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Assessing the Effectiveness of Passive Noise Control Strategies in Vocational Training Centers in Rivers State.

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ABSTRACT

Noise pollution is a persistent challenge in vocational training environments, where both practical workshop activities and theoretical instruction creates complex acoustic conditions that negatively affect learning outcomes. The purpose of this study is to find out how passive architectural design strategies can be used to mitigate the impact of noise and enhance acoustic comfort in vocational training centers. With the use of qualitative case study approach, the research analyzes two projects—the Vocational Education Center by Durisch + Nolli Architetti and the Ecove Centre of Vocational Empowerment by SEZA Architects & Interior Designers—with focus on spatial organization, material selection, and environmental responsiveness. Findings in this study reveal that strategies such as functional zoning, use of buffer zones, and the use of dense construction materials are effective in reducing noise transmission between spaces and improving learning conditions. However, the study also points out a critical trade-off in tropical contexts, where the need for natural ventilation can compromise acoustic performance. The comparison between analysis of both factors highlights the importance for balance between acoustic control and climate responsive design. The study concludes that passive acoustic design, when implemented early in the planning and design stages, gives a sustainable and cost-effective method for improving learning experience in vocational training centers. It recommends a design framework that combines spatial separation, material optimization, and environmental strategies to enhance both acoustic comfort and learning experience, particularly in a high-noise urban setting.

Keywords*: Passive acoustic design; vocational training centers; noise mitigation; learning environments; spatial zoning; acoustic comfort; educational architecture; sustainable design; Nigeria; case study analysis*

1. Introduction

The quality of the learning environment is an important factor in determining the effectiveness of education, especially in spaces designed for skill acquisition and practical training. Vocational training centers, unlike regular classrooms, accommodate a larger range of educational activities including machine operation, fabrication, and hands-on workshops, most of which expels high levels of noise. This persistent exposure to high noise levels can negatively affect students' concentration, communication, cognitive performance, and overall learning efficiency (Marie-Eve Héroux and Dorota Jarosinska,World Health Organization, 2018).

In vocational settings, where both theoretical instruction and practical engagement occur simultaneously, the challenge of managing noise becomes even more critical. Poor acoustic conditions not only hinder effective teaching and learning but may also pose long-term health risks to occupants (Marie-Eve Héroux and Dorota Jarosinska, World Health Organization, 2018).

In response to these challenges, architectural design plays a vital role in shaping acoustically comfortable learning environments. While active noise control methods such as mechanical insulation and electronic soundproofing systems are available, they are often costly, energy-intensive, and less feasible in resource-constrained contexts. Passive acoustic design strategies, on the other hand, offer a sustainable and cost-effective approach by integrating noise mitigation measures into the building's form, materials, and spatial organization. Techniques such as appropriate zoning of noisy and quiet areas, use of sound-absorbing materials, building orientation, and incorporation of landscape buffers can significantly reduce noise transmission and improve acoustic quality (M. David Egan, M. D. Architectural Acoustics, 2007; American National Standards Institute, 2010).

Despite the growing emphasis on sustainable design, the application of passive acoustic strategies in vocational training centers remains underexplored, particularly in developing countries. There is a need to better understand how these design approaches can be effectively utilized to enhance learning outcomes in such environments (Ms. Amina J. Mohammed, and Professor W. John Morgan, Mr. Peter Ronald DeSouza, Mr. Georges Haddad, Ms. Fadia Kiwan, Mr. Fred van Leeuwen, Mr. Teiichi Sato, and Ms. Sylvia Schmelkes, United Nations Educational, Scientific and Cultural Organization, 2015).

This study therefore aims to examine the impact of passive acoustic design on learning outcomes in vocational training centers. By evaluating the relationship between architectural design strategies and acoustic comfort, the research seeks to provide practical insights and recommendations for architects, designers, and policymakers in the planning and development of more effective and conducive learning spaces.

1.1 Statement of Problem.

Excessive noise levels in vocational training centers, generated by workshops, machinery, and dense activity patterns, create acoustically poor learning environments that hinder students' concentration, communication, and overall learning performance. Despite the known impact of noise on cognitive efficiency and skill acquisition, many vocational facilities are designed with little consideration for acoustic comfort. In resource-constrained contexts, reliance on mechanical noise control systems is often impractical, yet the potential of passive architectural strategies remains underutilized and insufficiently studied. This gap highlights the need to explore how passive acoustic design can be effectively applied to improve learning outcomes in vocational training environments.

1.2 Aim of The Study.

The aim of this study is to evaluate the effectiveness of passive acoustic design strategies in mitigating noise and improving learning outcomes in vocational training centres.

1.3 Objective of The Study.

The objectives of this study are to:

1. **Assess the existing noise conditions** in vocational training centers and their impact on the learning environment.
2. **Examine the effects of noise on students' learning outcomes**, including concentration, comprehension, and performance.
3. **Identify relevant passive acoustic design strategies** applicable to vocational training centers.
4. **Develop design recommendations** for integrating passive acoustic strategies into the planning and design of vocational training centers.

1.4 Research Questions.

1. What are the existing noise conditions in vocational training centers?
2. How does noise affect students' learning outcomes in vocational training environments?
3. What passive acoustic design strategies are suitable for noise mitigation in vocational training centers?
4. How effective are passive acoustic design strategies in improving acoustic comfort and reducing noise levels?
5. How can passive acoustic strategies be integrated into the design of vocational training centers to enhance learning outcomes?

1.5 Study Area.

The study area is the **Trans-Amadi Industrial Layout**, situated in the northeastern flank of the Port Harcourt metropolitan area in Rivers State, Nigeria. Bounded to the north by Elelenwo, to the east by Abuloma, to the south by the Amadi Creek, and to the west by Ogbunabali and the Garrison axis, Trans-Amadi is the primary industrial and commercial hub of Port Harcourt.

It accommodates a dense concentration of heavy fabrication yards, manufacturing plants, logistics bases, and oil-field servicing companies. Consequently, the area is characterized by a complex, high-decibel acoustic environment generated by industrial machinery, heavy-duty diesel generators, and intense commercial vehicular traffic along major arteries like the Eastern Bypass and Trans-Amadi Road. This industrial-urban profile presents a highly challenging acoustic setting, making it an ideal real-world context for testing the effectiveness of passive noise mitigation strategies in vocational training centers.

Fig. 1 - Site location.

Source: Google Earth.

Site Area: 18,987.33 SQM

Perimeter: 572.25M

Location: Eleme Junction, Off East-West Road, Port Harcourt, Rivers State.

2. Literature Review

2.1 Noise Pollution In Educational Environments

Noise pollution is widely recognized as an environmental stressor that interferes with communication, cognitive processing, and learning efficiency. It is defined as unwanted or harmful sound that disrupts normal human activities (Marie-Eve Héroux and Dorota Jarosinska World Health Organization, 2018).

Research across multiple contexts confirms that learning environments frequently exceed acceptable acoustic standards. For instance, classroom noise levels above 55 dB(A) are considered disruptive, yet studies have recorded levels ranging from 60–90 dB(A) in urban schools and institutions (Klatte, Bergström, & Lachmann, 2013). In developing countries, the situation is often more severe due to poor urban planning and infrastructural constraints (Oyedepo, 2012).

In Nigeria, environmental noise studies have documented excessive exposure in institutional settings, particularly in urban areas influenced by traffic, commercial activity, and generator usage (Avwiri & Nte, 2003; Aluko & Nwokoro, 2015).

2.2 Effect of Noise on Learning Outcomes.

Recent studies in higher education contexts in Africa also show that noise levels exceeding 70 dB(A) negatively influence student concentration and academic performance (Nwankwo & Orji, 2020; Ighalo et al., 2021). These findings reinforce the need for environmental control strategies in learning spaces.

2.3 Acoustic Conditions in Vocational Training Centers.

Vocational training centers present unique acoustic challenges due to their dual-function environments. Unlike traditional classrooms, these facilities accommodate workshops involving machinery, fabrication, and technical equipment that generate high internal noise levels.

According to UNESCO (2015), technical and vocational education requires learning environments that support both theoretical instruction and practical skill acquisition, making environmental quality a critical factor in educational effectiveness.

Studies show that workshop environments can exceed 85–100 dB(A), depending on the equipment used (Beranek & Vér, 2012). When combined with external urban noise, this creates complex acoustic conditions that interfere with speech intelligibility and instruction delivery.

In many developing cities, vocational facilities are located in mixed-use urban zones without proper zoning separation, further intensifying exposure to environmental noise (Ogunbiyi & Okunola, 2019).

2.4 Passive Acoustic Design in Architecture.

Passive acoustic design refers to architectural strategies that control sound transmission through spatial planning, material selection, and building configuration without reliance on mechanical systems.

Early-stage architectural decisions such as building form, orientation, and materiality significantly influence acoustic performance. Similarly, Long (2014) highlights that effective acoustic design integrates absorption, diffusion, and insulation strategies into building envelopes.

Common passive strategies include:

- Spatial zoning (separating noisy and quiet areas)
- Use of absorptive materials (acoustic panels, ceilings)
- Buffer zones (corridors, storage spaces)
- Landscape barriers (trees and earth mounds)
- Building orientation away from noise sources

Recent studies confirm that passive strategies can reduce indoor noise levels by 10–25 dB(A), significantly improving speech intelligibility and occupant comfort (Oldham, 2018; Kang et al., 2016).

In educational architecture, research shows that acoustically optimized environments improve student performance and reduce cognitive fatigue (Barrett et al., 2015).

2.5 Urban Noise and Building Performance in Nigeria.

Urban centers in Nigeria, particularly industrial zones, are characterized by high levels of environmental noise due to manufacturing operations, heavy transport, and localized power generation. Studies within the Trans-Amadi Industrial Layout have recorded noise levels ranging from 65.26 dB(A) to 83.79 dB(A), with peak exposures occurring along heavy transport links such as the Eastern Bypass and major industrial frontage roads (Digha & Oyegun, 2017). These documented levels far exceed the World Health Organization’s recommended limit of 55 dB(A) for educational environments (WHO, 2018). This high-exposure baseline compromises speech intelligibility and cognitive performance, underscoring the necessity of structural and spatial mitigation within institutional facilities located in the zone.

2.6 Passive Design and Learning Outcomes.

The integration of acoustic design in educational architecture has been shown to improve learning outcomes through enhanced concentration, reduced stress, and better communication clarity.

Barrett et al. (2015) demonstrated that well-designed classrooms can improve academic performance by up to 16% through environmental quality factors, including acoustics.

However, most existing studies focus on primary, secondary, or tertiary classrooms, with limited attention to vocational training environments, particularly in developing countries.

2.7 Research Gap.

While literature confirms the importance of acoustic comfort in learning environments, several gaps remain:

1. Most studies focus on general classrooms rather than vocational training centers.
2. Limited research exists on passive acoustic strategies in tropical urban contexts.
3. Few studies investigate real-world implementation in high-noise environments such as Oil Mill, Port Harcourt.
4. There is insufficient integration between architectural design strategies and measurable learning outcomes in vocational settings.

This gap highlights the need for context-specific research on how passive acoustic design can be applied to improve learning environments in vocational training centers located in high-noise urban areas.

3. Methodology

3.1 Research Design.

This study adopts a **qualitative case study approach** to examine how passive architectural strategies can mitigate the impact of noise and enhance learning outcomes in vocational training centers. The approach prioritizes **architectural analysis and user perception**, rather than quantitative acoustic measurements, in order to evaluate how design decisions, influence perceived acoustic comfort within real learning environments.

The case study method is particularly appropriate for this research as it enables an in-depth investigation of context-specific conditions, including building configuration, spatial organization, and environmental influences within high-density urban settings.

3.2 Case Study Selection.

The study focuses on selected vocational training centers around the world. Case selection is based on the following criteria:

- Presence of both theoretical and workshop-based training spaces
- Accessibility for observation and data collection
- Representation of typical vocational training environments in urban Nigeria

A small number of case studies (two) will be selected to allow for detailed analysis and cross-case comparison.

3.3 Data Collection Methods.

Data collection is based on qualitative and perception-driven techniques, as outlined below:

Architectural and Spatial Analysis

A detailed analysis of the physical and spatial characteristics of each case study is conducted. This includes:

- Zoning and spatial separation of noisy and quiet areas
- Building orientation relative to dominant noise sources
- Circulation patterns and the presence of buffer spaces
- Relationship between workshops, classrooms, and outdoor spaces

Material and Construction Assessment

An evaluation of building materials and construction techniques is undertaken to determine their role in passive noise control. This includes:

- Wall, ceiling, and floor materials
- Openings (windows and doors) and their placement
- Presence or absence of sound-absorbing or insulating elements

Secondary Data Review

Relevant literature and established guidelines are reviewed to support the analysis and provide benchmarks for acceptable acoustic conditions. These include standards from the World Health Organization and the American National Standards Institute.

3.4 Data Analysis

Data analysis is conducted using qualitative techniques, including:

- **Architectural evaluation** of spatial and material strategies employed in each case study
- **Comparative analysis** across case studies to determine the relative effectiveness of different passive design approaches

The findings are interpreted to establish how specific architectural strategies influence perceived acoustic comfort and learning efficiency.

4. Case Study

4.1Case study 1

Case Study Summary: Vocational Education Centre SSIC in Gordola – Durisch + Nolli Architetti

- Clear **functional zoning** separates noisy workshop areas from quiet learning spaces
- Strategic use of **buffer zones** (corridors, circulation spaces) reduces sound transmission
- **Building layout and massing** act as physical barriers to noise
- **Orientation of spaces** minimizes exposure of classrooms to noise sources
- Use of **dense construction materials** (e.g., concrete) enhances sound insulation
- Interior finishes help **reduce reverberation** and improve acoustic comfort
- **Circulation spaces serve dual roles**: movement + acoustic buffering
- Design integrates **passive acoustic strategies from the early stage**, not as an afterthought

Fig. 2 - Interior

Source: ArchiDaily.com

Fig. 3 - Elevation

Source: ArchiDaily.com

Key Takeaways for Study

- Zoning is the **most effective passive strategy**
- Buffer spaces are **simple but powerful**
- Layout and orientation are **critical in noise control**
- Passive design can significantly improve **learning environments without mechanical systems**

Critical Insight

Design works well in its context but may require ***adaptation for high-noise urban areas*** *like Oil Mill, Port Harcourt*

Fig. 5 -Floor plan

Source: ArchiDaily.com

4.2 Case Study 2: Ecove Centre of Vocational Empowerment – SEZA Architects & Interior Designers

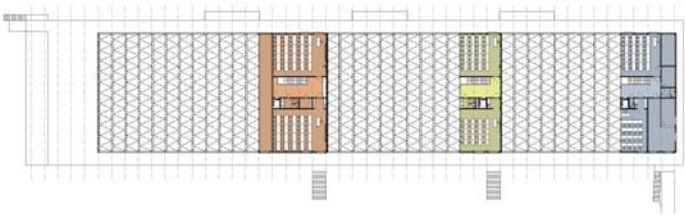

Fig. 4 -Floor plan

Source: ArchiDaily.com

Fig. 6 -Courtyard

Source: ArchiDaily.com

Fig. 7 -Interior space

Source: ArchiDaily.com

Key Architectural Analysis (Bullet Summary)

- Designed as a **community-focused vocational hub**, integrating learning, training, and social interaction
- **Open and semi-open spatial layout** promotes natural ventilation but increases exposure to external noise
- Use of **courtyards and internal open spaces** helps organize activities and create spatial separation
- **Zoning strategy present but less rigid**—workshops and learning areas are connected, encouraging interaction but allowing sound spill
- **Lightweight materials** (e.g., blocks, glazing, open facades) improve airflow but provide **limited sound insulation**

- **Perforated facades and large openings** enhance daylight and ventilation but reduce acoustic control
- **Landscape elements (green areas, setbacks)** serve as partial buffers against external noise
- Circulation spaces are **integrated with activity zones**, rather than acting as strong acoustic buffers

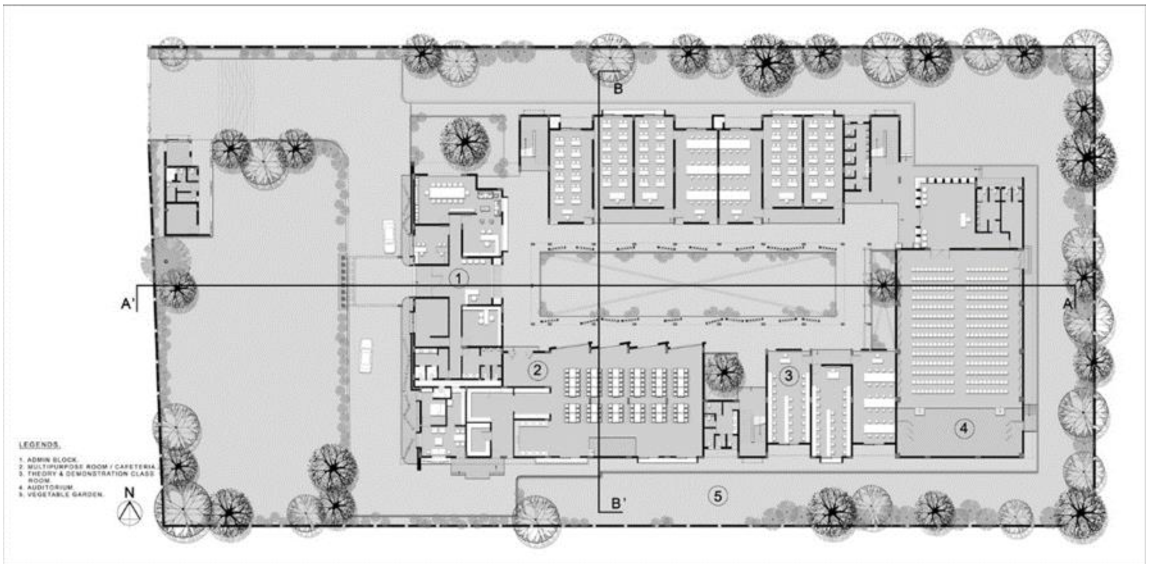

Fig. 8 -Floor plan

Source: ArchiDaily.com

Passive Acoustic Design Evaluation

- **Strengths:**
  - Use of **courtyards as spatial buffers**
  - Natural ventilation reduces need for mechanical systems
  - Some level of **zoning through spatial arrangement**
- **Limitations:**
  - **Weak acoustic separation** between noisy and quiet spaces
  - **Open-plan design allows noise transmission** across functions
  - **Material choice prioritizes ventilation over sound insulation**
  - Limited use of **dedicated buffer zones**

Relevance to Your Study (Very Important)

- Represents a **more relatable context to Nigeria** compared to Case Study 1
- Shows the **real trade-off** between:
  - Ventilation (important in tropical climates)
  - Acoustic control

- Highlights a key challenge:

Passive design strategies must balance **thermal comfort and acoustic performance**

Key Lessons for Your Research

- Open designs must be **carefully controlled** to avoid noise spill
- **Zoning should be stronger and more deliberate** in vocational spaces
- **Courtyards can act as buffers**, but only if properly designed
- Material selection must balance:
  - Ventilation
  - Acoustic insulation

Critical Insight

Unlike the Vocational Education Center by Durisch + Nolli Architetti, which emphasizes strong acoustic control through zoning and massing, the Ecove Centre prioritizes **openness and environmental responsiveness**, resulting in weaker acoustic performance.

This contrast highlights the need for a **context-sensitive approach** that integrates both **acoustic control and climatic responsiveness** in vocational training center design.

Discussion

The comparison highlights a fundamental tension in architectural design for vocational training centers: the need to balance **acoustic control** with **environmental responsiveness**, particularly in tropical climates.

The Vocational Education Center by Durisch + Nolli Architetti demonstrates that **clear zoning, spatial separation, and material density** are highly effective passive strategies for minimizing noise interference. By isolating workshops from classrooms and incorporating buffer spaces, the design ensures that noise generated from practical activities does not disrupt learning in quieter zones. This approach supports improved concentration and overall learning outcomes.

In contrast, the Ecove Centre by SEZA Architects & Interior Designers prioritizes **openness, ventilation, and spatial interaction**, which are essential in tropical contexts such as Nigeria. However, this openness results in **acoustic spillover**, where sound travels freely between spaces due to weak zoning and limited use of insulating materials. While the design enhances thermal comfort and accessibility, it compromises acoustic performance.

These findings suggest that **passive acoustic design is most effective when integrated early in the planning stage through deliberate zoning and spatial organization**. However, in climates like that of Port Harcourt, strategies must also account for ventilation needs. Therefore, an optimal design approach should not replicate either model entirely but rather **synthesize both**, combining:

- Strong **zoning and buffer strategies** (from Durisch + Nolli)
- Climate-responsive features such as **courtyards and natural ventilation** (from Ecove Centre)

5.1 Implication for the Study

For vocational training centers in high-noise urban areas such as Trans-Amadi, Port Harcourt, the results indicate that:

- **Zoning is the most critical passive strategy** for noise mitigation
- **Open-plan designs should be carefully controlled** to prevent noise spill
- **Buffer spaces and transitional zones are essential**
- Passive strategies must balance **acoustic performance with thermal comfort**

Conclusion

This study has demonstrated that passive architectural design plays a crucial role in mitigating the impact of noise and enhancing learning outcomes in vocational training centers. Through the analysis of the Vocational Education Center by Durisch + Nolli Architetti and the Ecove Centre of Vocational Empowerment by SEZA Architects & Interior Designers, it is evident that spatial planning, material selection, and building configuration significantly influence acoustic comfort.

The findings reveal that **functional zoning, buffer spaces, and the use of dense materials** are highly effective passive strategies for controlling noise. At the same time, the study highlights the importance of **climate-responsive design features**, such as natural ventilation and open courtyards, particularly in tropical environments. However, excessive openness without adequate acoustic control can lead to noise spill and reduced learning efficiency.

Therefore, achieving optimal acoustic performance in vocational training centers requires a **balanced integration of acoustic control and environmental responsiveness**. Designers must adopt context-sensitive approaches that combine strong spatial organization with appropriate material strategies to create conducive learning environments.

In conclusion, passive acoustic design offers a **sustainable and cost-effective solution** for improving educational spaces, especially in high-noise urban areas such as Trans-Amadi, Port Harcourt

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