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OPTIMIZING ARCHITECTURAL STRATEGIES FOR CROWD MANAGEMENT IN MULTI-LEVEL SPORTS FACILITIES, LAGOS

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Abstract
As urban environments grow denser and available land becomes increasingly limited, vertical sports complexes have emerged as innovative solutions to meet the rising demand for recreational facilities in compact cities. However, the vertical arrangement of these complexes introduces significant challenges related to crowd control, circulation efficiency, and emergency management. This study explores design strategies that enhance crowd management within vertical sports complexes, focusing on Victoria Island in Lagos, Nigeria, as a case study. Through comprehensive analysis of spatial planning, architectural zoning, and human movement patterns, the research identifies critical principles that promote safety, functionality, and user comfort in high-density environments. Key strategies examined include vertical zoning, modular circulation cores, intuitive wayfinding systems, and the incorporation of smart technologies for real-time crowd monitoring. The study offers a design-focused perspective, providing practical insights and recommendations for architects, urban planners, and facility managers involved in the development of future-proof, crowd-efficient vertical sports facilities in rapidly urbanizing cities.

Keywords: *Crowd Control, Sports facility, Design strategy*

INTRODUCTION

The rapid urbanization of Lagos State, particularly in dense districts such as Victoria Island, has placed immense pressure on existing infrastructure, including recreational and sports facilities. With an estimated population of 16.5 million within a land area of just 1,171.28 km^2, Lagos is Nigeria's most densely populated metropolis (MacroTrends, 2024). The scarcity of buildable land, rising property values, and increasing demand for urban amenities have catalysed a transition from horizontal sprawl to vertical development. This shift is not only transforming the city's residential and commercial landscapes but is also reshaping how public and recreational facilities are conceived and delivered.

In this context, vertical sports complexes present an innovative architectural solution to the dual challenge of space scarcity and growing recreational needs. These multi-level facilities stack sports arenas, courts, training zones, and auxiliary services within a compact footprint maximizing land use and integrating seamlessly into constrained urban plots. However, the spatial efficiency gained through verticality introduces a new design imperative: how to effectively control and manage crowds within stacked circulation systems.

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To ensure safety, comfort, and operational efficiency, architects must adopt multi-layered design strategies that go beyond basic code compliance. These include:

- **Vertical Zoning:** Functionally segregating floors based on usage intensity to distribute crowd pressure.
- **Redundant Circulation Cores:** Incorporating multiple egress routes (stairs, lifts, ramps) to reduce bottlenecks.
- **Smart Wayfinding Systems:** Integrating visual, auditory, and digital guidance systems to support user orientation.
- **Behavioural Flow Design:** Strategically sizing and sequencing circulation paths based on user behaviour modelling.
- **Real-Time Monitoring:** Embedding sensor-based crowd analytics and surveillance to anticipate and respond to movement surges.

Victoria Island, with its premium land value, mixed-use density, and limited recreational infrastructure, represents a critical testbed for these principles. Field observations show that existing public sports facilities, such as Onikan Stadium (3.2 km away) and Oworonshoki Youth Sports Centre (11 km), are either inaccessible or inadequate for the area's growing population (Author's Fieldwork, 2024). This underscores the urgency of implementing a purpose-built vertical sports complex that not only fills the recreational gap but sets a benchmark for crowd-safe urban design.

This journal investigates the design strategies essential for crowd control in vertical sports complexes, using Victoria Island as a case study. By analysing international precedents and aligning them with Lagos' spatial, social, and infrastructural realities, the study proposes a set of architectural interventions tailored to dense, vertical environments.

LITERATURE REVIEW

As urban populations grow and land availability shrinks, the architecture of sports facilities is undergoing a significant transformation. The emergence of vertical sports complexes reflects a broader trend in urban design that seeks to optimize space, increase accessibility, and integrate multifunctional uses within dense cityscapes. This literature review explores existing scholarly discourse on vertical sports infrastructure, compact urban design, crowd control dynamics, and the integration of adaptive technologies for safe and efficient movement in multi-level sports environments.

1. Urban Space Constraints and the Rise of Verticality

Contemporary urban centres such as Lagos face immense pressure to provide functional public infrastructure amid rapid densifications. Scholars like Umezinwa et al. (2024) argue that vertical infrastructure is no longer a luxury but a necessity for sustaining public services, including sports and recreation. Their research emphasizes that vertical sports facilities offer a viable alternative to land-intensive horizontal complexes by stacking functions, such as training, competition, and leisure, across multiple floors.

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Case studies such as the Jianshang Sports Complex in China (CCDI, 2022) and the Vertical Gymnasium in Caracas demonstrate the success of vertical design in addressing spatial scarcity. These facilities integrate vertical zoning and modular design strategies that enhance both spatial efficiency and user experience. However, while such projects are well documented in Asian and South American contexts, literature remains sparse regarding their applicability and performance in African urban environments, particularly in relation to crowd movement and safety**.**

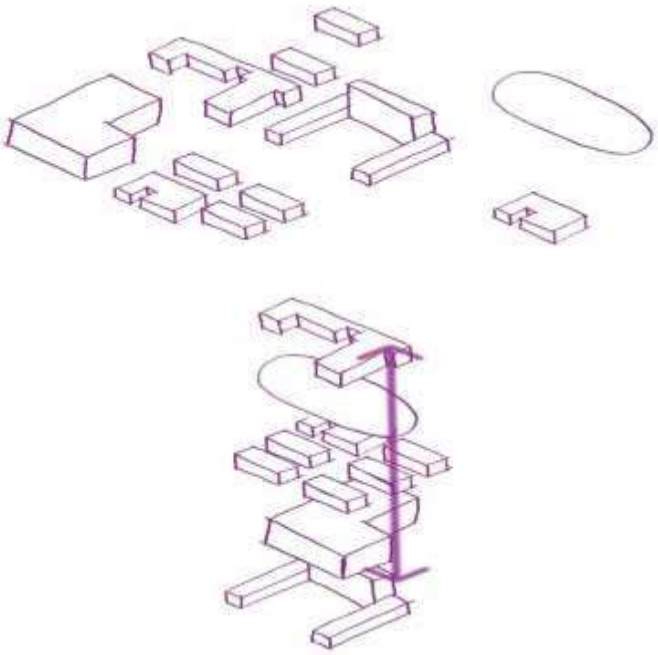

Figure: Horizontal Configuration to a Vertical Configuration Source: (Swinburn & Hadley, 2017)

2. Crowd Control in Multi-Level Facilities

Crowd control refers to the strategic design and management of spaces to facilitate the safe, efficient, and predictable movement of people especially under high-density or emergency conditions (Still, 2014). In vertical environments, this becomes particularly complex due to constrained circulation cores (e.g., stairwells, lifts, escalators) and the psychological stress induced by elevation and confinement (Chertoff et al., 2017).

Researchers like Kuligowski (2016) emphasize that emergency evacuation in vertical buildings demands redundant egress strategies, intuitive signage, and synchronized crowd control systems. Similarly, Dober (2000) notes that in sports environments, where user density and emotional energy are high, design must accommodate sudden surges of movement while maintaining comfort and safety. However, most studies focus on office towers and malls, not **sports facilities**, which host thousands of users with varied circulation behaviors during short timeframes.

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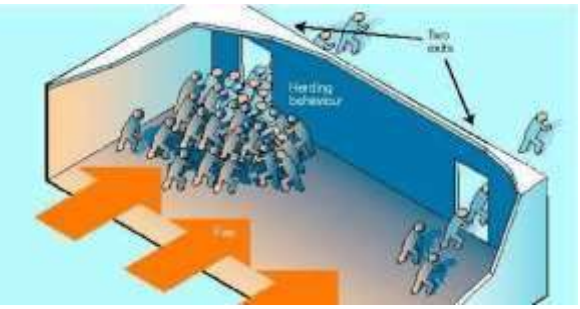

Figure: Crowd trying to escape from smoke-filled room Source: (Almeida et al., 2013).

3. Architectural Design Strategies for Vertical Circulation

Design strategies play a crucial role in optimizing crowd control. Kolarevic and Parlac (2015) introduce the concept of **building dynamics**, suggesting that spaces must be designed to respond to changing occupancy levels and circulation pressures. Features such as flexible stair cores, dual-function corridors, atrium visibility, and distributed entry/exit nodes can significantly improve movement efficiency.

Moreover, **vertical zoning** the deliberate distribution of functions by level (e.g., lower floors for public use, upper floors for athletes and staff) has been proven effective in separating circulation flows and reducing bottlenecks (Umezinwa et al., 2024). Studies also highlight the importance of modular planning, where circulation elements are repeated in scalable units across floors, facilitating ease of use and wayfinding.

4. Integration of Smart Technology and Behavioural Design

Recent advancements in smart technologies have introduced new tools for real-time crowd monitoring and control. IoT sensors, CCTV analytics, AI-driven simulation, and mobile wayfinding apps can be integrated into vertical sports complexes to manage crowd density, direct flow, and trigger alerts in case of emergencies (Watson & Adams, 2011).

From a behavioural perspective, Fruin's Levels of Service (LOS) model and Still's crowd dynamics theory underscore the need to anticipate user psychology and group behaviour. Architectural cues such as lighting, signage, and colour can guide users intuitively, minimizing confusion and congestion during high-traffic events (Chertoff et al., 2017).

5. Gaps in Existing Literature

While international case studies provide valuable insights, there is a noticeable lack of contextual literature addressing crowd control in vertical sports complexes within African cities. The uniqueness of Lagos its urban intensity, informal transport systems, infrastructural deficits, and socio-cultural crowd behaviours demands a tailored design approach. Moreover, current Nigerian building regulations have yet to fully incorporate design codes for vertical recreational facilities, leaving architects and planners without a comprehensive framework for implementation.

This gap underscores the need for localized research into how **design strategies** can be adapted to the African urban environment, ensuring both efficiency and safety in future sports development.

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DEFINITION OF TERMS

Crowd Control refers to the activities required to direct and regulate people who are at or may assemble at a disaster site so that they do not interfere with emergency operations. "Designate" refers to a person who has been officially allocated responsibility and authority for a role that was previously performed by another person. (Law Insider Dictionary, 2022).

Sport Facility refers to the enclosed areas of sports pavilions, stadiums, gymnasiums, health spas, boxing arenas, swimming pools, roller and ice rinks, billiard halls, bowling alleys, and other similar places where the public gathers to engage in physical activity, compete in athletic competition, or watch sporting events (Law Insider Dictionary, 2022).

Design Strategy refers to the confluence between business strategy and design thinking (Jahan Hussain, 2010). It is the intersection of what is important to people and what is profitable for organizations (Ed Orozco, 2020).

THE STUDY AREA

Victoria Island (VI), located beside Lagos Island, Ikoyi, and the Lekki Peninsula within the Eti-Osa LGA, is a densely built-up district marked by high-rise buildings and intense urban activity. As Lagos faces rapid urbanization and limited land availability, traditional horizontal sports facilities have become impractical. In VI, this scarcity, combined with heavy traffic and limited access routes, highlights the need for vertical sports complexes with efficient crowd control strategies.

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Figure: Map of Nigeria, Lagos State Showing Study Area Source: https://fluswikien.hfwu.de?index.php?title=file:LAGOS_STATE_MAP

Figure: Map of Eti osa Local Government Area Showing Study Area, Victoria Island Source: https://www.mdpi.com/2504-3900/2/22/1398

Figure: Map of Victoria Island (Amadu Bello way axis), showing the proposed site Source: Google Earth pro

METHODOLOGY

This research adopts a qualitative case study approach to investigate design strategies for efficient crowd control in vertical sports complexes, with Victoria Island, Lagos serving as the contextual focus. The methodology integrates case analysis, spatial mapping, and literature synthesis to derive context-specific insights relevant to dense urban environments. A descriptive and exploratory research design was employed to examine the dynamics of crowd control and vertical circulation in sports complexes, enabling a detailed investigation of spatial arrangements, circulation logic, and design interventions that enhance user flow and emergency response in high-rise recreational facilities. Data collection methods included site analysis, architectural plan reviews, and a comprehensive literature review. Victoria Island was chosen due to its high-density urban profile, limited land availability, and increasing demand for mixed-use development. Site visits and visual assessments were conducted to observe existing land use patterns, vertical development trends, and pedestrian behaviour in multi-level facilities. Architectural plans of both

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local and international vertical sports complexes were reviewed to evaluate zoning layouts, core design elements such as stairs, lifts, and ramps, access points, and internal circulation strategies. Additionally, secondary data was gathered through an extensive review of academic literature, architectural reports, planning documents, and building codes relevant to vertical sports architecture and crowd management. Influential studies, including those by Umezinwa et al. (2024), CCDI (2022), and local Lagos planning authorities, helped shape the conceptual framework and grounded the analysis within both global and regional best practices.

DATA ANALYSIS

This section presents an in-depth analysis of crowd control strategies utilized in selected vertical and hybrid sports complexes. Drawing insights from case studies across different urban contexts, the analysis identifies and synthesizes key design approaches that successfully manage large-scale pedestrian movement in vertical sports environments. The findings inform crowd control solutions suitable for the proposed vertical sports complex in Victoria Island, Lagos State, a high-density urban zone with significant space constraints.

Key Design Strategies for Crowd Control

Effective crowd control in vertical sports complexes relies on a holistic blend of spatial planning, circulation design, and safety systems. Zoning and functional segregation are foundational allocating high-traffic sports (e.g., basketball or swimming) to lower floors and lighter, specialized activities to upper levels helps balance user load and ease movement. Case studies like Vertical Gym Caracas and Jianshang Sports Complex demonstrate how layered zoning reduces cross-flow conflicts. Providing multiple entry and exit points strategically placed on different sides or levels of the building allows users to access designated zones without bottlenecks, particularly during peak periods or emergencies. Vertical staggering of crowd-heavy programs minimizes elevator/stair usage and expedites evacuation, while segregated circulation systems for athletes, spectators, and staff streamline internal traffic. Integration of buffer zones such as lobbies, terraces, and foyers between major functional areas serves to decompress crowd pressure, especially between games or sessions. Emergency safety is enhanced with wide, clearly marked staircases, dual egress routes, fire-rated cores, and integrated smoke evacuation systems compliant with international standards. Lastly, intuitive wayfinding using multilingual signage, digital directories, color-coded floor markings, and visual cues enhances navigation and reduces confusion. These strategies, adapted for a dense urban setting like Victoria Island, Lagos, ensure safe, efficient, and user-friendly movement across all levels of a vertical sports facility.

FINDINGS AND DISCUSSION

This study explored design strategies for efficient crowd control in vertical sports complexes, with specific attention to how such strategies apply within the dense urban environment of Victoria Island, Lagos. The findings revealed a series of key spatial and architectural solutions necessary for safe, fluid, and responsive user circulation in multi-level sports infrastructure.

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1. Functional Zoning Enhances User Flow

One significant finding is the importance of vertical functional zoning, where distinct floors are designated for different user groups, athletes, spectators, officials, and support services. This spatial segregation reduces unnecessary user overlap, minimizing congestion and potential conflict points. In particular, the use of dedicated vertical circulation routes—such as athlete-only staircases or service lifts emerged as a practical way to streamline internal movement.

2. Distributed Vertical Cores Reduce Bottlenecks

The integration of multiple vertical circulation cores, instead of centralized ones, was observed to reduce pressure on single access points. This was evident in the analysis of international precedents like the Vertical Gym in Caracas, where separated access routes for spectators and athletes prevented crowd pileups. In Victoria Island, where traffic intensity is high and land is limited, such decentralization would allow for smoother vertical movement during events.

3. Wayfinding and Visual Communication Are Underutilized

The study identified a recurring issue: inadequate visual signage and intuitive wayfinding in local public structures. In vertical facilities, where disorientation is more likely, effective signage, floor numbering, and digital navigation aids (e.g., smart kiosks, mobile maps) become essential. When absent, user frustration increases, leading to confusion and potential crowd build-up, especially at intersections and access points.

4. Emergency Circulation Requires Greater Attention

Emergency egress planning in many Lagos-based public structures does not meet the demands of high-rise occupancy. In a vertical sports complex, emergency staircases, smoke-pressurized cores, and dedicated refuge areas must be integrated at every level. The study recommends not only spatial design but also emergency simulation drills and smart systems (e.g., occupancy sensors) to monitor and guide crowd dispersal in real-time.

Technological Integration Is Emerging but Not Standardized

The use of smart building systems for crowd monitoring such as occupancy sensors, realtime alerts, and app-based guidance was found to be largely absent in Lagos vertical public buildings. Yet these systems are now central to modern crowd control, especially in compact vertical environments. Incorporating such technology can significantly improve both user experience and safety in future developments.

CONCLUSION AND RECOMMENDATIONS

This study critically examined the challenges and design strategies for effective crowd control within vertical sports complexes, with a particular focus on Victoria Island, Lagos a dense and rapidly urbanizing context where horizontal land expansion is increasingly constrained. The research confirms that the move toward vertical sports infrastructure is not merely an innovative design trend, but a pressing urban necessity driven by land scarcity, population growth, and the rising demand for multifunctional recreational spaces. However, while vertical structures offer spatial efficiency, they introduce heightened complexities in managing the movement of large groups through stacked spatial arrangements. Findings

reveal that conventional crowd control techniques developed for horizontal layouts fall short when applied to vertical environments. Instead, successful crowd control in vertical sports architecture requires a holistic integration of architectural foresight, user-cantered functional zoning, adaptable and redundant circulation systems, behavioural design techniques, and smart technology deployment. Key conclusions drawn from the study include the critical need to separate vertical circulation paths based on user categories (e.g., athletes, spectators, media, maintenance), the strategic decentralization of circulation cores to avoid congestion bottlenecks, and the imperative of embedding emergency evacuation systems such as pressurized stairwells, smoke-free refuge zones, and clearly marked egress points into the conceptual design stage rather than as afterthoughts. In addition, the study stresses the importance of responding to local crowd behaviour and cultural movement patterns, ensuring that global best practices are not adopted wholesale but tailored to suit the infrastructural realities and user behaviours in Lagos. Recommendations emerging from the study advocate for designing with vertical zoning principles, where each floor or vertical segment is programmed according to its specific user group and function, thereby streamlining access and reducing cross-traffic. Furthermore, the incorporation of multiple and redundant circulation cores, including staircases, elevators, and ramps, ensures directional flow, ease of access, and fast evacuation during peak use or emergencies. Emergency movement planning must begin at the design phase, incorporating smoke-proof escape routes, refuge floors, and emergency signage from the outset. Behavioural design strategies such as visual cues, lighting, material textures, and subtle architectural guides can naturally influence movement patterns and reduce confusion in high-density moments. The integration of smart building technologies, including occupancy sensors, real-time digital signage, mobile navigation systems, and centralized crowd management dashboards, offers dynamic tools to monitor, analyse, and direct human movement efficiently. Additionally, architects and planners must contextualize international best practices by incorporating local constraints, behaviour, and infrastructure into crowd control strategies. Finally, the study recommends that urban development policies and building regulations in Lagos be updated to reflect the unique circulation demands of vertical sports facilities. These policy shifts should mandate crowd control design standards for vertical complexes, ensuring they are not only architecturally ambitious but also functionally safe and socially responsive. Overall, managing crowds in vertical sports complexes is not merely a spatial challenge but a multidisciplinary Endeavor that blends architecture, urban policy, technology, and human-centered design to create spaces that are efficient, safe, and adaptable for the future of sports in urban environments.

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