Investigation of The Impact of Noise Control Strategies in Sustainable Building Design

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Investigation of The Impact of Noise Control Strategies in Sustainable Building Design

B. A. Adewale[1] and Mozimo Stephanie[2]

Department of Architecture, Covenant University, Ota, Ogun State, Nigeria.

Authors email: [1]bukola.adewale@covenantuniversity.edu.ng
[2]stephanie.mozimopgs@stu.cu.edu.ng

Abstract. The design of each city inextricably influences the pattern of noise pollution across the globe. Many aspects of urban planning can significantly affect vehicular distribution, traffic conditions, and the volume of traffic. Lagos State, in particular, is afflicted by some of these factors. Numerous studies have established the significance of noise control strategies in this context. This paper focused on precautionary noise control strategies incorporated at the design stage, which are an integral part of a sustainable urban planning approach. Data were collected via a structured questionnaire from a sample consisting of 96 designers and 67 users of mixed-use buildings in Lagos state; as these building types promote sustainability in building design. This research utilized the Statistical Package for the Social Sciences (SPSS) to analyze data. The results reveal which noise control strategies have been adopted and implemented in sustainable building designs and as a result, its users are not affected by external noise sources. The study's findings had a positive impact on the implementation of sustainable urban planning strategies that incorporate precautionary noise control strategies.

Keywords: Noise control strategies, Sustainable solutions, Urban planning, Mixed-use buildings

1. Introduction

The two biggest issues facing cities are a growing population and urban sprawl. Such is the motivation of baby boomers to downsize and choose to live in smaller, more convenient locations. Government at various policy scales are doing their utmost to ensure that the country's major urban centers have more compact and integrated settlements. It is the intention of these initiatives to reinvigorate these urban areas by reinforcing the local economy while simultaneously addressing both social and environmental issues that may be more appropriate. These developments use a mixed-use development concept, and that concept has become a critical element in city revitalization, as asserted by [1]. While mixed-use developments are typically horizontal because of their ease of development, vertical mixed-use developments, or VMU developments, are becoming popular because of regulations and controls favoring vertical development [2]. Mixed-use developments are faced with diverse challenges due to the nature of the building type and its various functions. For this study, the authors focused on noise being that it is considered as one of the challenges faced in the design of mixed-use buildings.

Noise pollution is one of the most critical factors in assessing urban residents' quality of life. The volume of noise pollution throughout the city is also being hindered by various other things. A key difficulty is the quantification of the population's noise-related effects. Population growth leads to higher noise generation. The area's connectivity will increase the noise volume generated if transportation routes are used. The negative effects of noise pollution have grown to the point where it is considered a serious health hazard [3]. Noise pollution is a serious concern for the quality of life in metropolitan places across the world. Noise pollution has increased in lockstep with the growth of car ownership and industrialization. The

majority of main highways in metropolitan areas are now plagued by excessive noise. Nigeria's experience with sustainable urban development is awful. Urban development reflects the problems of sustainable development in Nigeria's cities and urban regions. Environmental noise pollution is a frequent adverse effect of urbanization. Urban noise pollution is a broad term that encompasses everything that makes urban centers uninhabitable and contributes to environmental deterioration. This raises concerns about the issues and challenges now confronting metropolitan regions in Nigeria in terms of utility, livelihood, and aesthetic enjoyment.

2. Literature Review

Cities have been showing symptoms of environmental issues in recent years due to unfavorable urban activities. Cities are increasingly concerned about natural resource deterioration and the impact of climate change on green areas. As a result of these challenges, cities have begun developing new ways for improving urban ecosystems [4]. An urban ecosystem's key purpose is to keep natural systems and communities healthy. Thus, ecological planning is required to create a sustainable constructed environment. Ecological planning fulfills human demands while maintaining ecological balance and efficiency.

2.1. Sustainable Urban Planning

Examples of innovative sustainable solutions for urban planning include green buildings and housing, mixed-use projects, walkability, greenways and greenspaces, solar and wind energy, and alternate means of transportation. Calthorpe [5] facilitates the realization of this range of connections: between people, between people and place, between sets of data, and between solutions that reinforce one another. Calthorpe also stated that sustainable urban planning investigates alternative urban futures, evaluates new policies, and assesses their long-term consequences. Successful urban development and the survival of cities depend on a mix of factors, including appropriate land use, new technology, economic investment, and social standards. Unless we plan for the future, what is currently feasible may become outdated tomorrow [5].

2.2. Noise Control Strategies

According to WHO, noise control is multidisciplinary and ensures that people are protected from noise by limiting their exposure to it. Noise management aims to create limits for maximum safe noise exposure levels, as well as to encourage the implementation of noise assessment and control in environmental health programs. Without basic knowledge and background information, it is impossible to develop noise abatement policies. Moreover, the people and the authorities need to be aware that noise is a hazard to the environment and should be controlled [6].

2.3. Noise control Strategies

Noise control strategies are divided into two categories: passive noise control and active noise control. Noise control mechanisms help stop sound spreading. The passive method of noise control reduces transmitted noise, while the active method reduces noise created at its source. Worker exposure to noise is reduced by arranging the site layout so equipment and materials can move freely. Solution: avoid unnecessary noise; isolate noisy activities to designated areas; label designated areas; use hearing protection devices; adequately train employees to avoid equipment misuse and protect themselves.

Active noise control strategies involve exchanging activities that generate noise for quieter ones, such as using concrete mixers instead of concrete vibrators. Controlling noise can also be achieved by using electric lifts instead of cranes, installing impact dampers, performing routine maintenance, and adapting

machinery to reduce overall noise output. Using a walkie-talkie instead of shouting commands saves time and money [7].

To ensure a high level of protection for their citizens, national noise policies should advocate the precautionary principle. Adverse noise effects should be considered in all situations where noise may be hazardous, regardless of whether the noise meets regulatory standards. Educational and public awareness initiatives. Schools should make sure to include the subject of noise in their curricula, and scientific institutes should be established to study the field of acoustics and noise control [6].

2.4. Materials

When it comes to noise control, materials are classified into three; sound-absorbing materials, sound-blocking materials, and materials for vibration isolation and dampening. Sound-absorbing materials are those that dissipate or convert sound energy upon impact. There are a wide variety of natural fibers, allowing the development of material for just about any absorption requirement. Various natural materials, including kenaf, flax, sisal, hemp, cork, sheep wool, bamboo, and coconut fibers, possess strong absorption qualities, so they can be utilized as sound absorbers and noise barriers in the home acoustics and interior noise control [8]. Sound-blocking materials are known as barrier materials while materials for vibration isolation and dampening are those that reduce radiated sound. Silencers, both passive and active, are devices that suppress sound.

Many of the acoustic materials in use today aren't sustainable; in addition, some are bad for people's health. Mineral wool insulation is used frequently because of its good performance and low cost, but it can cause irritation to the skin and has been known to embed in the lung alveoli. Because of this, materials should be covered if exposed directly to the air. This makes their application inappropriate for noise barriers because they cannot stand up to water, oil, and chemical agents. In recent years, green materials have received significant attention, especially in the construction industry. Numerous research facilities have produced novel materials, often with unusual acoustical qualities. Building materials, such as timber, straw, and hemp, are in the process of changing from what was merely seen as a novelty into a mainstream solution [8]. Municipalities in Italy, for example, have included specific recommendations to improve the use of ecological materials in new constructions, allowing for a reduction in construction taxes. A list of materials to avoid is also included in these regulations (e.g. mineral fibers).

The use of passive mediums has been quite common recently to minimize noise. Soundproofing sustainable materials are an alternative to synthetic materials for many projects, with either recycled or natural products working well. These materials are generally more environmentally friendly to produce than conventional materials, but they need to be fully examined using a Life Cycle Assessment. The sound insulation of recycled cellulose fibers is comparable to rock or glass wool, both of which are also natural materials. Bamboo, kenaf, and coco fibers all display excellent sound absorption properties, and cork or recycled rubber layers are very effective at soundproofing against impacts. These materials have also been found to offer a good level of thermal insulation, are often lightweight, and pose no threat to human health. Even more troubling, most of these products are available to consumers at competitive rates. Passive and active noise reduction methods can be categorized in various ways. Passive control, which uses energy absorption to cut down on the radiated noise, is distinct from active control, which includes methods for cutting down on source strength or modulating the acoustic field in the duct to achieve noise reduction. At low frequencies, active noise control is the only choice [9].

Efforts to discover noise control materials and Green Design housing in noisy urban areas have resulted in ongoing studies of green materials. In the study of housing near the airport that was affected by

aircraft noise, middle-class dwellings were the focus [10]. Also, the housings should have absorbers installed on their walls. Some types of wood produce sawdust with unique characteristics. Due to the noise from the airport, residences near the airport are disturbed daily. Some strategies are needed to reduce the amount of noise that residents of these homes are subjected to. Additionally, Setyowati mentioned in previous studies that there is a relationship between the orientation of a house and the noise received by the inhabitants.

2.5. Design Considerations

If sites are deemed at risk of excessive noise, they should be investigated. Local and national land-use guidelines should be consistent with this evaluation. Sources of sound that might still be present at the sites should be identified and analyzed [6]. The outdoor noise from nearby streets, which could contaminate the area, should also be examined.

Buildings should be built to control sound within, making them soundproof. When soundproofing is incorporated into the architectural and engineering design process, outside noise must be prevented from entering the building. For soundproofing in an outdoor environment, both the indoor total noise load and the quality of the internal space should be taken into account. Commercial and residential properties alike need adequate soundproofing against outdoor noise, and interior spaces should be re-evaluated when they are rebuilt or renovated.

Building residences next to a barrier raises the danger of a negative pressure wave and restricts wind flow. Due to the strong noise it emits, the area around the exit/entrance is not appropriate for residential usage. The low cost-effectiveness of their soundproofing is further affected by the increased price of land and construction. The public may also object to the aesthetic impact of the barriers and enclosures; therefore, they are not always acceptable. As crowded regions are difficult to incorporate into rehabilitation efforts, urban adoption can be challenging [11].

Reduction of the number of residential units is an inevitable consequence of such noise control methods as the exchange of buildable land and space. Thus, given the city's heavy traffic, constructing sound barriers, enclosures, setbacks, and longer platforms should be avoided. Due to the scarcity of land, it has been suggested that usage of sound-insensitive structures be employed as noise barriers, in addition to a more meticulous construction of street canyons. However, due to the high density of the built environment, these methods are challenging to apply. For noise reduction, the easiest way is to close the windows of a residential unit. When it comes to windows, even with the use of air conditioning and mechanical ventilation, it is impossible to make use of them due to a lack of natural ventilation. As a whole, double and triple-glazed windows, as well as those with mechanical ventilation, have proved to be effective devices for reducing exterior noise [11]. These types of devices, however, either cannot provide natural ventilation, or they must use energy to do so.

The building design should prioritize noise reduction and provide a pleasant acoustical environment. Reducing reverberation times indoors will be a part of the design. Sound-absorbing materials should be encouraged, and materials with the best sound-absorbing properties should be specified by designers and contractors. The use of these materials should be a supplemental, not primary, solution [12]. It is also important to identify any potential environmental conflicts, including those that are unique to sensitive populations, such as people with allergies.

3. Methods

This study employed a combination of both quantitative and qualitative methods, which was beneficial because it allowed the researchers to identify various research objectives. The study adopted a critical review

of existing literature and close-ended structured questionnaires were administered to a total of 96 designers and 67 users of 2 mixed-use buildings in Lagos state. Questionnaires were analyzed using descriptive statistics, using Statistical Package for the Social Sciences (SPSS) and the outcome was compiled into thematic categories and then offered to the reader using a descriptive approach, aided by a table for enhanced comprehension.

4. Results and Discussion

The table below represents the findings and interpretations from the data analysis conducted in this study. This includes data on the extent to which noise control strategies identified in literature have been applied in practice and how users are impacted by these strategies.

4.1. Existing noise control strategies used in the design of the mixed-use building

Table 1: Designers' variables on the adoption of noise control strategies in the design of mixed-use buildings

Variables	N	Strongly disagree (%)	Disagree (%)	Undecided (%)	Agree (%)	Strongly agree (%)	Mean	Rank
Implementation of "silenced" or muffled equipment	96				74	26	4.26	9th
Location of noisy equipment far from private areas	96				61.5	38.5	4.39	7th
Proper zoning of spaces according to their respective use	96				59.4	40.6	4.41	5th
Window orientation	96				56.3	43.8	4.44	3rd
Use of acoustic actuators to cancel vibration from the sound source	96			1	54.2	44.8	4.44	4th
Use of absorptive material	96				43.8	56.3	4.56	1st
Use of white noise to cancel noise	96	1	8.3	61.5	25	4.2	3.23	11th
Setting noise limits	96			7.3	71.9	20.8	4.14	10th
Implementation of noise control in building components (windows, ceilings, floor, roof)	96				66.7	33.3	4.33	8th
Implementation of land-use planning	96				59.4	40.6	4.41	6th
Orientation of buildings	96				50	50	4.50	2nd

Table 1 represents the identification of existing noise control strategies used in the design of mixed-use buildings. The survey pointed out that the noise control strategies identified in the literature have been adopted in the design of mixed-use buildings in practice. The survey also points out that "use of absorptive materials" is ranked as the highest variable with a mean of 4.56 while "use of white noise to cancel noise" is ranked as the lowest variable. According to the respondents, "orientation of buildings", "window orientation", "use of acoustic actuators to cancel vibration from sound source", and "proper zoning of spaces according to its respective use" were also ranked highly as 2nd, 3rd, 4th, and 5th respectively. This suggests that these highly ranked variables should be put into consideration when designing for noise control particularly in mixed-use buildings. From literature, it was found that as a result of the low cost and high performance of porous materials obtained from synthetic fibers, such as mineral wool and glass wool, they are commonly used for thermal insulation and sound absorption [9]. WHO also reemphasized the need for designers and contractors should specify materials with the best sound-absorbing properties.

Table 2: Frequency of privacy in mixed-use buildings

Mixed-use building		Frequency	Percentage (%)
King's tower, Ikoyi.	Very private	8	29.6
	Private	17	63.0
	Semi-private	1	3.7
	Publicly accessible	1	3.7
	Total	27	100.0
The wings complex, V.I.	Very private	7	17.5
	Private	25	62.5
	Semi-private	5	12.5
	Publicly accessible	1	2.5
	Total	38	95

Table 2 represents the frequency for the privacy of the respondents' space in the mixed-use buildings. The survey induced that in King's tower private spaces are more frequent with a percentage of 63% and in the wings office complex private spaces are more frequent with a percentage of 62.5%. The survey points out that both buildings have predominantly private spaces.

Table 3: Frequency of mood in mixed-use buildings

Mixed-use building		Frequency	Percentage%)
King's tower, Ikoyi.	Yes	2	7.4
	No	25	92.6
	Total	27	100.0
The wings complex, V.I.	Yes	17	42.5
	No	23	57.5
	Total	40	100.0

Table 3 represents the frequency of the mood of the users due to the activities of the commercial sector. The survey showed that in Kings tower 92.6% of users are not affected by the activities in the commercial sector. In the wings complex, however, 57.5% of its users are not affected by the activities in the commercial sector

but 42.5% agree that the activities of the commercial sector affect their moods. The survey points that the users of the Kings tower building are not affected by the commercial sector but the wings office complex still has a fair percentage of users who are affected by the activities of the commercial sector.

Table 4: Comfort in mixed-use buildings

Mixed-use building		Frequency	Percentage (%)
King's tower, Ikoyi.	Yes	26	96.3
	No	1	3.7
	Total	27	100.0
The wings complex, V.I.	Yes	27	67.5
	No	13	32.5
	Total	40	100.0

Table 4 represents the frequency of the comfort of the users due to the activities of the commercial sector. The survey showed that in King's tower, 96.3% of the users agree that noise control strategies implemented in the building have increased physical comfort. The survey also showed that in the wings office complex, 67.5% of the users agree that noise control strategies implemented in the building have increased physical comfort. This suggests that most users have experienced more physical comfort due to the noise control strategies in both buildings.

Table 5: Frequency of sound improvement

Mixed-use building		Frequency	Percentage (%)
Kings tower, Ikoyi.	Yes	27	100.0
	No		
	Total	27	100.0
The wings complex, V.I.	Yes	35	87.5
	No	5	12.5
	Total	40	100.0

Table 5 represents the frequency of improvement in the sound environment in mixed-use buildings. The survey showed that in King's tower, 100% of the users agree that noise control strategies implemented in the building have improved the sound environment. The survey also showed that in the wings office complex, 87.5% of the users agree that noise control strategies implemented in the building have improved the sound environment. This suggests that, when implemented, noise control strategies have a significant impact on the sound environment in mixed-use buildings.

Table 6: Familiarity with noise pollution

Mixed-use building		Frequency	Percentage (%)
King's tower, Ikoyi.	Yes	27	100.0
	No		
	Total	27	100.0
The wings complex, V.I.	Yes	31	77.5
	No	9	22.5
	Total	40	100.0

Table 6 represents the frequency of familiarity of the users of mixed-use buildings with noise pollution. The survey showed that in King's tower, 100% of the users are familiar with the term noise control pollution. The survey also showed that in the wings office complex, 77.5% of the users are familiar with the term noise control pollution. This suggests that the analyzed data is influenced by respondents who understand the term noise control pollution.

Table 7: Frequency of reduced noise pollution

Mixed-use building		Frequency	Percentage (%)
King's tower, Ikoyi.	Yes	27	100.0
	No		
	Total	27	100.0
The wings complex, V.I.	Yes	26	65.0
	No	14	35.0
	Total	40	100.0

Table 7 represents the frequency of reduced noise pollution due to existing noise control strategies. The survey showed that in King's tower, 100% of the users agree that noise control strategies have reduced noise pollution in the building. The survey also showed that in the wings office complex, 65% of the users agree that noise control strategies have reduced noise pollution in the building. This suggests that noise control strategies are responsible for the reduction in noise pollution in mixed-use buildings.

Table 8: Frequency of impact of vibration

Mixed-use building		Frequency	Percentage (%)
Kings tower, Ikoyi.	Yes	2	7.4
	No	25	92.6
	Total	27	100.0
The wings complex, V.I.	Yes	40.0	40.0
	No	60.0	60.0
	Total	40	100.0

Table 8 represents the frequency of the impact of vibration from heavy machinery on the users. The survey showed that in King's tower, 92.6% of the respondents are not impacted by the vibration from heavy machinery. The survey also showed that in the wings office complex, 60% of the respondents are not impacted by the vibration from heavy machinery in the building. This suggests that the majority of the respondents do not feel the impact of vibration from heavy machinery in mixed-use buildings.

Table 9: Frequency of hearing problems

Mixed-use building		Frequency	Percentage (%)
King's tower, Ikoyi.	Yes	1	3.7
	No	26	96.3
	Total	27	100.0
The wings complex, V.I.	Yes	13	32.5
	No	27	67.5
	Total	40	100.0

Table 9 represents the frequency of hearing problems due to unwanted noise while in the building. The survey showed that in King's tower, 96.3% of the respondents do not experience hearing problems due to unwanted noise in the building. The survey also showed that in the wings office complex, 67.5% of the respondents do not experience hearing problems due to unwanted noise in the building. This suggests that the majority of the respondents do not feel they experience any hearing problems as a result of unwanted noise in mixed-use buildings.

Table 10: Frequency of undisturbed communication

Mixed-use building		Frequency	Percentage (%)
King's tower, Ikoyi.	Yes	27	100.0
	No		
	Total	27	100.0
The wings complex, V.I.	Yes	26	65.0
	No	14	35.0
	Total	40	100.0

Table 10 represents the frequency of undisturbed communication while in mixed-use buildings. The survey showed that in King's tower, 100% of the respondents agree that noise control strategies improve undisturbed communication while in the building. The survey also showed that in the wings office complex, 65% of the respondents agree that noise control strategies improve undisturbed communication while in the building. This suggests that the majority of the respondents agree that noise control strategies positively impact undisturbed communication in mixed-use buildings.

From literature, it is evident that acoustic performance is an important aspect of sustainable urban planning. The results from the tables above show how noise control strategies implemented by designers have been able to impact the users of the mixed-use buildings which were examined. A number of factors derived from literature were used as the basis of this investigation.

5. Conclusion

Evidently, despite substantial noise generation in Nigerian cities, the type and size of noise-producing activities, their impacts on urban communities and inhabitants are rarely investigated and documented. Both the Nigerian local and federal governments must take action to address the primary causes of noise pollution in the metropolitan areas of Nigeria to achieve sustainable urban planning. However, the results from this research show that designers are aware of noise control strategies and have put these strategies into consideration in the design of mixed-use buildings. This study shows the importance of absorption, especially amongst other noise control strategies. The reviewed works of literature also emphasize the need for absorption with noise isolation in mind. Several measures can be taken to utilize noise control strategies to ensure that sustainability is achieved in urban planning. The authors recommend that designers should conduct in-depth research on noise control strategies and ensure that it is implemented in design with consideration of materials particularly.

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