International Journal of Multidisciplinary Research and Growth Evaluation.

Influence of topography on the integration of biophilic design strategies in mixed-use buildings: A case study of Lagos State

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Article Info

ISSN (online): 2582-7138
Volume: 05
Issue: 04
July-August 2024
Received: 15-06-2024
Accepted: 21-07-2024
Page No: 1023-1028

Abstract

The integration of biophilic design strategies within urban mixed-use buildings is increasingly recognized for enhancing human-nature connections and promoting environmental sustainability. This study investigates how topographical factors—specifically elevation, slope, natural landforms, vegetation patterns, solar exposure, and wind patterns—affect the effectiveness of biophilic design in mixed-use buildings in Lagos State, Nigeria. Mixed-use buildings, which combine residential, commercial, and recreational spaces, present unique challenges and opportunities for biophilic integration. Despite the known benefits of biophilic design, the influence of Lagos' varied topography on such strategies has been underexplored. To address this gap, the study employs a quantitative approach, utilizing structured surveys and questionnaires distributed to stakeholders involved in mixed-use developments across Lagos. The research focuses on how elevation and slope impact natural light access and terraced landscaping, how natural landforms influence aesthetic and functional design, and how existing vegetation patterns affect green spaces. A total of 103 questionnaires were distributed, with 71 responses analyzed using statistical methods, including mean intervals and the relative significance index. The results reveal that elevation and slope play a critical role in enhancing biophilic elements, with Case Study I (King Tower, Ikoyi) demonstrating more effective utilization of these features compared to Case Study II (Nestoil Tower, Victoria Island). Additionally, natural landforms and vegetation patterns were better integrated in Case Study I, leading to higher effectiveness in preserving biodiversity and enhancing design quality. In contrast, Case Study II showed less effective integration, impacting the overall biophilic quality. The study also highlights the substantial influence of topographical factors on biophilic design strategies in mixed-use buildings. Recommendations include adapting designs to leverage specific site features such as elevation and slope, integrating terraced landscaping, and incorporating natural water management systems. Future research should explore the long-term impacts of these design strategies on building performance and user satisfaction, aiming for more sustainable and contextually responsive architectural solutions.

Keywords: Biophilic design, topography, mixed-use buildings and lagos state

1. Introduction

The integration of biophilic design strategies in architecture has gained numerous considerations as a means of enhancing the connection between urban environments and nature, promoting well-being, sustainability, and ecological balance. According to Wolfs (2015) [11], the integration of biophilic design into built environments, shows potential as a sustainable design strategy that enhances human health and well-being, but further exploration is needed for industrial applications. In mixed-use buildings, where diverse functions such as residential, commercial, and recreational activities converge, the role of biophilic design becomes increasingly significant. These structures integrate residential, commercial, and recreational facilities into a single, cohesive complex, often under the ownership of a single developer. Mixed-use buildings can also be described as multi-functional structures composed of several interconnected building masses with different uses (Lubis *et al*., 2021) [9].

According to the International Building Code and The Building Construction and Safety Code, a mixed-use building is defined as a structure that contains two or more distinct occupancies, each with unique uses and characteristics. In Nigeria, factors such as urban requirements, regulatory constraints, and a growing economy are driving the rise of mixed-use developments as a vital solution to the challenges of urbanization. These buildings, which combine multiple functions and focus on energy efficiency, address human needs and enhance comfort in urban (Mansi *et al*., 2021) [10]. These biophilic designs shows the human-nature interaction in the built environment which improve productivity, emotional, physical, and mental health, at various scales (Dalay & Aytaç, 2022) [3]. In Nigeria, the influence of topography in the integration of these biophilic design is not been properly address. Topography which is the study of an area's slope or contour and geological formation of an area is very crucial in the integration of biophilic design in building. Surface topography attributes, such as feature dimensions, geometry, and stiffness, affect the settlement and adhesion of natural and synthetic particles, influencing biophilic design in architecture (Erramilli & Genzer, 2019) [5]. These topography aspects include the influence of slope and elevation, natural landforms such as hills, valleys, and bodies of water, solar exposure and wind patterns, and access and circulation pattern which include the design pathways, trails, and entry points in building. These elements of topography are important when designing mixed used building. This study focuses on assessing how topography influences the integration of biophilic design strategies in mixed-use buildings within Lagos State, Nigeria. The research aims to evaluate the impact of elevation and slope on the effectiveness of biophilic elements, the role of natural landforms in shaping design, and the influence of existing vegetation patterns on green spaces. Additionally, it explores how topographical features affect sustainable water management systems, solar exposure, wind patterns, and circulation design within these developments. By examining these aspects, the study seeks to propose solutions and recommendations for optimizing biophilic design integration in mixed-use buildings, considering Lagos State's unique terrain and extending insights to other urban environments globally.

2.0 Literature Review

2.1 Relationship between mixed use building and it built environment

A mixed-use building refers to an urban development concept that integrates multiple functions or land uses within a single structure or complex. These buildings often combine residential, commercial, office, retail, recreational, or institutional spaces within one development. Mixed-use developments blend residential, commercial, and cultural uses into a unified space (Han *et al*., 2021) [6]. They serve more than one purpose, catering to at least two distinct user groups who benefit from each other's presence (Bradecki, 2019) [2]. The design of mixed-use buildings integrates various functions within one structure, considering the needs of the area, the surrounding environment, and building users while incorporating energy efficiency principles (Lubis *et al*., 2021) [9]. Such developments are crucial for promoting a sustainable and high-quality urban lifestyle, reducing the need for automotive travel, shortening commute times, offering smaller living units, enhancing walkability, and fostering a stronger sense of community (Driskill & Elliott, 2020) [4]. In upper-middle-class residential zones, mixed-use developments can improve the quality of life and help transform cities into creative hubs (Arbab, 2021). The design of mixed-use buildings prioritizes the needs of the area, the environment, and users, aiming to meet human needs and enhance comfort (Lubis *et al*., 2021) [9].

2.2 Relationship between Biophilic design and Mixed-Use Building

Biophilic design and mixed-use buildings share a symbiotic relationship, as both concepts emphasize creating environments that enhance the well-being of occupants while promoting sustainability. Biophilic design, which seeks to integrate natural elements and principles into architectural spaces, complements the multifunctional nature of mixed-use buildings by fostering a connection between people and nature within densely built urban environments. In mixed-use developments, where diverse activities such as living, working, and recreation are combined within a single complex, the inclusion of biophilic elements like natural light, greenery, water features, and natural materials can significantly enhance the quality of life (Arof *et al*., 2020) [1]. These elements not only provide aesthetic value but also contribute to the psychological and physiological well-being of occupants, making the spaces more inviting and comfortable. The integration of biophilic design in mixed-use buildings also supports sustainability goals by improving energy efficiency, enhancing air quality, and reducing the environmental impact of urban development (Lee & Park, 2022) [8]. For example, green roofs, vertical gardens, and natural ventilation systems in mixed-use buildings can reduce energy consumption and promote biodiversity, aligning with the sustainability objectives often associated with such developments. Additionally, the presence of natural elements within these buildings encourages social interaction and a sense of community, which are essential components of successful mixed-use environments. By harmonizing biophilic design with mixed-use building strategies, architects and planners can create urban spaces that are not only functional and efficient but also deeply connected to the natural world, ultimately leading to healthier, more sustainable urban communities.

2.3 Relationship between topography and Biophilic Design in Building

The topography of Lagos State which is predominantly characterized by its coastal and low-lying terrain, with much of the area sitting just a few meters above sea level. The state features a mix of lagoons, creeks, and islands, contributing to its unique landscape (Isiaka *et al*., 2023) [7]. Topography which is a major factor in shaping the application of biophilic design in buildings, as it directly influences how natural elements are integrated into the built environment. The unique characteristics of a site’s topography, such as elevation, slope, and natural landforms, can guide the placement and orientation of buildings, allowing for the strategic incorporation of natural light, ventilation, and views of the surrounding landscape. Building located on a hillside can take advantage of the slope to create terraced gardens or stepped green spaces that blend seamlessly with the natural terrain. These design strategies not only enhance the aesthetic appeal of the building but also strengthen the connection between occupants and the natural environment, a core principle of biophilic design. Moreover, topography can influence the selection and design of biophilic elements such as water features, vegetation, and pathways within a building or site. Natural drainage patterns dictated by the terrain can be harnessed to create sustainable water management systems, like rain gardens or bioswales, that mimic natural hydrological processes and enhance the biophilic experience. Similarly, the existing vegetation and landforms can be preserved and integrated into the design, creating a harmonious relationship between the building and its environment (Yin *et al*., 2019) [12]. This approach not only supports biodiversity but also fosters a sense of place, grounding the building in its natural context. By thoughtfully considering topography in the design process, architects and planners can create buildings that not only respect and respond to their natural surroundings but also promote the health and well-being of their occupants through biophilic design principles.

3.0 Research Methodology

The study adopts a quantitative methodology to assess the influence of topography on the integration of biophilic design strategies in mixed-use buildings in Lagos State. Structured surveys were employed using distributed questionnaires as the primary research technique. The study relies on responses from the questionnaires as the main data source. The study area focuses on mixed-use buildings across Lagos State, with the questionnaires divided into several sections. Section A gathers demographic information of the respondents, such as age and sex. Section B assesses respondents' knowledge on how Lagos' topography influences the placement and effectiveness of biophilic elements in mixed-use buildings. Section C collects data on the integration of natural landforms, vegetation patterns, and their impact on biophilic design effectiveness, while Section D evaluates the overall impact of biophilic design on user satisfaction in relation to topographical features. A total of 103 questionnaires were distributed, with 71 collected. Statistical analyses, including the calculation of mean intervals (from Strongly Ineffective to Highly Effective) and relative significance index, were employed to analyze the responses and determine key findings based on the study's objectives.

3.1 Case Study 1: Nestoil Tower, Victoria Island Lagos State.

Nestoil tower is a fifteen-storey building located in Victoria Island Lagos, Nigeria, it was completed in the year 2016 and is owned by Nestoil Ltd, an indigenous Nigeria Oil and Gas Company. The tower has a total floor space of 21,000 square meter and is one of the tallest buildings in Lagos, it is an energy conserved building and has been awarded Leadership in energy and environment design (LEED) gold certificate. For its sustainable design feature, the tower has modern design with a glass façade and an open plan interior layout. It also has won several awards for it architectural design.

Fig 1: Nestoil Tower (source: Juliusberger.com)

3.2 Case Study II: Kings Tower, Ikoyi, Lagos State

Kings Tower is a 22-story mixed-use building located in Ikoyi, Lagos, Nigeria. Originally known as the Union Bank Building, it was constructed in 1979. Positioned on Alfred Rewane Road, one of Lagos' busiest thoroughfares, the tower is a notable landmark, offering expansive views of the Lagos skyline and Lagos Lagoon. With a total floor space of 38,000 square meters, the building accommodates offices, retail spaces, and parking facilities. It serves as the headquarters for several prominent companies, including Deloitte, Standard Chartered Bank, and Eco Bank. The building underwent extensive renovations in 2017, which included upgrades to the façade, common areas, and elevators, as well as the addition of new amenities such as recreational facilities. The architectural merits of Kings Tower include an efficient lighting system, Sample natural light, proper building insulation, enhanced energy-efficient heating, ventilation, and air conditioning (HVAC) systems, and effective water conservation measures.

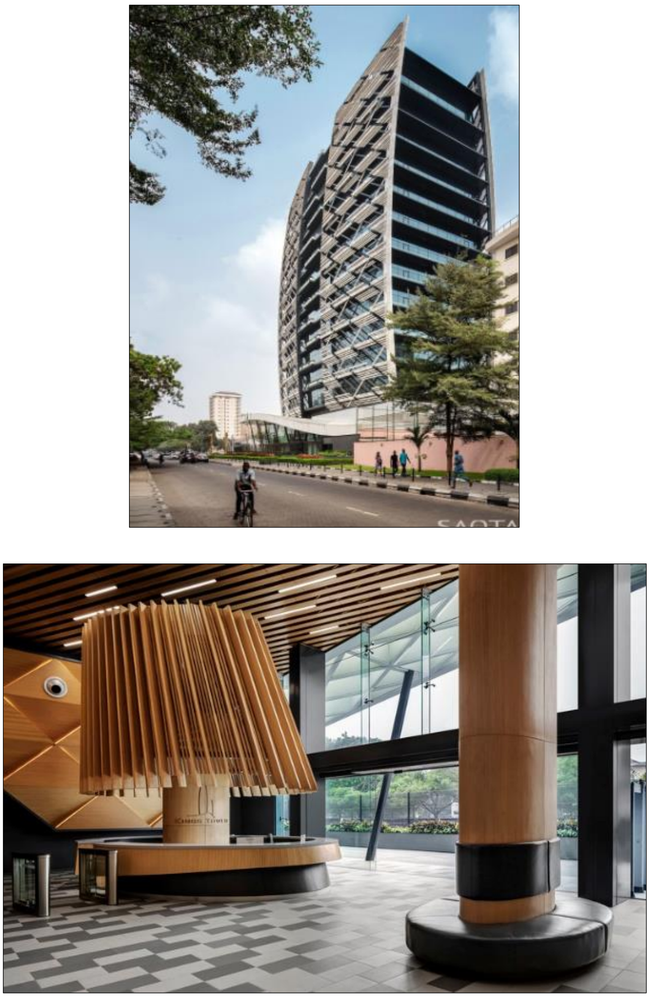

Fig 2: Kings tower exterior and interior (Source: Kingtower.ng)

4.0 Study Finding

Table 1: Influence of Elevation on Natural Light Access and Slope on Terraced Landscaping Integration

SN	Evaluation Criteria	Case Study I: King Tower, Ikoyi	Case Study II: Nestoil Tower, Victoria Island
		Mean Interval	Mean Interval
i	Influence of elevation on natural light access	4.15 (Effective)	3.65 (Neutral)
ii	Influence of slope on terraced landscaping integration	4.05 (Great Extent)	3.25 (Moderate Extent)

The analysis of the effectiveness of elevation and slope in influencing biophilic elements within the case studies reveals variations between the two buildings. In Case Study I (King Tower, Ikoyi), the elevation shows a strong influence on natural light access with a mean interval of 4.15, categorized as "Effective." This suggests that the elevation is well-utilized to optimize natural lighting within the building. Case Study II (Nestoil Tower, Victoria Island) shows a more neutral influence, with a mean interval of 3.65, indicating that natural light access is moderately affected by the elevation. Regarding the slope's impact on terraced landscaping integration, Case Study I demonstrates a greater extent of effectiveness with a mean interval of 4.05, categorized as "Great Extent." This highlights the effective use of sloped terrain in enhancing terraced landscaping. On the other hand, Case Study II exhibits a more moderate extent of integration, with a mean interval of 3.25.

Table 2: Incorporation and Significance of Natural Landforms in Biophilic Design

SN	Evaluation Criteria	Case Study I: King Tower, Ikoyi	Case Study II: Nestoil Tower, Victoria Island
		Mean Interval	Mean Interval
i	Incorporation of natural landforms in building design	3.85 (Well)	3.45 (Neutral)
ii	Significance of natural landforms in enhancing biophilic design	4.30 (Significant)	3.80 (Neutral)

The analysis of natural landforms in biophilic design reveals that Case Study I (King Tower, Ikoyi) incorporate natural landforms well into its design, with a mean interval of 3.85, while Case Study II (Nestoil Tower, Victoria Island) has a neutral incorporation with a mean interval of 3.45. In terms of the significance of natural landforms in enhancing the building's biophilic design, Case Study I ranks higher, with a mean interval of 4.30, indicating a significant impact. Case Study II shows a more neutral impact, with a mean interval of 3.80.

Table 3: Preservation and integration of existing vegetation patterns in green spaces

SN	Evaluation Criteria	Case Study I: King Tower, Ikoyi	Case Study II: Nestoil Tower, Victoria Island
		Mean Interval	Mean Interval
i	Preservation and integration of existing vegetation	4.20 (Effective)	3.50 (Neutral)
ii	Contribution of green spaces to preserving native biodiversity	4.05 (Great Extent)	3.65 (Moderate Extent)

The effectiveness of existing vegetation preservation and integration into green spaces is more pronounced in Case Study I (King Tower, Ikoyi) with a mean interval of 4.20, categorized as "Effective." Case Study II (Nestoil Tower, Victoria Island) shows a neutral effectiveness with a mean interval of 3.50. Regarding the contribution of green spaces to preserving native biodiversity, Case Study I ranks higher, with a mean interval of 4.05, while Case Study II has a more moderate contribution, with a mean interval of 3.65.

Table 4: Facilitation of Sustainable Water Management Systems by Topography

SN	Evaluation Criteria	Case Study I: King Tower, Ikoyi	Case Study II: Nestoil Tower, Victoria Island
		Mean Interval	Mean Interval
i	Topography's facilitation of sustainable water management	4.25 (Well)	3.70 (Neutral)
ii	Effectiveness of water management systems in handling drainage	4.10 (Effective)	3.45 (Neutral)

The analysis of how topographical features affect water drainage and hydrology indicates that Case Study I (King Tower, Ikoyi) facilitate sustainable water management well, with a mean interval of 4.25, while Case Study II (Nestoil Tower, Victoria Island) shows neutral facilitation, with a mean interval of 3.70. The effectiveness of water management systems in handling natural water flow and drainage challenges is rated as "Effective" in Case Study I, with a mean interval of 4.10. In contrast, Case Study II has a neutral rating, with a mean interval of 3.45.

Table 5: Influence of Topography on Solar Exposure and Wind Patterns

SN	Evaluation Criteria	Case Study I: King Tower, Ikoyi	Case Study II: Nestoil Tower, Victoria Island
		Mean Interval	Mean Interval
i	Topography's influence on window and courtyard orientation	4.30 (Great Extent)	3.85 (Moderate Extent)
ii	Consideration of coastal wind patterns in natural ventilation	4.15 (Effective)	3.55 (Neutral)

Table 6: Alignment of Pathways and Circulation with Natural Contours

	Evaluation Criteria	Case Study I: King Tower, Ikoyi	Case Study II: Nestoil Tower, Victoria Island
		Mean Interval	Mean Interval
i	Alignment of pathways with natural contours	4.25 (Well)	3.60 (Neutral)
ii	Terrain's enhancement of user experience in access and circulation	4.00 (Great Extent)	3.55 (Moderate Extent)

The analysis of site terrain's influence on access and circulation reveals that in Case Study I (King Tower, Ikoyi), the building's pathways and circulation routes align well with the natural contours of the site, with a mean interval of 4.25. In Case Study II (Nestoil Tower, Victoria Island), the alignment is rated as neutral, with a mean interval of 3.60. Regarding the terrain's enhancement of the user experience in terms of access and circulation, Case Study I exhibits a greater extent of enhancement, with a mean interval of 4.00, while Case Study II shows a more moderate extent, with a mean interval of 3.55.

4.1 Discussion of Study Finding

The analysis of the impact of elevation and slope on the effectiveness of biophilic elements within mixed-use buildings in Lagos shows a difference between the two case studies. Case Study I (King Tower, Ikoyi) demonstrate a stronger influence of elevation on natural light access and slope on terraced landscaping integration compared to Case Study II (Nestoil Tower, Victoria Island). The higher mean intervals for elevation and slope in Case Study I suggest a more effective utilization of these site features to enhance natural light and integrate terraced landscaping, which contributes to a more responsive and biophilic design approach. In contrast, Case Study II shows moderate to neutral impacts, indicating a less pronounced incorporation of these elements, which could affect the overall biophilic quality of the design. Similarly, the role of natural landforms and existing vegetation patterns in shaping biophilic design is more pronounced in Case Study I. The incorporation and significance of natural landforms in Case Study I are rated higher, reflecting a greater emphasis on integrating these features into the building design, thereby enhancing aesthetic and functional aspects. Case Study I also demonstrates more effective preservation and integration of existing vegetation, contributing significantly to native biodiversity. In contrast, Case Study II's lower mean intervals for these criteria suggest less effective integration and preservation, potentially impacting the biophilic benefits of the building. This analysis underscores the importance of leveraging site-specific features and natural elements to achieve a more effective and sustainable biophilic design in mixed-use developments.

5. Conclusion

In conclusion, the evaluation of topographical influences on biophilic design strategies within mixed-use buildings in Lagos reveals significant insights into how site characteristics shape the effectiveness of these design elements. The analysis indicates that elevation, slope, natural landforms, and existing vegetation patterns substantially impact the integration and functionality of biophilic features, enhancing both aesthetic appeal and environmental sustainability. Case Study I (King Tower, Ikoyi) demonstrates more effective utilization of these topographical elements compared to Case Study II (Nestoil Tower, Victoria Island), reflecting a deeper alignment with the natural context of the site. Recommendations for future mixed-use developments in Lagos include a greater emphasis on adapting building designs to the specific topographical features of the site, such as optimizing natural light access through elevation and integrating terraced landscaping according to slope. Additionally, preserving and incorporating existing vegetation and considering natural water management systems can further enhance the biophilic quality of the buildings. Future research could focus on longitudinal studies to assess the long-term benefits of these biophilic design strategies on building performance, user satisfaction, and environmental impact, thereby contributing to more sustainable and contextually responsive architectural practices.

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