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Ergonomic Evaluation of Automotive Training Workshops in Commercial Premises within TVET Institutions

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Abstract. This study evaluates the suitability of a modified commercial premise used as an automotive training workshop in a TVET institution from the perspective of environmental ergonomics. A quantitative approach was employed using environmental observation and a questionnaire administered to 54 students. Data were collected across seven workshop zones, focusing on temperature, humidity, air flow, lighting, and noise levels. The findings indicate that thermal comfort factors did not comply with ASHRAE 55 standards, lighting in several zones was below the minimum requirement, and noise levels exceeded 70 dB in most areas. Student perceptions also recorded moderate mean scores for comfort and safety, with the questionnaire reliability measured at Cronbach's Alpha of 0.897. The limitations of this study include the use of a single commercial premise, a limited sample size, and the measurement of only selected ergonomic parameters. The study recommends improvements in ventilation, artificial lighting, and workspace layout to ensure that alternative workshop spaces provide a safe and conducive environment for TVET practical training.

Keywords: TVET, ergonomics, commercial premises, thermal comfort, training workshop.

1. INTRODUCTION

Ergonomics plays an important role in creating a safe, comfortable, and productive learning environment, particularly in the field of Technical and Vocational Education and Training (TVET). Automotive training workshops are generally designed to meet the physical and technical requirements of practical activities, including aspects such as lighting, ventilation, and workspace layout. However, challenges arise when some institutions utilize commercial premises, such as shop lots, as training workshops due to cost and facility constraints. This raises the question of whether spaces originally intended for business purposes are truly suitable to be used as technical learning environments.

Previous studies have indicated that temperature, humidity, lighting, and ventilation directly influence students' concentration, performance, and safety during practical training. A study conducted across three TVET institutions found that the average thermal sensation vote (TSV) was 1.85, resulting in 66.5% of respondents experiencing thermal discomfort. In addition, analysis using the adaptive model showed that the workshop environment was outside the comfort zone and did not comply with ASHRAE 55 standards [1]. However, this study was carried out in institutional workshops that were specifically designed for technical training activities. Therefore, situations involving commercial premises, such as modified shop lots repurposed for training purposes, are expected to face even greater ergonomic challenges. Hence, it is essential to assess the level of thermal comfort and other environmental ergonomic factors within the context of commercial premises functioning as TVET workshops to ensure a conducive and safe learning environment. A comprehensive evaluation to determine the suitability of such spaces is thus necessary.

Accordingly, the objectives of this study are to:

i) Evaluate the level of thermal comfort (temperature, humidity, and air flow) in automotive training workshops operating in commercial premises.
ii) Analyze the levels of lighting and environmental noise in the workshop in relation to students' comfort.
iii) Propose improvements in the design of training spaces to make them more ergonomic and conducive for practical learning.

The findings of this study are therefore expected to contribute to the enhancement of TVET facilities, thereby supporting the effectiveness of teaching and learning in the field of automotive education.

2. LITERATURE REVIEW

2.1 Ergonomics in Technical and Vocational Education and Training (TVET)

In technical and vocational education, practical learning represents the foundation of skills acquisition. Students are not only expected to master theoretical knowledge but also to engage in intensive hands-on tasks requiring endurance, focus, and the use of multiple tools. In such conditions, ergonomics plays a decisive role because it directly influences comfort, safety, and learning effectiveness. Without adequate spatial layout, proper thermal regulation, or sufficient lighting, students are more likely to experience fatigue, concentration loss, and exposure to potential risks of injury.

Ergonomics, by definition, is the science of how humans interact with their working environments with the aim of improving comfort, efficiency, and safety. Within TVET, this role is amplified since learning is dominated by practical work that is physically demanding and repetitive. Thus, the effectiveness of a workshop cannot be measured solely by the availability of tools and equipment but also by how far the space is designed to accommodate both the physical and cognitive needs of learners [2].

However, despite its importance, the integration of ergonomics in the TVET curriculum remains limited. Several studies highlight that ergonomics is often treated only as a subtopic within technical modules rather than as a discipline deserving in-depth coverage. In contrast, engineering education embeds ergonomics more formally in its curriculum, which equips students with a stronger awareness of workplace safety and human factors [3]. This gap places TVET learners at a disadvantage, especially when entering real work environments that demand not only technical ability but also an understanding of ergonomic principles.

Earlier studies in Malaysia, for example, show that ignoring ergonomics in workshop design can cause issues such as heat strain, muscle fatigue, and postural discomfort, which eventually reduce learning motivation (Ismail et al., 2020). Salleh (2024) goes further by proposing a three-domain ergonomic intervention framework that is physical, organizational, and cognitive, which when implemented together, could mitigate these risks. This view is consistent with international research that links structured ergonomic interventions with higher student productivity, better safety compliance, and long-term employability. In short, ergonomics in TVET should not be seen as supplementary but as an essential element of training quality.

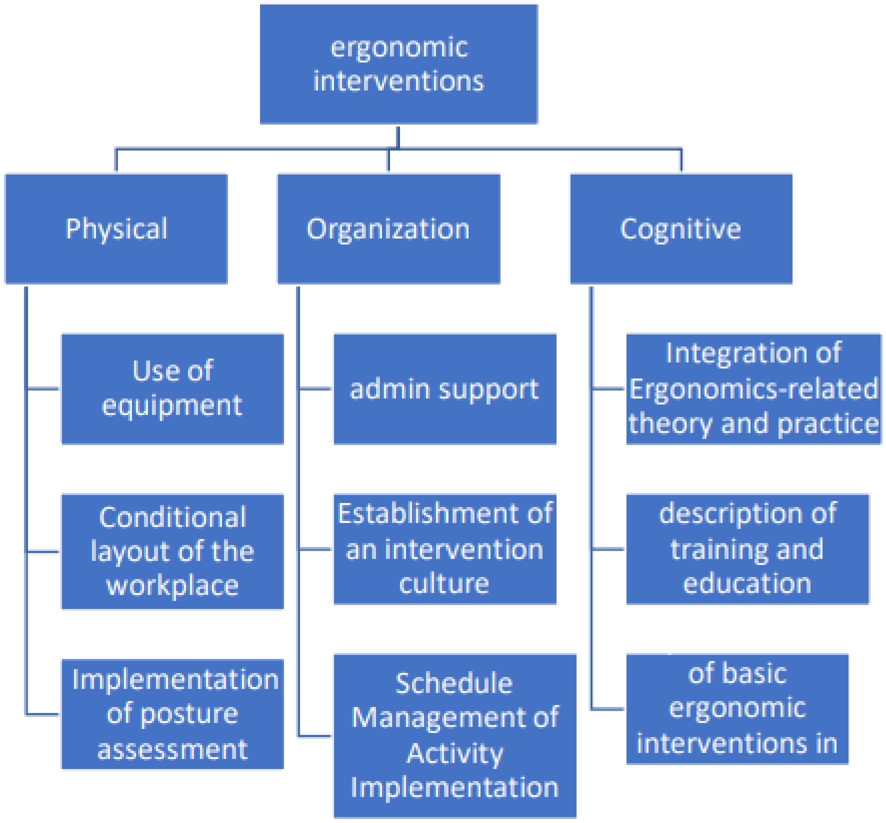

Figure 1. Proposed Ergonomic Intervention Framework in the Context of TVET Education

2.2 The Importance of Ergonomic Learning Environment Design

The design of ergonomic learning environments plays a critical role in enhancing the learning process, particularly in the context of technical and vocational education and training (TVET), where practical activities form the foundation of skills acquisition. Poorly designed environments such as those with limited space, inconsistent lighting, and inadequate thermal control, affect not only students' comfort but also their ability to concentrate, sustain performance, and remain safe during hands-on tasks. In training workshops located within commercial premises, these challenges become more visible, as such spaces were originally intended for business rather than intensive technical training.

Previous studies consistently demonstrate that student focus and comfort improve significantly when ergonomic requirements are fulfilled. Factors such as sufficient natural lighting, effective ventilation, and a well-structured equipment layout directly influence learning outcomes and ensure safer participation in practical sessions [4]. When these conditions are absent, students are more prone to fatigue and distraction, which undermines the quality of their training. For example, Alias and Kassim (2023) found that temperature and humidity in Malaysian TVET workshops often exceeded the thermal comfort zone specified by ASHRAE 55, leading to discomfort among students [1]. Similar observations in international literature highlight that failure to regulate thermal comfort reduces task efficiency and compliance with safety standards, showing that this is not only a local issue but a broader challenge faced by TVET systems.

In addition to physical conditions, cognitive and psychological aspects are equally significant. Students who experience a conducive environment demonstrate stronger motivation, confidence, and willingness to engage with technical content. Conversely, environments that are too hot, noisy, or poorly ventilated heighten stress levels and weaken knowledge absorption. The Health and Safety Executive (2025) similarly reported that unconducive spaces negatively affect both mental well-being and the pace of learning [5]. Taken together, these studies underline that ergonomic design should not be seen merely as the provision of facilities or layout but as an educational investment.

Within the context of TVET, ensuring ergonomic environments represents a strategy to enhance training effectiveness and prepare students for the physical and cognitive demands of real workplaces.

2.3 Transformation of Commercial Premises into TVET Training Workshops: Ergonomic Needs and Challenges

Skills education today increasingly emphasizes broad and accessible pathways for all segments of society, particularly those in small towns and rural areas. To address this, institutions such as Community Colleges and GiatMARA have been established in strategic locations closer to communities, enabling wider participation in technical programs without the need for long-distance travel. In practice, repurposing existing commercial premises such as shop lots or light industrial units has become a practical strategy. This approach reduces infrastructure costs, accelerates program implementation, and ensures that TVET remains community-centered [6].

However, not all commercial premises are immediately appropriate for technical training. Many of these facilities were originally intended for retail or residential use, which means they lack the structural and environmental requirements for hands-on activities involving heavy equipment, active student mobility, and proper ventilation or lighting systems. Empirical observations highlight that cramped layouts, low ceilings, and insufficient airflow directly compromise both safety and comfort during training. This underlines the need for ergonomic adaptation, covering workspace layout, movement flow, lighting intensity, and air circulation before such spaces can function effectively as training workshops.

The use of commercial premises should therefore be seen not simply as a short-term measure but as part of a broader national strategy to make TVET delivery more flexible, inclusive, and responsive to local contexts. The National TVET Policy 2030 emphasizes the importance of optimizing existing facilities to expand opportunities while controlling financial burdens [8]. This is consistent with findings from the ISEAS–Yusof Ishak Institute, which stress that skills education must remain contextually responsive and accessible without excessive bureaucracy [8]. At the same time, the Government–Industry TVET Coordination Council (GITC) demonstrates that closer collaboration between institutions and industry can accelerate the upgrading of these spaces to meet ergonomic and safety standards [9]. Taken together, these insights suggest that while the adaptation of commercial premises is pragmatic, it requires deliberate ergonomic interventions to ensure such spaces truly support quality technical training.

3. Research Methodology

3.1 Research Design

This study employed a quantitative descriptive research design involving two main methods of data collection, namely direct observation of the physical workshop environment and the distribution of questionnaires to students. This approach was chosen to obtain a comprehensive overview of the suitability of ergonomic elements within commercial premises utilized as automotive practical training workshops in TVET institutions.

Direct observation was conducted to obtain objective data on physical environmental elements such as air temperature and humidity, air flow rate, lighting, noise levels, and workshop layout. The measuring instruments used included an anemometer for air flow, a lux meter for lighting, and a decibel meter for noise. Data were collected from seven distinct learning zones, covering both enclosed and semi-open spaces with varying dimensions and degrees of exposure to outdoor air flow. The results of these observations enabled an in-depth analysis of thermal comfort factors and the suitability of the existing training environment.

Figure 2. Zones of Learning Spaces at the Study Area

A questionnaire was used to collect subjective data from students undergoing practical training in the workshop. Respondents were selected using a convenience sampling method, whereby students who were actively involved in workshop sessions during the data collection period were invited to participate. A total of 54 students responded to the questionnaire, which consisted of items related to comfort in terms of workspace layout, lighting, temperature, ventilation, and noise levels, measured using a five-point Likert scale.

To ensure the reliability of the questionnaire, a Cronbach's Alpha analysis was conducted, yielding a value of $\alpha = 0.897$, which indicates a high level of internal consistency and confirms that the instrument was suitable for this study. Prior to data collection, respondents were informed about the purpose of the study, assured that their participation was voluntary, and that all responses would be treated confidentially and used solely for academic purposes. No personal identifying information was collected. The combination of observational data and questionnaire responses enabled effective data triangulation, thereby strengthening the validity of the findings by integrating both objective measurements and students' subjective perceptions.

3.2 Description of the Research Premises

This study was conducted at a TVET institution, specifically the Automotive Workshop of Kolej Komuniti Kluang, which conducts automotive practical training in a two-storey shop-lot type commercial premise. The premise is located in a business area near the town center and has been modified to accommodate students' practical learning needs. The ceiling height of the premise is 3.548 meters, with the original structure retained following renovation, along with the existing facilities.

The workshop learning area is divided into seven zones based on the functional layout of the space, with each zone designated for different practical activities. These zones vary in terms of spatial size, level of enclosure, and exposure to natural ventilation

Table 1. Zones of the Workshop, Space Area, and Ventilation Openness

Zone	Type of Space	Width (m)	Length (m)	Area (m^2)	Ventilation Openness
1	Enclosed space	7.108	6.964	49.49	Open on 1 side
2	Semi-enclosed	7.108	11.172	79.42	Open on 2 sides
3	Semi-exposed	5.119	9.067	46.41	Open on 3 sides
4	Semi-exposed	5.119	9.235	47.62	Open on 3 sides
5	Semi-exposed	6.497	13.186	85.70	Open on 3 sides
6	Semi-exposed	6.497	5.322	34.59	Open on 3 sides
7	Semi-exposed	6.436	9.537	61.38	Open on 2 sides

In terms of ventilation, the workshop utilizes a combination of natural and mechanical systems. Natural ventilation is provided through doors and window openings that allow outdoor air circulation, particularly in semi-open zones. Mechanical ventilation is supported by several ceiling-mounted and wall-mounted fans installed at selected locations within the workshop. However, the distribution of these fans is not uniform across all zones, resulting in variations in air flow conditions between different learning areas.

4. Results and Discussion

Thermal comfort is a key element in assessing the suitability of commercial premises as practical training workshops, particularly for hands-on activities in the automotive field. Based on observations and physical measurements conducted across seven workshop zones using a digital anemometer (HT605 Habotest), variations were recorded in air flow, temperature, and humidity levels. The average air flow rate ranged from 0.13 m/s in Zone 3 to 0.87 m/s in Zone 2, indicating uneven air movement across the training space and suggesting that ventilation effectiveness differs by zone.

In terms of ambient temperature, all zones recorded readings between 30.1°C and 31.0°C. Although the temperature variation was minimal, the overall range generally exceeded the recommended comfort range of approximately 23°C to 28°C for light activities in tropical settings [10]. Relative humidity readings were consistently high (74.6%–79.0%), and when combined with elevated temperature, such humidity levels may intensify perceived heat and discomfort, particularly in zones with weaker air circulation. Importantly, ASHRAE 55 emphasizes that thermal acceptability is determined by the combined interaction of environmental variables (e.g., air temperature and air speed) and personal factors, rather than by temperature alone [10]. Therefore, zones with comparable temperature but lower air speed may still feel significantly less comfortable to occupants.

A critical observation is the contrast between Zone 2 and Zone 3. Zone 2 recorded the highest average air flow (0.87 m/s), whereas Zone 3 recorded the lowest (0.13 m/s). This difference may be explained by the interaction between zone openness and actual ventilation pathways. Although Zone 3 is classified as semi-exposed (open on three sides), the measured air flow suggests that cross-ventilation may have been restricted by local obstructions (e.g., partitions, stacked equipment, workstation density), the position of openings relative to prevailing wind direction, or non-uniform fan placement. Conversely, Zone 2 (open on two sides) may have benefited from a more direct air path and better mechanical fan support, producing stronger air movement. This indicates that "openness" alone does not guarantee effective ventilation; airflow performance depends on how openings, internal layout, and mechanical assistance collectively support air movement. From an ergonomic perspective, this finding is significant because inconsistent air speed across zones can lead to unequal thermal comfort conditions, which may affect students' concentration, endurance during practical sessions, and overall learning quality in a workshop setting [10].

Table 2. Air Flow, Humidity, and Ambient Temperature Readings Measured Using Digital Anemometer Model HT605 Habotest

Zon	Air Flow (m/s)				Air Humidity (%)	Ambient Temperature (°C)
	Spot 1	Spot 2	Spot 3	Average		
1	0.26	0.85	0.35	0.49	76.6	31.0
2	0.85	0.35	1.42	0.87	76.8	30.1
3	0.21	0.14	0.04	0.13	79.0	30.2
4	0.78	0.14	1.25	0.72	75.3	30.3
5	0.78	0.64	0.78	0.73	74.9	30.5
6	1.46	0.21	0.21	0.63	74.7	30.4
7	0.11	0.64	0.21	0.32	74.6	30.5

The lighting analysis also revealed noticeable differences between zones. Several zones recorded high illumination readings, such as Zone 3 (842.1 lux) and Zone 5 (829.3 lux), indicating that certain areas are well-lit and suitable for visual task performance. However, Zone 2 and Zone 6 recorded relatively low lighting levels (211.4–194.3 lux and 266.6–230.2 lux, respectively), falling below the minimum requirement set by Malaysian Standard MS 1525:2014, which recommends at least 300 lux for learning spaces such as workshops and laboratories [11]. This pattern suggests uneven lighting distribution, likely influenced by the placement of luminaires, shading from structural elements, and distance from openings that provide natural lighting. From an ergonomic and learning perspective, insufficient lighting can reduce task accuracy, increase eye strain, and impair the effectiveness of hands-on training, especially for activities involving fine inspection or component handling [12]. Hence, zones with consistently low lux readings should be prioritized for lighting enhancement through targeted artificial lighting or layout adjustments to minimize shadowing and ensure uniform illumination [11][12].

With regard to noise, the measurements indicate that Zone 1 (84.6 dB) and Zone 2 (83.2 dB) recorded the highest readings, exceeding the recommended noise threshold for learning environments of around 70 dB [13]. Although several other zones ranged between 70.1 dB and 72.6 dB, the overall pattern suggests that students are frequently exposed to elevated noise during practical activities. Critically, the fact that Zone 1 and Zone 2 show substantially higher readings may be linked to functional zoning, these zones may be closer to high-noise equipment, active workstations, or areas with frequent tool usage. From an ergonomic standpoint, persistent noise exposure is not only a hearing-related issue; it can reduce verbal communication clarity, increase fatigue, and elevate stress, which in turn affects learning engagement and safety compliance. Therefore, noise management strategies such as isolating high-noise tasks to specific zones, scheduling noisy activities, or introducing basic acoustic interventions, should be considered to improve the learning environment without compromising workshop functionality.

Table 3. Lighting Level Readings Using HT603 Habotest Digital Light Meter and Noise Level Readings Using HT602B Habotest Sound Level Meter

Zone	Lighting Level Reading (lux)		Noise Level Reading (dB)
	Spot 1	Spot 2	
1	321.6	274.1	84.6
2	211.4	194.3	83.2
3	842.1	505.5	70.1
4	304.7	270.6	72.3

5	701.6	829.3	72.6
6	266.6	230.2	72.5
7	371.4	325.6	70.6

Based on the questionnaire responses from 54 students, overall satisfaction with the training workshop operating in a commercial premise was reported to be high. The analysis showed that most students agreed that the workshop layout was appropriate and allowed comfortable movement during practical sessions. This item recorded the highest mean score of 4.26. This was followed by the suitability of the workshop space to continue being used as a training venue, which also obtained a high mean score of 4.24. These findings reflect a positive acceptance of the overall function of the space.

In addition, students expressed high satisfaction with the lighting aspect, with an average score of 4.20. Adequate and non-glaring lighting is indeed crucial to ensuring safety and concentration during hands-on activities. High scores were also recorded for the statement that the workshop design helps students to concentrate (mean = 4.06), as well as students feeling confident and comfortable using the space (mean = 4.11). The safety aspect of equipment usage also recorded a mean score of 4.22, indicating that students felt safe with the layout and facilities provided.

However, several aspects recorded moderate mean scores, among which were the temperature and ventilation of the workshop space, with an average of 3.65. This suggests that some students may have experienced thermal discomfort while in the workshop, particularly in enclosed or semi-enclosed zones. Furthermore, the noise level in the workshop also recorded a moderate score (mean = 3.70), indicating that noise from equipment or the surrounding environment has the potential to disrupt concentration. The aspect of fatigue after practical sessions was also noted with a mean score of 3.96, suggesting a degree of physical strain due to either the layout or the extended duration of training.

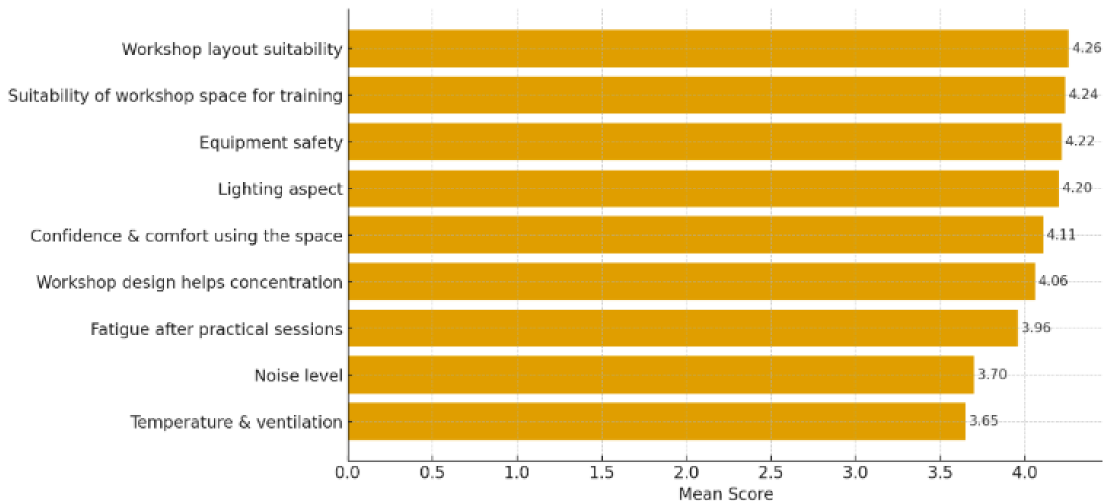

Figure 3. Mean Scores of Students' Satisfaction with Workshop Environment Factors

Overall, the questionnaire findings indicate that although most aspects of the workshop environment were positively rated by students, thermal comfort and acoustic conditions still require attention. Improvements to the ventilation system and noise management could help enhance students' learning experiences by creating a more conducive and ergonomic workshop environment.

5. Conclusion

The findings of this study provide a comprehensive evaluation of the ergonomic suitability of a commercial premise repurposed as an automotive practical training workshop within a TVET institution. Through a quantitative approach combining environmental observations and student questionnaires, several critical limitations were identified, particularly in relation to thermal comfort, lighting adequacy, and noise exposure. Measurements obtained using an anemometer, lux meter, and decibel meter revealed that temperature, humidity, and air flow levels in most workshop zones were outside the recommended comfort ranges, indicating that the existing environmental conditions were not optimal for sustained practical learning. These findings are consistent with the principles outlined in ASHRAE 55, which emphasize the importance of maintaining acceptable thermal conditions to support user comfort, concentration, and task performance in work environments.

In addition, lighting levels in several work zones were found to fall below the recommended minimum of 300 lux for technical and workshop-based activities, highlighting shortcomings in the current lighting layout and distribution. Noise levels exceeding 75 dB in multiple zones further suggest potential disruption to communication, focus, and safety during practical sessions. Student feedback collected through questionnaires reinforced these observations, particularly with respect to ventilation inefficiency, elevated temperatures, and space constraints. These results align with previous findings by Alias et al. (2023), which reported that a significant proportion of TVET students experienced thermal discomfort in workshops lacking ergonomic considerations. Despite these limitations, students expressed moderate acceptance of equipment safety and basic workshop functionality, suggesting that while the space is usable, it requires systematic ergonomic enhancement to support long-term training effectiveness.

From a broader perspective, the findings indicate that commercial premises not originally designed for technical training are less suitable for long-term use as TVET workshops unless substantial ergonomic adaptations are implemented. This underscores the need for a formal and standardized guideline for the design and adaptation of TVET workshops in commercial premises, incorporating minimum requirements for thermal comfort, lighting, ventilation, noise control, and spatial layout. Such a guideline would provide a clear reference for institutions and support more consistent implementation across different locations. Furthermore, the integration of real-time environmental monitoring systems is strongly recommended to enable continuous assessment of workshop conditions and to support data-driven improvements under varying operational loads and weather conditions.

Future research should be expanded to include a wider range of TVET institutions utilizing commercial premises, allowing for comparative analysis across different building typologies and geographical contexts. In addition to students, the inclusion of lecturers, technical instructors, and administrative personnel as respondents would provide a more holistic understanding of operational challenges and ergonomic needs from multiple stakeholder perspectives. At the policy level, these findings highlight the importance of strengthening TVET accreditation and quality assurance frameworks by explicitly incorporating ergonomic criteria into facility evaluation standards. By embedding ergonomics within institutional policy and accreditation requirements, TVET providers can ensure that learning environments not only meet functional demands but also promote safety, comfort, and effective skill development in line with international best practices.

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