection	4	12	Extreme
8	Riots	Social Hazard	Damage to laboratory facilities or injury to personnel due to Riots or Vandalism	2	2	Incidental inspection	3	6	Medium

The Basic Electronics and Embedded System Design Lab layout depicted in Figure 2. is used as the fundamental reference for hazard mapping and risk assessment. This laboratory consists of several key work zones: two large central workbenches, a solder station at the top side, equipment racks at the top right, an electronic cabin at the bottom left, and a power supply rack at the bottom right. The clear separation and arrangement of these areas support efficient equipment access, structured workflows, and facilitate systematic identification of potential hazards and risk zones within the space.

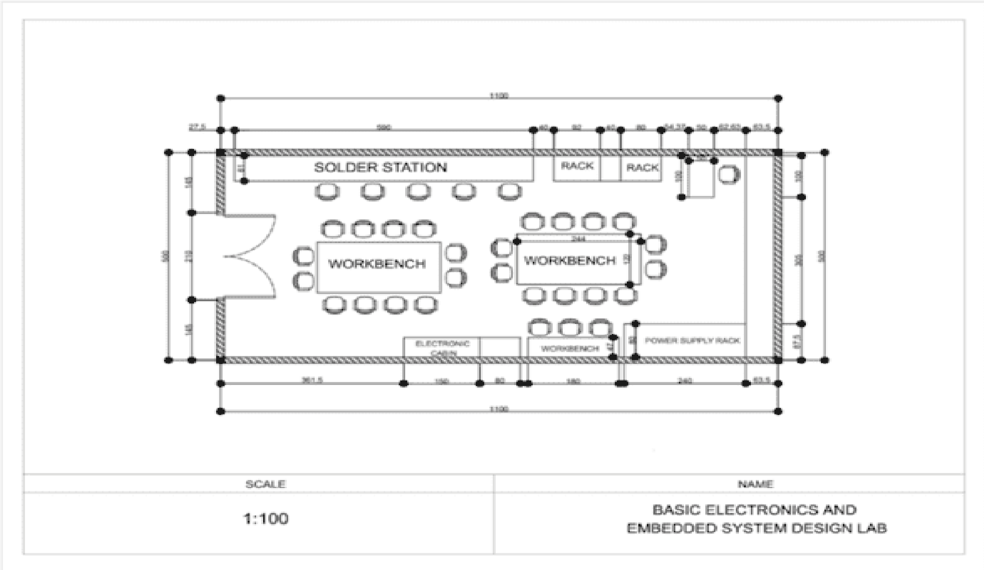

Figure 2. Laboratory layout

4. Discussion

The comprehensive hazard identification, as detailed in Table. 3, established a complex risk profile for the Electronics and Embedded Systems Laboratory, dominated by electrical hazards. The analysis identified six types of hazards across eight activity factors, with electrical hazards having the highest frequency (7 occurrences), followed by noise and vibration hazards (4 occurrences). This finding is logical given the core function of the facility, emphasizing the recurring threat posed by "direct contact with energized wires or terminals" across various internal activities.

The subsequent Risk Assessment (Table 4) solidified this observation by assigning High to Extreme Risk categories to scenarios involving direct electrical exposure. Notably, the Extreme Risk Value of 12 (Likelihood L=3; Severity S=4) was recorded for a "short circuit" event during "Handling high-voltage equipment," signaling the potential for catastrophic outcomes. Furthermore, scenarios related to "Working with live electrical circuits" and "Using power tools" were classified as High Risk (Value 8). This high-risk classification is compounded by the finding that the current primary control measure for virtually all hazards is merely "Incidental inspection." This heavy reliance on passive, opportunistic observation demonstrates a critical gap in the existing safety infrastructure, rendering it inadequate for effectively managing High and extreme risk assessments.

The spatial arrangement shown in the laboratory layout (Figure 2) plays a significant role in shaping the overall hazard profile identified in Table 3 and Table 5. Each workstation and equipment zone contributes differently to the emergence of electrical, thermal, mechanical, and environmental hazards. The layout's workflow efficiency enables practical learning, yet it simultaneously increases the likelihood of hazardous interactions between users and equipment. The following discussion links the laboratory’s physical arrangement with the risk assessment findings.

These findings highlight critical deficiencies in risk management for electrical hazards in the lab, especially since scenarios involving direct electrical exposure—such as handling high-voltage equipment during a short circuit—were assigned Extreme Risk, and other activities like live circuit work or using power tools remain in the High-Risk category. The prevalent reliance on "Incidental inspection" as the main control measure illustrates a reactive safety culture, which is insufficient to address the severity and likelihood of these hazards.

To achieve effective risk control, a more proactive, robust framework must be implemented. This includes engineering controls (such as barriers, insulation, residual current devices), administrative measures (clear procedures, lockout/tagout protocols, scheduled inspections), mandatory use of personal protective equipment (PPE) tailored for electrical work, periodic training for all lab users, and explicit signage for hazardous zones. Bridging these proposals into the risk control strategy will transition the lab's safety infrastructure from passive observation to active, systematic hazard mitigation—addressing both the identified risks and compliance with laboratory safety standards.

Table 5. High and extreme risk assesment

No	Activity	Hazard Potential	Current Control	Current Risk Value	Proposed Control	New Likelihood	New Severity	New Risk Value
1	Working with live electrical circuits	Direct contact with energized wires or terminals	Incidental inspection	8	- Lock Out Tag Out (LOTO) before starting work - Use insulated tools - Install safety barriers / panel covers - Voltage checks before working (test before touch) - Electrical safety training - Mandatory use of PPE: insulated gloves, safety shoes	1	4	4
2	Soldering and using hot tools	Fire and Explosion Hazard	Incidental inspection	8	- Temp-control soldering station - Fire extinguisher (APAR), fume extractor - Area free from flammable materials - PPE (Personal Protective Equipment)	1	3	3
3	Using power tools & drilling equipment	Direct contact with energized wires or terminals	Incidental inspection	8	- RCD (Residual Current Device) - Double insulation - Cable inspection - Dry working conditions - PPE (Personal Protective Equipment)	1	4	4
4	Using power tools & drilling equipment	Moving component	Incidental inspection	6	- Machine guard - Clamping device - PPE (safety goggles and gloves) - Operator training	1	3	3
5	Earthquake	Structural collapse, falling electrical equipment, or short circuit leading to injury or fire.	Incidental inspection	9	- Anchoring - Cable management - Main breaker auto-off - Evacuation route - Earthquake drill	2	4	8
6	Handling high-voltage equipment	Short circuit	Incidental inspection	12	- Lock Out Tag Out (LOTO) - High-voltage warning signage - Use insulated tools & rated PPE (arc-rated gloves, arc flash face shield) - Routine maintenance & insulation resistance testing - Safe distance barriers - Only trained & authorized personnel allowed	1	4	4
7	Fire	Burns, smoke exposure,Equipment and property damage	Incidental inspection	12	- Install smoke detector & fire alarm - Provide APAR (Class ABC/CO_2) - Regular electrical inspection - No-flammable materials near heat sources - Emergency evacuation plan - Fire drill training - Fire-resistant cable management	1	4	4
Average				9	Average			4.29
Standard Deviation				2.23	Standard Deviation			1.70

Based on the risk assessment results presented in Table.5, the implementation of hazard controls was carried out to ensure a systematic and measurable reduction in risk levels. The applied controls demonstrate that most hazards are managed through a combination of engineering and administrative measures, which aligns with the principle that these strategies are more effective than relying solely on Personal Protective Equipment (PPE). For activities involving electrical hazards, such as operating powered tools and handling installations, control measures include Lock Out Tag Out (LOTO) procedures, voltage testing prior to work, the use of insulated tools, and electrical safety training. These measures reduce the likelihood of direct exposure to energized components and represent mid-level controls within the hierarchy. PPE such as insulated gloves and safety shoes is utilized as the final line of defense when hazards cannot be fully eliminated.

Hazards associated with soldering and thermal equipment are mitigated through engineering controls such as temperature-regulated soldering stations and fume extraction systems, supported by administrative measures such as the removal of flammable materials from the workspace. These approaches directly limit potential ignition sources while minimizing opportunities for workers to come into contact with heat or combustible residues. Risk generated from mechanical and electrical exposure during power drill operation is reduced through the installation of Residual Current Devices (RCD), double insulation, cable inspections, and procedures ensuring the workspace remains dry. These measures address hazards at their source by providing technical isolation from electrical faults, thereby lowering both failure probability and worker exposure.

Hazards arising from earthquakes and falling objects are controlled through equipment anchoring and clamping systems as engineering interventions that prevent movement or impact. These are reinforced by administrative controls such as evacuation planning and earthquake drills, which enhance worker readiness in the event that an incident occurs. Overall, the results indicate that the application of the hierarchy successfully reduced the initial risk levels to a safer and more acceptable condition. The mitigation strategy does not rely solely on PPE but emphasizes higher-order controls that modify the hazard source and working environment.

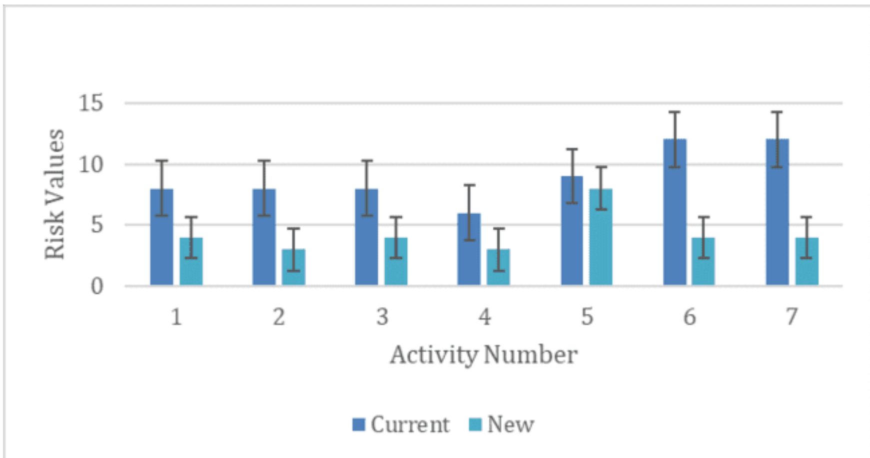

Figure 3. Risk Values comparison chart

Figure 3 illustrates the risk values of seven assessed activities: (1) Working with live electrical circuits, (2) Soldering and using hot tools, (3) Using power tools and drilling equipment, (4) Operating machinery with moving parts, (5) Earthquake hazards, (6) Handling high-voltage equipment, and (7) Fire hazards. The figure demonstrates a clear reduction in risk values across all activities following the implementation of the proposed control measures described in Table 5.

Figure. 3 illustrates a clear reduction in risk values across all assessed activities following the implementation of the control measures described in Table 6. Initially, several activities such as operating high-voltage equipment, working with live circuits, and using powered tools were classified within High to Extreme risk categories. After applying engineering and administrative controls, these risks were successfully reduced to lower and more acceptable levels.

The chart shows that the largest reductions occurred in activities originally associated with direct electrical exposure. This improvement reflects the effectiveness of measures such as the installation of Residual Current Devices (RCD), the application of Lock Out Tag Out (LOTO) procedures, routine voltage testing, tool insulation, and improved equipment maintenance. These engineering solutions played a major role in decreasing the likelihood of electrical failure and preventing accidental contact with energized components.

In addition, administrative controls, including regular safety training, workspace organization, and the implementation of emergency response procedures, further contributed to reducing the probability of incidents. Although Personal Protective Equipment (PPE) was still applied, it served as the final barrier rather than the primary control, aligning with the principle of the Hierarchy of Controls.

Overall, Figure 3. confirms that the post-control risk profile of the laboratory environment is significantly safer. The reduced values provide measurable evidence that prioritizing higher-order controls, particularly engineering interventions, offers substantial and sustainable improvements in occupational safety within the Electronics and Embedded Systems Laboratory.

5. Conclusions

Through this study, a total of 8 laboratory activities and 18 potential hazards were successfully identified, assessed, and systematically controlled in the Basic Electronics and Embedded System Laboratory at Fablab President University. The application of the HIRAC framework revealed that electrical hazards are the most dominant and critical risk category, particularly in activities involving energized circuits and high-voltage equipment. The initial assessment recorded five activities categorized as High Risk and two activities categorized as Extreme Risk, a condition largely resulting from the dependence on incidental inspections as the primary control measure.

Through the implementation of a structured hierarchy of controls, including engineering controls, administrative procedures, and targeted safety training, the laboratory's risk profile was significantly reduced. All activities categorized as high and extreme risk were successfully controlled, where the initial average risk value of 9 for these categories was reduced to a safer and more acceptable level with an average value of 4.29. This confirms that a proactive HIRAC approach aligned with modern safety standards is effective in improving laboratory safety performance and supporting the application of more robust occupational health and safety (OHS) practices.

These findings affirm that the HIRAC framework developed in this study is effective in strengthening occupational health and safety management within electronics-based laboratory environments. Future research is recommended to integrate real-time hazard monitoring and adaptive control strategies to further enhance risk mitigation in dynamic laboratory settings.

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