

Occupational Health and Safety Risk Analysis of Six Engineering Laboratories Using an Activity-Based HIRARC Approach

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Article Information	ABSTRACT
Article History Received : September 09, 2026 Revised : September 29, 2026 Published : October 02, 2026	Engineering laboratories combine high-energy machinery, live circuits, pressurised fluids and open flames with novice student operators, yet occupational health and safety in Indonesian higher education is still managed largely through academic rather than risk-based instruments. This study applies Hazard Identification, Risk Assessment and Risk Control (HIRARC) to six practicum laboratories of the Department of Mechanical and Industrial Engineering, Universitas Tidar, using the practicum activity rather than the room as the unit of analysis. Hazards were identified through direct observation and document review and scored by an assessor panel on a 5 x 5 matrix with predefined severity and likelihood criteria. Three main findings emerge. First, the 27 activity-level hazards are dominated by mechanical sources, and nearly half of the activities (44%) are high risk before control. Second, risk profiles differ between laboratories: the machining-intensive Production Process, Welding and CNC laboratories carry the highest mean risk, while the single most severe activity is CNC operation with a running spindle, so mean-based and peak-based rankings point to different priorities. Third, combined engineering and administrative controls, each mapped to the Indonesian regulation that requires it, are expected by the assessor panel to bring every activity to the low band, an estimated mean reduction of 58.5%; this is a prospective panel estimate, not a result measured after implementation. The study contributes an activity-based, regulation-linked risk register that allows laboratories with different energy profiles to be compared on one scale and to be prioritised for safety investment.
Keywords: <i>Engineering laboratory; Hazard identification; HIRARC; Occupational health and safety; Risk assessment.</i>	

INTRODUCTION

Occupational health and safety constitutes a legal obligation rather than a discretionary practice. Indonesian law defines a workplace through three elements, and these are people performing work, identifiable sources of danger, and an organised activity. Any facility that satisfies these elements falls within the scope of Undang-Undang No. 1 of 1970 and Permenaker No. 5 of 2018, while SNI ISO 45001:2018 provides the management framework through which compliance is achieved. Umar & Arifin (2025) observe that the effectiveness of such a framework depends on the integration of technical operation with safety administration. Malinda (2022) and Selvia (2025) associate ISO 45001 adoption with lower incident rates and reduced accident cost. Glevitzky (2025) advances a related argument, maintaining that risk management becomes

effective only when hazards are recorded in a form that supports decision making rather than compliance reporting alone.

Engineering laboratories represent a category of workplace in which these obligations apply with particular force. Practicum activities involve machinery of substantial power, live electrical circuits, pressurised fluids, elevated temperatures and open flames, frequently within a single room and during a single session. The distinguishing characteristic of such facilities, however, is not the energy present in the equipment but the inexperience of the operator. Students handle a lathe chuck, a spindle or a welding torch for the first time, often in several groups operating simultaneously under a single supervisor. Exposure is brief but recurrent across an entire cohort, and the margin ordinarily provided by operator experience is absent. Controls that depend on the operator recognising an abnormal condition are therefore less dependable in this setting than in industry, which increases the relative value of engineering and administrative barriers.

Safety governance in higher education has not kept pace with this exposure. Universities tend to administer laboratories through academic instruments such as practicum schedules, equipment loan procedures and housekeeping rules rather than through a documented occupational health and safety management system. Astete-Cornejo et al. (2025) report that systematic adoption within campus facilities remains limited. The consequence is Hazard documentation is incomplete, risk exposure is not mapped across the facility, and control measures are applied reactively after an incident rather than on the basis of prior assessment. Institutions consequently possess neither an evidentiary basis for prioritising safety expenditure nor an instrument through which compliance with national regulation can be demonstrated.

Hazard Identification, Risk Assessment and Risk Control, abbreviated HIRARC and written HIRAC in part of the literature, provides a structured means of addressing this deficiency by converting qualitative concern into a ranked and documented risk register. Published applications in Indonesia are concentrated in the construction sector. Burhanudin et al. (2024) recorded 29 work risks during hotel construction, whereas Cahyo & Sutarto (2022) identified heavy equipment and disorganised electrical installation as the principal hazards on a museum project. Dewantari et al. (2022), Artamil et al. (2023) and Permana et al. (2025) reported comparable profiles for a business centre, a rectorate building and a primary school, and Wong et al., (2022) combined HIRARC with a risk register across the phases of a dam project. A second body of work addresses manufacturing and process plant (Giovanni et al. 2023; Nurfaizah, 2022; Siboro et al., 2025; Tompo, 2024). Angriani (2025) confirms in a review that construction remains the predominant setting, a pattern also evident in Abdurrahman et al., (2025), Adi (2023), Febiani (2024) and Setiawan et al. (2024).

Two properties of this literature limit its transferability to laboratories. The projects examined are temporary, so that their hazards belong to an assembly phase and cease at handover, whereas laboratory hazards recur each semester throughout the operating life of the facility. The unit of analysis is furthermore a location or work package rather than a task, which yields registers organised according to where a hazard was found instead of what the operator was performing when it arose. Studies conducted in educational settings remain scarce and narrow in scope. Manik et al. (2024) applied HIRAC to a single analytical procedure in one chemistry laboratory, Khamis & Din (2025) assessed hazards at the level of an entire engineering faculty, and Putra and Haq (2024) examined campus buildings from a management and cost perspective. No study located by the author compares several laboratories with differing physical processes on a common risk scale.

The present study addresses this gap through three measures. The practicum activity serves as the unit of analysis in place of the laboratory as a whole, so that each laboratory is decomposed into the tasks an operator performs, from mounting a workpiece to closing a gas valve, and hazards are identified against those tasks. Six laboratories with differing energy profiles are then assessed on a single scale, covering precision measurement, electrical circuits, combustion and fluid power, computer controlled machining, conventional machining and gas welding, so that risk may be compared between them and control resources allocated accordingly. Every control is finally mapped to the specific national regulation that requires it, which renders the register an audit

instrument as well as a technical one. The objective of this research is to identify, assess and control occupational health and safety risks in six laboratories of the Department of Mechanical and Industrial Engineering, Faculty of Engineering, Universitas Tidar, and to produce a prioritised risk profile capable of serving as the technical basis of a laboratory safety programme.

RESEARCH METHODS

This research is a descriptive quantitative case study using the HIRARC method. The object is the laboratory complex of the Department of Mechanical and Industrial Engineering, Faculty of Engineering, Universitas Tidar, Magelang, comprising six laboratories: Metrology, Physics, Energy Conversion, CNC, Production Process and Welding. All six are operational facilities used for scheduled undergraduate practicum sessions, and all six were included; no sampling was applied, because the population is small enough to be assessed in full.

Data collection was undertaken through direct observation, photographic documentation and document review from August to December 2025, and encompassed at least one complete practicum session in each laboratory. Each session was observed from preparation through operation to shutdown and housekeeping, so that hazards arising after the principal task, such as the clearing of metal chips or the closing of a gas valve, would be recorded rather than incorporated into the operation itself. The documents reviewed comprised the standard operating procedures held by each laboratory, the practicum modules issued to students, and the equipment inventory.

Risk assessment was carried out by a panel of two assessors for each laboratory: the first author, an industrial engineering lecturer who conducted the assessment within the Professional Engineer Programme of Universitas Sebelas Maret under the supervision of the co-authors, and the lecturer responsible for the practicum course held in that laboratory. Every course lecturer on the panel holds an occupational health and safety (K3) competency certificate issued by the Indonesian National Professional Certification Agency (Badan Nasional Sertifikasi Profesi, BNSP). Course lecturers were chosen for three reasons. Their BNSP certification provides formally recognised competence in occupational health and safety practice, including the identification and control of workplace hazards. Direct observation within a single semester does not reliably reveal how students behave during a session, whereas the course lecturer possesses accumulated knowledge of student conduct across successive practicum cycles, of past incidents and near misses, and of the conditions under which errors most frequently occur. The course lecturer is also the person who writes the practicum module and supervises the session, and is therefore the person able to implement the administrative controls that the register recommends.

The instrument was a HIRARC worksheet with columns for the activity, the equipment and materials used, the hazard source, the potential consequence, severity, likelihood, risk value, the recommended control classified by hierarchy, the estimated residual severity, likelihood and risk value, and the regulation governing the control. Severity and likelihood were each rated on a five-point scale and the risk value obtained as $R = S \times L$, giving a range of 1 to 25 on a 5 x 5 matrix. Table 1 sets out the descriptors and risk bands, both fixed before scoring began so that the reported categories are reproducible rather than assigned after the fact. The scales were developed on the basis of the risk assessment and control requirements of Undang-Undang No. 1 of 1970 and Permenaker No. 5 of 2018, and the descriptors were written for the practicum setting: severity is anchored to the level of treatment and the time lost, and likelihood to how often harm can be expected in terms of practicum sessions and academic years.

Table 1. Severity and likelihood rating scales and risk level classification

Score	Severity (S): consequence descriptor	Likelihood (L): frequency descriptor
1	Insignificant. No injury; the session continues without interruption.	Rare. Conceivable but not expected during the operating life of the laboratory.
2	Minor. First-aid injury only; no lost time.	Unlikely. May occur once in several years of practicum operation.
3	Moderate. Injury requiring medical treatment; short absence.	Possible. May occur once during an academic year of practicum.

Score	Severity (S): consequence descriptor	Likelihood (L): frequency descriptor
4	Major. Serious injury, hospitalisation, or permanent partial impairment.	Likely. Expected at least once in every practicum cycle.
5	Catastrophic. Fatality or permanent total disability.	Almost certain. Expected in every practicum session.
Risk level classification (R = S x L)		
1-4	Low. Acceptable; maintain the existing control and monitor routinely.	
5-9	Moderate. Control required within the running semester.	
10-15	High. Control required before the next practicum session.	
16-25	Extreme. Activity suspended until an effective control is in place.	

Source: adapted by the author from the risk matrix convention used in HIRARC practice and from the requirements of Permenaker No. 5 of 2018.

Three operational rules were applied so that the scores can be replicated. First, severity was assigned to the credible worst-case consequence of the hazard source under the existing condition, judged from the type and magnitude of the energy involved and expressed by the care the injury would require: first aid on site with no lost practicum time ($S = 2$), treatment outside the laboratory with a short absence ($S = 3$), hospitalisation, fracture, finger amputation or permanent partial impairment ($S = 4$), and fatality or permanent total disability ($S = 5$). Contact with a spindle rotating at machining speed was the only situation judged capable of $S = 5$. Second, likelihood was assigned from how often students are exposed and how easily exposure turns into harm, considering the number of sessions per semester in which the activity is performed, the number of students exposed at the same time, the controls observed to be in place and actually used, and the incidents and near misses recalled by the course lecturer and technician from earlier practicum cycles. Third, both scores describe the condition observed during the session, not the condition prescribed in the SOP, so a procedure that existed on paper but was not followed did not lower the likelihood score. Residual scores were assigned by the same panel with the same descriptors, under the assumption that each recommended control is fully implemented and maintained.

The worksheet and the descriptors were not validated statistically; their content validity was instead established through expert review before scoring began. The rating scales, the descriptors in Table 1 and the worksheet columns were reviewed by the course lecturers on the assessment panel, all of whom hold a BNSP occupational health and safety competency certificate, to confirm that each descriptor was unambiguous, consistent with Undang-Undang No. 1 of 1970 and Permenaker No. 5 of 2018, and applicable to the practicum activities in their laboratories. Descriptors that the reviewers found ambiguous were reworded before the assessment started. Reliability of the scores therefore rests on the predefined descriptors in Table 1, the independent-then-consensus scoring procedure described below, and the confirmation steps that follow it.

Scoring followed a consensus procedure. Each assessor rated severity and likelihood independently for every activity. Where two ratings differed by more than one point on either dimension, the activity was re-examined and discussed until agreement was reached, using the observation photographs and the relevant regulation as reference. Ratings agreeing within one point were resolved by taking the higher value, a conservative rule adopted because the operators are students rather than trained technicians.

Three mechanisms were used to check the results. Observation findings were triangulated against photographic evidence and laboratory documents, so that no hazard entered the register on a single unsupported observation. The completed register was returned to each technician for confirmation that the activities matched the way the practicum is actually run. Every proposed control was then checked against Undang-Undang No. 1 of 1970, Permenaker No. 5 of 2018, Permenaker No. 12 of 2015, Permenaker No. 8 of 2010 and Peraturan Pemerintah No. 22 of 2021, to confirm that it satisfies an existing legal requirement rather than merely reflecting local practice.

Analysis was descriptive in nature. Hazards were counted by laboratory and by hazard category, mean initial risk value, the mean estimated residual risk value and the percentage reduction were computed for each laboratory and for the complex as a whole. One limitation arises from the research design and is stated at this point because it governs the manner in which the results should be interpreted. The residual values represent the prospective estimate of the

assessment panel concerning the risk that would remain once the recommended controls are fully implemented. They do not constitute a measurement obtained after implementation, and no post implementation incident data were collected during the study period.

RESULTS AND DISCUSSION

Activity Decomposition and Hazard Profile

Decomposing the six laboratories into practicum tasks produced 27 distinct activities and, correspondingly, 27 activity-level hazard entries. The Physics, Energy Conversion, CNC and Welding laboratories contributed five activities each, the Production Process laboratory four, and the Metrology laboratory three. The count reflects the structure of the practicum rather than the size of the room: Metrology runs three defined tasks, whereas welding involves five distinct operations from cylinder connection to shutdown.

Classifying the entries by hazard source gives mechanical hazards 11 entries (41%), thermal and fire hazards 7 (26%), electrical hazards 3 (11%), slip and trip hazards 3 (11%), ergonomic hazards 2 (7%) and hazardous waste 1 (4%). Mechanical dominance is expected in a department built around machining, but two features of the distribution deserve attention. Thermal and fire hazards are not confined to the welding laboratory; they also appear on the 3D printer in Metrology, the engine test rig in Energy Conversion and the grinding machine in Production Process, so fire response capability is needed in four of the six rooms rather than one. Slip and trip hazards appear in three laboratories and always for the same reason, cables, hoses or fluid crossing a circulation route, which makes housekeeping a cross-cutting control rather than a local one.

The dominance of mechanical hazards is consistent with studies of educational machining workshops. In an Indonesian vocational machining workshop, Anwar & Kurniawan (2024) found that the turning practicum, machine guarding and hand-tool use were dominated by medium-level risks, and Jurgens (2024) reported that lathes and bench grinders accounted for the largest shares of serious injuries in school mechanical technology workshops, with fingers the most frequently injured body part, which corresponds to the pinching and cutting consequences recorded here for activities 14 to 21. Three features of the practicum explain the pattern. The learning objective itself requires the student to work close to rotating or moving parts; the setting, mounting and chip-clearing steps before and after cutting add further contact points, which an activity-based register counts separately; and the operators are novices, whereas Dodo et al. (2020) showed that laboratory experience is significantly associated with safer practice. By contrast Abu et al. (2022), assessing static and rotating laboratory work in which students mainly observe and record running equipment, found ergonomic hazards to be the largest group (47%) and no high-risk entry. The contrast suggests that the hazard profile of a laboratory is determined less by the equipment present than by how directly the student handles the energy source.

Ergonomic hazards were assessed explicitly rather than mentioned in passing. Both entries lie in the Metrology laboratory, where students lift and position metal workpieces and then hold a sustained static posture during repeated precision measurement. The second carries an initial risk value of 9 despite involving no machine at all. Its consequence, cumulative musculoskeletal loading of the neck, shoulder and back, develops across repeated sessions rather than in a single event, which is why it is easily omitted from registers organised around machinery.

Risk Assessment Results

Table 2 presents the complete register: the activity, its hazard source and consequence, the initial severity, likelihood and risk value, the recommended control by hierarchy, the estimated residual value and the governing regulation. Of the 27 activities, 12 (44%) fell in the high band and 15 (56%) in the moderate band, none of them was rated low before control and none reached the extreme band. The share of high-risk activities is larger than in the vocational machining workshop studied by Anwar & Kurniawan (2024), where most entries were medium risk and high risk appeared only in the welding practicum. The difference reflects the presence of CNC machining

and gas welding in the university laboratories and the conservative rule used to resolve rating differences between assessors.

The residual values in the Est. Res column of Table 2, and the residual and reduction figures derived from them in Table 3, are predictions made by the assessment panel for the condition after the recommended controls are fully implemented. The controls had not been implemented during the study period, so these values were not observed and should not be read as proven control effectiveness.

Table 2. Activity-based HIRARC register for six laboratories, Department of Mechanical and Industrial Engineering, Universitas Tidar

No	Activity	Hazard source / consequence	S	L	R	Level	Recommended control	Est. Res	Reg.
Metrology Laboratory (3 activities)									
1	Lifting and positioning metal workpieces onto the measuring table	Heavy workpiece, non-neutral lifting posture. Pinched fingers, hand injury, low-back pain.	3	2	6	Moderate	Weight limit per workpiece; stable table; safe-lifting instruction; work gloves (EN, AD, PPE)	4	P5
2	Repeated precision measurement in a sustained static posture	Prolonged static loading of neck, shoulder and back. Musculoskeletal disorder.	3	3	9	Moderate	Table height adjustment; staged measurement schedule with recovery breaks (EN, AD)	4	P5
3	Operating the 3D printer: setup, monitoring and part removal	Hot nozzle and bed, moving carriage. Burns, pinching, slips when carrying parts.	4	3	12	High	Operating SOP; access restricted while printing; heat-resistant gloves (AD, EN, PPE)	4	P5
Physics Laboratory (5 activities)									
4	Measuring dimension and mass with calipers, micrometers and balances	Sharp instrument jaws, hard specimens. Cuts, pinched or bruised fingers.	3	2	6	Moderate	SOP for instrument use; ergonomic bench position; handling briefing (AD, EN)	4	P5
5	Assembling and energising series, parallel and combined circuits	Exposed terminals, live conductors. Electric shock, short circuit, fire.	4	3	12	High	Low-voltage supply only; cable inspection; circuit checked before switch-on (SUB, EN, AD)	4	P12
6	Mounting springs, hanging loads and running oscillation tests	Load or spring released from the stand. Foot and hand injury.	3	3	9	Moderate	Stable stands and clamps; maximum load limit; pre-use stability check (EN, AD)	4	P5
7	Swinging a pendulum and adjusting string length and amplitude	Freely swinging bob near bystanders. Impact injury to face or hands.	2	3	6	Moderate	Marked swing envelope; safe-distance rule; limit on people nearby (EN, AD)	4	P5
8	Moving around the laboratory during data collection	Cables and apparatus across circulation routes. Trips and falls.	3	2	6	Moderate	Defined circulation route; bench layout arrangement; supervision (EN, AD)	4	P5
Energy Conversion Laboratory (5 activities)									
9	Operating and starting or stopping the engine test rig	Hot and rotating engine parts, manual starter. Burns, pinched hands.	4	3	12	High	Engine test SOP; guarded machine zone; heat-resistant gloves (AD, EN, PPE)	4	UU1
10	Inspecting and operating the electrical control panel	Panel cover open, live parts exposed. Electric shock on contact.	4	3	12	High	Panel closed and labelled; switch functions marked; access restricted (EN, AD)	4	P12
11	Running the pump experiment; measuring flow and pressure	Rotating impeller, pressurised fluid. Pinching, high-pressure jet.	3	3	9	Moderate	Staged pressure increase; guarded pump area; work instruction (EN, AD)	4	P5
12	Handling and storing residual fuel and used oil after testing	Uncontrolled B3 waste. Environmental contamination, health exposure.	3	3	9	Moderate	Closed labelled waste containers; routine check; work gloves (EN, AD, PPE)	4	PP22
13	Moving through the test area during and after operation	Standing water and spilled fluid on the floor. Slips and falls.	3	2	6	Moderate	Immediate spill clean-up; floor drainage; scheduled housekeeping (EN, AD)	4	P5
CNC Laboratory (5 activities)									
14	Mounting the workpiece and tool before running the program	Sharp tooling near the spindle, unexpected axis motion. Severed fingers.	4	3	12	High	Machine off and locked during setting; two-step confirmation before start (EN, AD)	4	UU1
15	Operating the CNC machine and monitoring the running cut	High spindle speed and rapid feed. Severe injury on contact.	5	3	15	High	Operation from the control panel only; enclosure closed; supervision (EN, AD)	4	P5
16	Clearing metal chips and coolant after machining	Sharp chips, coolant film on the floor. Cuts, irritation, slipping.	3	3	9	Moderate	Cleaning only after spindle stop; chip hook and brush; gloves, apron (AD, EN, PPE)	4	P5
17	Inspection, light maintenance and cleaning of the machine area	Contact with cabling and live parts during cleaning. Electric shock.	4	2	8	Moderate	Isolation before maintenance; damaged cable replacement; technician access only (EN, AD)	4	P12
18	Measuring machined parts with gauges and micrometers	Sharp edges and burrs on the finished part. Minor hand cuts.	2	3	6	Moderate	Deburring before measurement; handling procedure; work gloves (AD, EN, PPE)	4	P5

No	Activity	Hazard source / consequence	S	L	R	Level	Recommended control	Est. Res	Reg.
Production Process Laboratory (4 activities)									
19	Preparing and mounting the workpiece on the milling machine	Sharp cutter, movable table. Pinched or severed fingers.	4	3	12	High	Mounting with the machine stopped; clamping check before start (EN, AD)	4	UU1
20	Operating the milling machine and monitoring the cut	Flying chips, high spindle speed. Eye injury, irritation, lacerations.	4	3	12	High	Operation from the control position; chip guard; glasses and dust mask (EN, AD, PPE)	4	P5
21	Running the lathe, including speed and feed setting	Rotating chuck, scattered swarf. Hand injury, particle exposure.	4	3	12	High	Machining sequence per SOP; chuck key removal check; supervision (AD, EN)	4	P5
22	Surface finishing on the grinding machine	Sparks and fine abrasive particles. Burns, skin and eye irritation.	3	3	9	Moderate	Spark guard and safe stand-off distance; face shield and apron (EN, PPE)	4	P5
Welding Laboratory (5 activities)									
23	Connecting the gas cylinder, regulator and hose before welding	Leak at cylinder, regulator or hose joint. Respiratory harm, fire, explosion.	4	3	12	High	Leak test before use; connection per gas-welding SOP; gloves, safety shoes (AD, EN, PPE)	4	UU1
24	Igniting and adjusting the welding flame on the torch	Open flame at high temperature. Burns, ignition of nearby combustibles.	4	3	12	High	Staged flame adjustment per SOP; combustibles cleared; goggles, heat gloves (AD, EN, PPE)	4	P8
25	Carrying out gas welding on the metal workpiece	Splatter and radiant heat. Burns, eye and skin irritation.	4	3	12	High	Welding screen; safe working procedure; helmet, gloves and apron (EN, AD, PPE)	4	P5
26	Extinguishing the flame and shutting off the gas after welding	Residual gas and pressure in the hose. Leak and post-work fire.	3	3	9	Moderate	Valve closing sequence per SOP; hose purge; valve re-check after work (AD)	4	UU1
27	Moving through the welding area with hoses and cables on the floor	Hoses across circulation routes. Trips, falls, hose pull-out and leak.	3	2	6	Moderate	Overhead hose routing or cable covers; defined walkway; supervision (EN, AD)	4	P5

Notes. S = severity, L = likelihood, R = S x L. Res. R = residual risk value predicted by the assessment panel for full implementation of the recommended control, not measured after implementation; the residual level is Low for all 27 activities. Hierarchy codes: SUB = substitution, EN = engineering control, AD = administrative control, PPE = personal protective equipment. Regulation codes: UU1 = Undang-Undang No. 1 of 1970 Art. 3; P5 = Permenaker No. 5 of 2018 Art. 6-7; P12 = Permenaker No. 12 of 2015 (electrical OHS); P8 = Permenaker No. 8 of 2010 (personal protective equipment); PP22 = Peraturan Pemerintah No. 22 of 2021 (hazardous waste management). Source: field data processed by the author.

The single highest initial value, 15, belongs to CNC operation while the spindle is running. It is the only activity scored at severity 5, on the ground that contact with a spindle turning at machining speed is capable of causing permanent disability or death, whereas the severity 4 activities elsewhere in the register are expected to produce serious but survivable injury. Eleven further activities scored 12.

That value of 12 arises in two different ways, and the distinction matters for control selection. In the machining and welding activities it comes from severity 4 combined with likelihood 3, where a serious injury is credible and the exposure occurs in every practicum cycle. In the two electrical activities, circuit assembly in Physics and control panel operation in Energy Conversion, the same product arises because an exposed conductor is a permanent condition rather than an intermittent one. The first case is best addressed by guarding and procedure, the second by removing the exposure altogether, which is why low-voltage substitution and panel closure lead the controls for those two entries.

Comparative Risk Profile Across Laboratories

Table 3 aggregates the register by laboratory. Production Process carries the highest mean initial risk at 11.25, with three of its four activities in the high band. Welding follows at 10.20 and CNC at 10.00, while Physics has the lowest mean at 7.80. The ranking does not follow the amount of equipment in the room. Production Process reaches the top position because all four of its activities are machining operations with no low-hazard task to dilute the mean, whereas CNC, which contains the single most dangerous activity in the whole complex, has a lower mean because two of its five activities are post-process inspection and cleaning tasks scored at 8 and 6.

Table 3. Risk profile by laboratory before and after the recommended controls

Laboratory	n	Dominant hazard type	High / Mod.	Mean initial R	Mean estimated residual R	Estimated reduction (%)
Metrology	3	Ergonomic	1 / 2	9.00	4.00	55.6
Physics	5	Mechanical, electrical	1 / 4	7.80	4.00	48.7
Energy Conversion	5	Thermal, electrical	2 / 3	9.60	4.00	58.3
CNC	5	Mechanical	2 / 3	10.00	4.00	60.0
Production Process	4	Mechanical	3 / 1	11.25	4.00	64.4
Welding	5	Thermal and fire	3 / 2	10.20	4.00	60.8
All laboratories	27	Mechanical (11 of 27)	12 / 15	9.63	4.00	58.5

Notes. High = risk value 10-15; Moderate = risk value 5-9. Mean estimated residual R and estimated reduction are the panel's predictions under full implementation of the controls in Table 2, not a post-implementation measurement. Source: field data processed by the author.

The differences between laboratories follow the energy profile of each practicum and how directly students handle it, a pattern also visible in earlier studies. Laboratories in which students control a cutting machine or a flame themselves, namely Production Process, Welding and CNC, have the highest means, in line with Anwar & Kurniawan (2024), where the only high-risk entries arose in welding, and with Jurgens (2024), where lathes, grinders and welding machines were among the main sources of serious injury. The Physics and Metrology laboratories, where students handle instruments and low-energy apparatus, have the lowest means and a larger share of handling and ergonomic hazards, a profile close to the observation-based laboratory work assessed by Abu et al. (2022). Energy Conversion lies between the two groups: its apparatus is powered and hot, but students mostly operate it by following a fixed test procedure, and it is notable that the highest score was likewise recorded during the start-up of a combustion engine. A single rating for the whole complex would therefore conceal where controls are most needed.

Risk Control and Estimated Residual Risk

Controls were assigned by hierarchy. Elimination was not available for any activity, because the hazards are intrinsic to the learning objective and a machining practicum cannot remove the rotating spindle. Substitution was applicable once, in the Physics laboratory, where low-voltage supplies replace mains-level sources for circuit assembly. The remaining controls are engineering, administrative and personal protective measures, and in 24 of the 27 entries a combination of at least two levels was recommended, on the ground that a single administrative control is unreliable when the operator is inexperienced. Anwar & Kurniawan (2024) likewise recommended combining several levels of the hierarchy, supported by training, equipment maintenance and signage, rather than relying on PPE alone.

Under full implementation the panel estimated a residual value of 4, from severity 2 and likelihood 2, for every activity. That gives a mean of 4.00 against an initial mean of 9.63, a reduction of 58.5%. Residual severity does not fall below 2 anywhere in the register, and this is deliberate. Guarding and procedure reduce the probability of contact but do not change the energy available in a rotating spindle or a gas flame. The reduction is therefore driven almost entirely by likelihood, which is consistent with the hierarchy: the controls available in an operational laboratory act on exposure rather than on the hazard itself.

The estimate is conditional on implementation discipline, since administrative controls and PPE depend on user behaviour and degrade without supervision and audit, which is why the register assigns a monitoring mechanism to each entry rather than treating a control as a completed action. The residual figures should not be read as evidence that risk has already fallen; they describe the state the controls are designed to reach, and verifying it requires measurement after implementation.

Comparison with Previous Studies

Comparing this profile with construction-phase studies clarifies what is distinctive about an operational laboratory. Burhanudin et al. (2024) recorded 29 risks on a hotel project dominated by falls from height and temporary electrical installation, and Cahyo & Sutarto (2022) reported heavy equipment and untidy wiring as the leading sources on a museum project. Neither profile

transfers. There is no work at height in the laboratories studied here, and the electrical hazards arise from permanent installations and from circuits that students build themselves rather than from temporary site wiring. What the two settings do share is the prominence of housekeeping: the trip hazards in three of the six laboratories are structurally the same problem as the site clutter reported by Setiawan et al. (2024).

The contrast with laboratory studies is one of scope. The single-procedure register of Manik et al. (2024) is detailed but self-contained and cannot support allocation decisions between laboratories, which is the question a department head actually faces, while the faculty-level assessment of Khamis and Din (2025) supports policy but not practicum design. The register produced here occupies the level in between, and the comparison in Table 3 is possible only because one scale was applied to all six rooms.

A third point concerns regulation. Several published HIRARC registers propose controls without linking them to a legal requirement, which leaves implementation dependent on local goodwill. Mapping each control to Undang-Undang No. 1 of 1970, Permenaker No. 5 of 2018, Permenaker No. 12 of 2015, Permenaker No. 8 of 2010 or Peraturan Pemerintah No. 22 of 2021 converts a technical recommendation into a compliance obligation and gives the laboratory manager an argument for the resources needed to meet it. Ten of the 27 entries in Table 2 are governed by instruments other than the general working environment regulation, and the five covering electrical work, PPE and hazardous waste are the most likely to attract external audit

CONCLUSION

An activity-based HIRARC assessment of the six laboratories of the Department of Mechanical and Industrial Engineering at Universitas Tidar identified 27 activity-level hazards: 11 mechanical, 7 thermal and fire, 3 electrical, 3 slip and trip, 2 ergonomic and 1 hazardous waste. Before control, 12 activities (44%) fell in the high risk band and 15 (56%) in the moderate band, with a mean initial risk value of 9.63 on a 5 x 5 matrix. The highest single value, 15, was recorded for CNC operation during machining. Ranked by mean initial risk, the Production Process laboratory is the most exposed at 11.25, followed by Welding at 10.20 and CNC at 10.00.

Applying the hierarchy of control produced a recommended control set combining engineering and administrative measures for 24 of the 27 activities. Under full implementation the panel estimated a residual value of 4 for every activity, a mean reduction of 58.5%, achieved almost entirely through reduced likelihood rather than reduced severity. These residual figures are a prospective estimate and not a post-implementation measurement.

Three practical recommendations follow. The department should treat Production Process and Welding as the first targets for guarding and PPE investment, and CNC spindle operation as a separate case requiring a physical barrier rather than a procedural control. Housekeeping should be managed as a complex-wide programme, since trip hazards recur in three laboratories for the same underlying reason. The register should be maintained as a live document with scheduled audit. Further research should measure risk after implementation so that the estimated reduction reported here can be verified, and extend the register to other departments to test whether activity-based decomposition scales.

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