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Occupational Health and Safety in Engineering Workshops: Hazards, Risk Assessment, and Control Strategies
A Case Study of the Higher Institute of Science and Technology (Tamzaoua, Libya)

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Abstract

Engineering workshops present complex occupational health and safety (OHS) challenges due to powered equipment, hot work activities, hazardous maintenance tasks, and diverse user groups. In Libya, empirical evidence on workshop-level safety readiness within technical institutes remains limited. This paper reports a case study of OHS practices and control implementation at the Target Institute using a structured 44-item questionnaire.

A cross-sectional survey design was adopted, and seventy respondents provided usable data (N = 70). The instrument covered six domains relevant to engineering workshop operations: machine and equipment safeguarding, hazardous energy control, hot work and chemicals, noise/vibration/ergonomics, risk assessment and permit-to-work, and safety culture/training/PPE. Statistical analyses included descriptive statistics, Relative Importance Index (RII), reliability testing (Cronbach's α), normality tests, ANOVA and Welch ANOVA with effect sizes, correlation analysis, and exploratory regression.

The overall scale demonstrated high reliability (α = 0.947). Results indicate moderate OHS readiness, with notable deficiencies in noise, vibration, and ergonomic controls and in formalized risk assessment and permit-to-work execution. Significant differences were observed across respondent roles and exposure frequency.

Keywords: Occupational health and safety; Engineering workshops; Risk assessment; Permit-to-work; Ergonomics; Libya.

Introduction

Engineering workshops are essential environments for technical education, applied learning, and skills development; however, they are inherently hazardous settings. Typical workshop activities may include machining and fabrication, welding and cutting, fitting and assembly, testing and maintenance, and the handling of tools, materials, and chemicals. These activities expose users to mechanical hazards, physical agents (e.g., noise and vibration), chemical risks (e.g., fumes and solvents), and ergonomic stressors; therefore, effective control measures should prioritize elimination and engineering controls before reliance on PPE (NIOSH, 2024; ISO, 2010; OSHA, 2023).

In Libya, empirical research across industrial and worksite contexts continues to report weaknesses in enforcement, training, and systematic risk management, which can translate into repeated exposure and preventable incidents. Evidence from Libyan construction, oil and gas, and industrial facilities shows that safety performance is strongly influenced by management commitment, operational discipline, and worker awareness (Omran et al., 2008; Elbagnog, 2025; Abdullah and Garad, 2025). However, technical institutes—where future technicians and industry personnel are trained—remain underrepresented in published OHS assessments. This study addresses this gap by evaluating workshop-level OHS readiness at the Target Institute and identifying priority gaps that can guide practical improvement actions (Zaatout et al., 2022; Nsser, 2025; Abudabbus et al., 2023).

2 Background and Related Work

Workshop environments combine acute injury hazards with long-term health risks. Acute hazards include moving parts, rotating components, cutting and grinding tools, pinch and crush points, high-temperature processes, and hazardous energy sources during servicing and maintenance; chronic risks include noise-induced hearing loss, vibration exposure, chemical inhalation, and musculoskeletal disorders driven by manual handling, awkward postures, and repetitive tasks (ISO, 2010; OSHA, 2024; NIOSH, 2024). Libyan empirical studies in garages, oil facilities, and industrial plants similarly emphasize chemical exposures, accident occurrence, and the importance of structured preventive systems and training (Shaboun and Alzunni, 2022; Abdullah and Garad, 2025; Zaatout et al., 2022).

Internationally, ISO 12100 emphasizes structured machinery and equipment risk assessment and risk reduction, while ISO 45001 integrates these principles into organizational OHS management systems emphasizing leadership, competence, communication, and operational control (ISO, 2010, 2018; OSHA, 2023). In Libya, case-based OHS research in oil and industrial organizations indicates that formal systems and procedures can improve perceived safety performance when consistently implemented, but gaps in safety culture and coordination may still persist (Abudabbus et al., 2023; Elbagnog, 2025; Nsser, 2025). Collectively, these findings support the need for operational, workshop-level assessments that examine both engineering controls and procedural controls such as PTW and reporting.

3 Methods

3.1 Study design and setting

This research adopted a cross-sectional survey design within a case study approach. Data were collected within engineering workshop environments at the Target Institute, focusing on day-to-day operations, equipment use, maintenance activities, and the implementation of key safety controls (ISO, 2018; El-bagnog, 2025; Abudabbus et al., 2023).

3.2 Participants

Seventy respondents provided complete and usable questionnaires (N = 70). The sample included trainees/students, technicians/lab assistants, instructors, supervisors/maintenance staff, and safety or administrative personnel, reflecting multiple perspectives within the workshop system (Abdullah and Garad, 2025; Abudabbus et al., 2023; Omran et al., 2008).

3.3 Instrument

A structured 44-item questionnaire was developed based on ISO 12100, ISO 45001, and OSHA guidance to capture control practices relevant to engineering workshop operations. Items were rated on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). The instrument covered six domains: machine and equipment safeguarding; hazardous energy control; hot work and chemicals; noise, vibration, and ergonomics; risk assessment and permit-to-work (PTW); and safety culture, training, and PPE (ISO, 2010, 2018; OSHA, 2024).

3.4 Data analysis

Data were coded and analyzed using the Statistical Package for the Social Sciences (SPSS). Analyses included descriptive statistics, Relative Importance Index (RII), reliability analysis using Cronbach's α, Shapiro–Wilk normality tests, one-way ANOVA or Welch ANOVA where assumptions were not satisfied, Pearson correlations, and exploratory ordinary least squares (OLS) regression (Nunnally and Bernstein, 1994; Panayides, 2013; Shapiro and Wilk, 1965).

4 Results

4.1 Respondent profile

Table 1: Respondent roles within the engineering workshop environment (N = 70).

Code	Role category	n	%
1	Students / Trainees	8	11.4
2	Technicians / Lab Assistants	8	11.4
3	Instructors / Lecturers	18	25.7
4	Maintenance & Supervisors	30	42.9
5	HSE / Administration	6	8.6

Table 1 shows that supervisory and maintenance staff constituted the largest respondent group, indicating that the dataset includes perspectives from individuals directly responsible for workshop operations, maintenance planning, and safety oversight.

Table 2: Age distribution of respondents. Code Age group (years) n%

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respondents. Code	Age group (years)		n %
1	18–24	14.3	10
2	25–34	22.9	16
3	35–44	32.9	23
4	45–54	22.9	16
5	55+	7.1	5

As shown in Table 2, more than half of the respondents were between 35 and 54 years old, suggesting a mature and experienced sample capable of evaluating workshop safety practices over time.

Table 3: Primary workshop unit/area of respondents.

Code	Workshop area	n	%
1	Machine shop	11	15.7
2	Welding & fabrication	10	14.3
3	Automotive/mechanical systems	22	31.4
4	Maintenance & utilities	18	25.7
5	Multi-area / Other	9	12.9

Table 3 indicates that respondents were distributed across multiple workshop units, reflecting diverse engineering workshop activities involving equipment operation, fabrication processes, and maintenance tasks.

Table 4: Workshop-related experience.

Code	Experience stage	n	%
1	<1 year	8	11.4
2	1–3 years	5	7.1
3	3–5 years	17	24.3
4	5–10 years	30	42.9
5	>10 years	10	14.3

As shown in Table 4, most respondents reported more than five years of workshop-related experience, supporting the credibility of safety-related judgments in an operational workshop setting.

Table 5: Exposure frequency to engineering workshop environments.

Code	Exposure frequency	n	%
1	Rarely	11	15.7
2	Monthly	15	21.4
3	Weekly	16	22.9
4	Daily	22	31.4
5	Several times/day	6	8.6

Table 5 demonstrates that more than 60% of respondents had weekly or daily exposure to workshop environments, underscoring the importance of evaluating day-to-day control implementation.

1.1 Reliability and domain performance

Table 6: Internal consistency of the questionnaire (Cronbach's α).

Domain	Items	α
Overall instrument	44	0.947
Machine safeguarding	8	0.800
Hazardous energy control	7	0.754
Hot work / chemicals	7	0.849
Noise, vibration & ergonomics	8	0.846
Risk assessment / PTW	8	0.776
Safety culture / PPE	6	0.748

Table 6 indicates excellent overall reliability and acceptable-to-good reliability across all domains, sup-porting the internal consistency of the measurement instrument.

Table 7: Descriptive statistics for OHS domains.

Domain	Mean	SD
Machine safeguarding	3.218	0.717
Hazardous energy control	3.329	0.718
Hot work / chemicals	3.327	0.848
Noise, vibration & ergonomics	3.066	0.755
Risk assessment / PTW	3.145	0.727
Safety culture / PPE	3.288	0.729

As summarized in Table 7, noise, vibration, and ergonomics emerged as the weakest domain, followed

Rank	Item (summary)	Mean	RII
1	Pinch/crush points controlled	2.714	0.543
2	Stop-work without blame	2.714	0.543
3	Lifting planned and supervised	2.829	0.566
4	Noise reduction measures applied	2.829	0.566
5	MSD symptoms addressed	2.857	0.571
6	Moving parts adequately guarded	2.943	0.589
7	Near-miss reporting practiced	2.943	0.589
8	PTW for confined space	2.957	0.591
9	Vibration exposure controlled	2.986	0.597
10	Chemical labeling/storage	3.000	0.600

Table 8 identifies priority improvement areas, indicating that several of the most critical deficiencies relate to engineering controls (e.g., pinch/crush hazards, guarding), empowerment mechanisms (stop-work), and disciplined application of procedural controls such as PTW and reporting.

1.2 Inferential analysis

Table 9: One-way ANOVA results by respondent role.

Domain	F	p-value	$\eta 2$
Noise, vibration & ergonomics	10.554	< 0.001	0.394
Risk assessment / PTW	4.707	0.002	0.225
Overall OHS score	7.072	< 0.001	0.303

As shown in Table 9, statistically significant differences were observed across roles, particularly in domains that depend on operational implementation and exposure-aware practices.

Table 10: Correlation between OHS domains and overall OHS score.

Domain	r	p-value
Machine safeguarding	0.902	< 0.001
Hazardous energy control	0.729	< 0.001
Hot work / chemicals	0.849	< 0.001
Noise, vibration & ergonomics	0.858	< 0.001
Risk assessment / PTW	0.815	< 0.001
Safety culture / PPE	0.841	< 0.001

Table 10 demonstrates strong and significant associations between all domains and the overall OHS score, suggesting that improvements in any domain can contribute meaningfully to overall workshop safety readiness.

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Predictor	B	SE	t	p
Role	0.81	0.19	4.31	< 0.001
Exposure frequency	0.12	0.05	2.42	0.018
Safety training	0.12	0.05	2.63	0.011
Near-miss reporting	0.22	0.06	3.96	< 0.001

As indicated in Table 11, operational role, exposure intensity, safety training, and near-miss reporting significantly predicted overall OHS performance, highlighting the importance of competence development and learning-based safety culture.

5 Discussion

5.1 Interpretation of overall readiness and control maturity

The results indicate a moderate level of OHS readiness in the Target Institute workshops. From a tech−nical perspective, the clustering of domain means around the mid−point of the Likert scale (Table 7) suggests that controls are present in principle but their implementation is not consistently engineered into daily operations. In workshop risk engineering terms, this corresponds to a partially mature control environment, where administrative measures and informal practices may exist, yet barriers are not sys−tematically verified (e.g., guarding integrity, PTW discipline, ergonomic exposure controls) (ISO, 2018, 2010; NIOSH, 2024). This interpretation is consistent with Libyan industrial and facility-based evi-dence showing that OHS performance depends strongly on implementation discipline rather than policy availability (Elbagnog, 2025; Abudabbus et al., 2023; Nsser, 2025).

5.2 Domain performance and engineering significance

The highest-rated domains were hazardous energy control (Mean = 3.329) and hot work/chemicals (Mean
,(3.327 =while noise/vibration/ergonomics was the lowest (Mean = 3.066). In engineering workshops, noise, vibration, and ergonomic risks are typically chronic exposure hazards, and weaker scores often indicate limited engineering solutions such as acoustic enclosures, damping, isolation mounts, exposure monitoring, tool selection, workstation redesign, and manual handling engineering controls (NIOSH, 2024; ISO, 2018, 2010). Libyan studies in garages and heavy industrial settings similarly report persistent chemical and exposure-related risks, highlighting that controlling chronic hazards requires sustained measurement and engineered interventions rather than one-time training (Shaboun and Alzunni, 2022; Zaatout et al., 2022; Abdullah and Garad, 2025.(

5.3 Priority gaps: barrier weaknesses and failure modes

The Relative Importance Index results (Table 8) identify the most critical weaknesses as (i) pinch/crush-point control and guarding, (ii) stop-work authority without blame, (iii) lifting planning and supervision, and (iv) exposure controls (noise and vibration). Technically, these gaps represent weaknesses in critical barriers that prevent high-consequence events: machine guarding and pinch-point management are pri-mary engineering barriers, while stop-work authority and PTW discipline are key organizational barriers that prevent escalation of unsafe conditions (ISO, 2010, 2018; OSHA, 2023). Similarly, low scores for PTW in confined spaces and near-miss reporting suggest that operational control systems are not fully institutionalized, which can reduce learning from weak signals and increase latent risk (OSHA, 2024; ISO, 2018; NIOSH, 2024).

5.4 Role-based differences: operational ownership and exposure-driven aware-ness

The ANOVA results (Table 9) show statistically significant differences by respondent role, particularly for noise/vibration/ergonomics ($F = 10.554$, $p < 0.001$, $\eta 2 = 0.394$) and overall OHS score ($F = 7.072$, $p < 0.001$, $\eta 2 = 0.303$). The effect sizes are technically meaningful, indicating that role explains a substantial proportion of variability in perceived control performance. This aligns with the concept of operational ownership: supervisors and maintenance personnel often interact with equipment states, task planning, and procedural enforcement more frequently than trainees, which shapes their judgment of control adequacy (ISO, 2018; Omran et al., 2008; Abudabbus et al., 2023). In Libyan settings, differences in safety perception across job categories have been linked to uneven training access, variable enforcement, and inconsistent monitoring across units (Elbagnog, 2025; Nsser, 2025; Abdullah and Garad, 2025).

5.5 System coherence: correlations and implications for integrated improve-ment

Strong correlations were observed between each domain and the overall OHS score (Table 10; r = 0.729–0.902, p < 0.001). From a measurement and systems perspective, this implies that workshop safety readiness is multi-component but coherent: improvements in one control cluster (e.g., safeguarding, PTW discipline, or training/PPE) tend to co-vary with improvements elsewhere, likely because they are jointly influenced by management commitment, supervision, and the consistency of operational routines (ISO, 2018; Nunnally and Bernstein, 1994; Panayides, 2013). Technically, these high inter-domain relationships also warn against treating domains as independent "silos"; instead, interventions should be engineered as a coordinated barrier program (engineering controls + procedural controls + competence assurance) (ISO, 2010; NIOSH, 2024; OSHA, 2023).

5.6 Predictors of overall readiness: actionable leverage points

The exploratory regression (Table 11) identified role, exposure frequency, safety training, and near-miss reporting as significant predictors of overall OHS score. Operationally, this is consistent with a learning-and-control mechanism: higher exposure increases contact with hazards and procedures, while training and reporting improve hazard recognition, feedback loops, and corrective action quality. Near-miss re-porting, in particular, functions as a leading indicator that supports proactive risk reduction (identifying weak signals before harm occurs) and enables targeted engineering and procedural improvements (ISO, 2018; NIOSH, 2024; Omran et al., 2008). Libyan evidence similarly emphasizes that safety performance improves when training is reinforced by supervision, monitoring, and a practical reporting culture rather than being treated as a one-time administrative activity (Elbagnog, 2025; Abudabbus et al., 2023; Nsser, 2025).

5.7 Engineering implications for control design and verification

The combined results (domain means, RII gaps, and predictors) point to two technically dominant improvement tracks. First, engineering barrier strengthening is needed for pinch/crush hazards, guarding completeness, and noise/vibration controls—this includes verifying guard integrity, interlocks (where applicable), machine isolation points, and maintenance-induced exposure scenarios. Second, procedural control discipline must be strengthened through risk assessment routines, PTW execution for high-risk tasks (e.g., confined space, hot work, isolation/LOTO), and reliable near-miss reporting workflows with corrective action closure. These tracks align with internationally accepted control logic: hazards must be reduced at source where possible, then controlled through engineered measures, with procedures and PPE serving as reinforcement layers (ISO, 2010, 2018; OSHA, 2024).

6 Conclusion

This case study assessed occupational health and safety readiness in engineering workshop environments at a Libyan technical institute using a structured 44-item questionnaire and responses from 70 partici-pants. The findings indicate a moderate overall level of OHS readiness, alongside clear priority gaps that require targeted intervention.

The most critical weaknesses were concentrated in chronic hazard control (particularly noise, vibration, and ergonomics) and in the consistent execution of formal operational controls such as risk assessment and permit-to-work. Significant differences across respondent roles and exposure frequency also suggest that day-to-day operational involvement, supervision responsibilities, and training exposure shape safety awareness and perceived control effectiveness.

To enhance workshop safety outcomes, the institute should prioritize strengthening engineering controls (guarding and pinch-point management), reinforcing stop-work authority without blame, improving lift-ing planning and supervision, and institutionalizing reliable reporting and follow-up mechanisms for near-misses. These actions can support safer technical training environments and provide a practical basis for continuous improvement in similar engineering workshop settings.

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