EVALUATION OF SMART DESIGN STRATEGIES FOR EFFICIENT ZONING AND CIRCULATION IN SELECTED TEACHING HOSPITALS IN LAGOS.

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ABSTRACT

Effective zoning and circulation are critical for the functionality of teaching hospitals, especially in rapidly urbanizing cities like Lagos, Nigeria. These hospitals serve dual roles—healthcare delivery and medical education—creating complex spatial demands that require careful planning. This study examines how smart design strategies can improve zoning and circulation efficiency in selected teaching hospitals in Lagos using a qualitative approach based on literature and institutional reviews.

Findings reveal that many existing hospital layouts are characterized by fragmented functional integration, overlapping circulation paths, congestion in high-traffic areas, and poor separation between public, clinical, and academic zones. Circulation systems are often linear and lack clear hierarchy, leading to inefficiencies in movement, navigation, and wayfinding. These issues contribute to spatial disorientation among users.The study identifies smart design solutions such as evidence-based adjacency planning, structured circulation hierarchies, flexible and modular zoning, improved spatial legibility, and the use of digital simulation tools. It also emphasizes the need for context-sensitive design approaches to address challenges like high patient volumes, limited expansion space, and aging infrastructure.In conclusion, while current layouts remain functional, they are not optimally efficient. Integrating smart design strategies can significantly enhance operational performance, user experience, and the interaction between healthcare and education. This study provides a framework to guide architects, planners, and policymakers in improving teaching hospital design.

KEYWORDS: *Teaching hospitals, Zoning, Circulation, Smart Design, Hospital Architecture, Lagos.*

1.0 INTRODUCTION

As urban areas grow and more individuals converge, hospitals are witnessing increased pressure on their services without much progress in design or technology. Lagos, known as one of the largest cities in Africa and a hub for demographic and economic activity potrays these difficulties. The city is dominated by infrastructure issues, severe traffic congestion, and swarmed public services. It is important to recognize that the architectural design of healthcare spaces can vary in form, purpose, and usage patterns. These spaces can include primary areas such as lobbies, patient rooms, theaters, wards, treatment rooms, laboratories, and various support areas, among others (Akinluyi et al., 2021). In hospital environments, the concept of a contemporary hospital building suggests a vast, highly advanced facility with various sites for delivering care, treatments, and administrative functions. Research shows that overly institutionalized environments in large healthcare facilities can lead to several effects on patients and users, including stress, anxiety, difficulties with directions and spatial awareness(Anselm et al, 2022).

The integration of smart design strategies, which leverage digital tools and analytical methods such as graph-based spatial analysis and visibility graph analysis (VGA), has become increasingly prominent in the global hospital design discourse. These strategies help architects and planners anticipate movement patterns, enhance visibility within built spaces, and reduce confusion in wayfinding for users (Akubue et al, 2024)

However, this technological progress has uncovered a significant gap. While citywide mobility is being enhanced by smart systems, healthcare facilities often lag in technological development. This creates a disconnect between external efficiency and the internal operations of hospitals. Emergency vehicles may reach healthcare facilities faster due to AI routing, but once they arrive, outdated layouts and limited digital support cannot effectively manage the influx of patients (Onechojo et al., 2024). Many hospitals still use static routes, traditional signage, and manual patient management systems, which are inadequate for today's complex healthcare demands (Ahmed et al., 2020). This issue shows a pressing need to incorporate smart design into hospital spaces to better align with overall smart city strategies (Ayegbo et al., 2025). The spatial organization of these institutions must address the challenges posed by building complexity and expansions over time, which often result in a lack of visual clarity that hinders navigation and access to desired destinations(Ahmed et al., 2022). Inadequate signage systems and suboptimal

architectural design often create physical barriers that result in uneven access, causing stress and uncertainty for both staff and patients during the wayfinding task(Salawu et al, 2022).

Research shows that inefficient circulation systems and inefficient spatial optimization lead to longer treatment times, overcrowding, and lower patient throughput. For instance, circulation patterns such as linear, looped, and radial configurations have been analyzed in Nigerian facilities to assess movement efficiency, but these studies do not fully address the embedded spatial design strategies needed for modern teaching hospitals (Anselm et al, 2022). Many Nigerian teaching hospitals still have designs that do not meet the needs of current patient numbers or modern clinical practices. Studies reveal ongoing problems like bottlenecks in hallways, unclear pathways, poorly defined zones, and overcrowded diagnostic and waiting areas (Ogunyemi & Lawanson, 2022; Omole et al., 2023). These spatial issues place extra pressure on healthcare staff, confuse patients and their families, and hinder the overall efficiency of the facility.

In a city like Lagos, where major hospitals cater to vast and varied populations, the effects of architectural inefficiency are even greater (Akinwale & Kuye, 2022; Abubakar et al., 2022). Structural delays due to poor zoning, insufficient pathways, or incomplete integration of smart systems can lead to preventable medical issues, delayed treatments, and systemic operational hold-ups (Adeleye & Akinyemi, 2021). Therefore, hospital design is not just a background for healthcare delivery but a critical factor in clinical efficiency, patient safety, and the resilience of healthcare institutions. The widening gap between advanced city systems and outdated hospital structures highlights the urgent need for evaluation and redesign of hospital layouts, guided by smart design principles that meet the demands of modern healthcare.

Despite increasing healthcare demand in rapidly urbanizing Nigerian cities such as Lagos, limited research has critically examined spatial efficiency in teaching hospital design, particularly in relation to zoning configuration and circulation performance. Existing studies tend to focus on general wayfinding or infrastructure challenges without systematically addressing spatial optimization and functional integration within complex teaching hospital environments. This gap highlights the need for a focused architectural evaluation of zoning strategies and circulation hierarchies to improve operational efficiency and healthcare delivery outcomes.

This study aligns with emerging smart hospital planning frameworks that integrate evidence-based healthcare design, digital infrastructure, and resilient spatial planning to enhance healthcare delivery in rapidly urbanizing contexts.

The aim of this study is the evaluation of smart design strategies for efficient zoning and circulation in selected teaching hospitals in Lagos, focusing on spatial performance and operational effectiveness.

The specific objectives are to:

I . Examine the existing spatial zoning and circulation patterns in selected teaching hospitals in Lagos ; and

II. Propose smart design strategies that can enhance zoning and circulation efficiency in teaching hospitals in Lagos.

2.0 LITERATURE REVIEW

This section examines relevant literature on zoning and circulation in teaching hospitals, with a focus on smart design strategies that enhance spatial efficiency. It reviews key concepts, theoretical frameworks, and previous studies that inform effective hospital planning and organization.

2.1 Circulation Systems in Hospitals

Circulation systems, such as corridors, staircases, elevators, and connections between departments, are essential for how individuals navigate healthcare facilities. Studies indicate that inefficiently designed circulation routes lead to difficulties in wayfinding, longer travel distances, and increased stress for both patients and healthcare staff (Jiang & Verderber, 2019).

A thorough examination of hospital circulation areas found that these spaces are frequently overlooked in design research despite their significant impact on wayfinding, cognitive stress, noise levels, and social interactions within healthcare environments (Jiang & Verderber, 2019). The authors advocated for a more deliberate incorporation of circulation in planning models to alleviate these adverse effects . A recent study outlined fundamental design principles to enhance internal circulation, such as clear axial corridors, the segregation of public and staff pathways, and visibility of destinations, all of which facilitate efficient movement and minimize confusion (Akubue et al, 2024). Architectural studies examining socio-cultural influences on building form also emphasise the importance of contextual design considerations in institutional environments (Olaoye, 2023)

2.2 Spatial Optimazation and Wayfinding Behaviour

Wayfinding refers to users' patients, visitors, and staff's capacity to find sites within a complicated spatial setting. Research in Nigeria and globally suggests that intricate spatial arrangements lead to confusion, annoyance, and prolonged travel durations (Salawu et al et al., 2019). For instance, a study on wayfinding behavior in a university hospital in Nigeria revealed that unfamiliar users faced considerable difficulties in navigating corridors, heightening anxiety and diminishing overall satisfaction.(Ahmed et al., 2020)

Additional studies on visual accessibility and inclusive wayfinding emphasize the impact of corridor layout, sign positioning, and visual signals on navigation ease. Limited visibility of important destinations and poorly designed junctions can obstruct movement, particularly for first-time visitors or older individuals(Ahmed & Muhammad, 2022). Global research also investigates wayfinding as a component of design. The layout of emergency rooms and critical care units significantly impacts how effectively users can navigate in stressful situations, affecting both patient safety and processing times(Haj-saleh et al, 2025).

2.3 Smart Design Strategies and Computational Tools

Recent built-environment research demonstrates that integrating sustainable and technologically responsive design strategies, alongside innovative approaches to circulation and zoning in healthcare settings, significantly enhances environmental performance and urban infrastructure resilience (Ibitoye et al., 2025. These approaches employ computational resources, including spatial decision support systems, visibility graph analysis (VGA), and simulation modeling to enhance layouts before construction. A comprehensive review of hospital layout design highlights the application of simulation modeling and spatial network analysis to assess wider concerns such as walkability, visibility, overcrowding, and wayfinding effectiveness. By viewing hospital layouts as intricate spatial networks, designers can predict congestion points, explore different arrangements, and minimize inefficiencies(Zhouran Jia et al., 2023)

A different open-access review regarding architectural spatial layout design explores how innovative digital techniques (such as machine learning and parametric design) enhance evidence-based planning, refining adjacency relationships and circulation clarity within hospitals(Ozlem et al., 2024). Collectively, these computational methods enhance intelligent design frameworks that

predict movement patterns, streamline workflow routes, and elevate patient experience by synchronizing spatial design with user behavior information. These approaches are consistent with smart healthcare infrastructure frameworks, which emphasize data-driven decision-making, spatial optimization, and healthcare resilience planning in contemporary hospital design.

2.4 Summary of Literature Gaps

Although global studies offer strong insights into circulation, wayfinding, and effective design strategies, there is a paucity of literature addressing Sub-Saharan Africa, especially concerning teaching hospitals in Lagos. Current Nigerian research emphasizes architectural wayfinding behavior or thematic analyses of circulation systems but falls short of thorough assessments of smart design strategies suited to the specific challenges of high-demand teaching hospitals. This discrepancy emphasizes the necessity for empirical research that evaluates how intelligent spatial strategies can enhance zoning effectiveness and circulation functionality within these intricate healthcare settings. Earlier studies within the Nigerian built environment have explored the adoption of sustainable architectural technologies and their impact on infrastructure performance; however, their application to healthcare circulation systems remains largely underexplored (Ibitoye et al., 2022).

3.0 METHODOLOGY

This study adopts a qualitative research approach grounded in case study analysis, content analysis, and architectural spatial layout review. The research involves a systematic examination of peer-reviewed literature, institutional documents, and hospital planning guidelines to evaluate zoning configurations and circulation systems in teaching hospitals.

Specifically, architectural plan analysis and spatial layout review are used to assess functional relationships, circulation hierarchy, and zoning efficiency, while content analysis is applied to identify recurring design strategies and performance gaps. Institutional document review further supports the evaluation of real-world planning frameworks and policy guidelines relevant to hospital design.

3.1 FINDINGS AND DISCUSSION

Based on the review of 20 peer-reviewed articles and institutional publications, several key themes emerged regarding smart design strategies for efficient zoning and circulation in teaching hospitals. The findings are organized under four main areas: zoning patterns, circulation systems, wayfinding and spatial clarity, and integration of smart design strategies.

Table 1: Synthesis of Selected Studies on Spatial Zoning, Circulation Systems, and Smart Design Strategies in Healthcare Facilities

Authors	**Year**	**Focus Area**	**Method**	**Relevance to Current Study**
Abubakar et al.	2022	Urban health infrastructure and access	Literature review	Highlights pressure on healthcare systems in rapidly urbanizing cities like Lagos
Adeleye & Akinyemi	2021	Hospital circulation and service efficiency	Case study analysis	Shows impact of circulation systems on hospital performance
Ahmed et al.	2020	Spatial layout and wayfinding behavior	Case study	Demonstrates how poor layouts affect navigation in Nigerian hospitals
Salawu et al	2022	Signage and wayfinding in hospital environments	Document analysis	Emphasizes role of visual cues and signage in spatial clarity
Jiang & Verderber	2019	Hospital circulation design	Systematic literature review	Provides foundational principles for circulation planning

Akubue et al	2024	Circulation systems and spatial configuration	Literature review	Identifies design strategies for improving movement efficiency
Anselm et al	2022	Circulation patterns in Nigerian hospitals	Case-based analysis	Highlights inefficiencies in linear circulation systems
Ogunyemi & Lawanson	2022	Spatial deficiencies in hospitals	Empirical study	Links poor zoning to operational inefficiencies
Omole et al.	2023	Congestion and service delays	Field-based study	Shows effects of overcrowding and poor layout in Lagos hospitals
Onechojo et al.	2024	Smart hospital systems and IoT	Review study	Introduces smart technologies relevant to hospital design
Ayegbo et al.	2025	Smart city and AI systems	Conceptual review	Provides context for integrating smart systems into hospitals
Haj-saleh et al	2025	Spatial design and wayfinding in emergency units	Comparative analysis	Shows importance of layout in high-pressure healthcare zones
Ahmed & Muhammad	2022	Visual accessibility in hospital design	Literature review	Explains role of visibility and layout in navigation

Zhouran Jia et al.	2023	Spatial decision support systems	Review study	Demonstrates use of simulation tools in hospital layout optimization
Ozlem et al.	2024	Computational design in healthcare	Literature review	Highlights role of AI and parametric tools in smart design
Talabi et al.	2022	Sustainable and flexible hospital design	Review study	Supports modular and adaptable zoning strategies
Akinluyi L. et al.	2021	Healthcare infrastructure challenges in Lagos	Contextual study	Provides local context for spatial inefficiencies
Ibitoye, O. O., et al.	2025	Sustainable building systems in Lagos	Empirical built environment study	Demonstrates relationship between architectural innovation and urban infrastructure performance
Olaoye, G. O.	2023	Socio-cultural influences on architectural form	Architectural case study	Highlights relationship between spatial form, user interaction, and built environment meaning

4.1 Existing Spatial Zoning Patterns in Teaching Hospitals

The review of literature and institutional documents reveals that zoning in teaching hospitals plays a decisive role in determining operational efficiency, safety, and user experience. Effective

hospital zoning is characterized by clear functional clustering, defined hierarchies of space, and logical adjacency relationships between departments.

However, evidence from studies on Nigerian and comparable contexts indicates that many teaching hospitals exhibit fragmented zoning patterns. Clinical, administrative, and public zones are not always clearly delineated, leading to overlaps between patient, staff, and student pathways.(Anselm et al, 2022). In several cases, diagnostic and treatment areas are located at considerable distances from inpatient wards, increasing internal travel and reducing workflow efficiency. Such inconsistencies often stem from phased expansions, retrofitting of older structures, and limited integration of evidence-based planning during initial design stages.(Jiang & Verderber, 2019)

Vertical zoning in multi-storey teaching hospitals is frequently under-optimized. High-traffic departments such as emergency units and outpatient clinics are not consistently positioned for ease of access, contributing to congestion and circulation conflicts(Salawu et al, 2022). These findings suggest that while zoning frameworks may exist conceptually, their implementation in Lagos teaching hospitals requires strategic refinement and contextual adaptation.The literature indicates that existing zoning patterns in many teaching hospitals lack the spatial coherence necessary to fully support efficient healthcare delivery and medical education functions.

4.2 Circulation Patterns and Movement Efficiency

Circulation systems emerged as a critical determinant of spatial performance in teaching hospitals. The reviewed studies consistently demonstrate that corridor configuration, pathway hierarchy, and separation of user flows significantly influence operational effectiveness.

Many hospitals in developing urban contexts rely predominantly on linear corridor systems. While simple to implement, these layouts often create long travel distances and central bottlenecks, particularly during peak hours. In contrast, literature on smart hospital design emphasizes the advantages of looped or radial circulation systems, which provide alternative routes and reduce congestion.

A recurring issue identified in Nigerian hospital environments is the inadequate separation of circulation flows. The overlap of circulation paths negatively impacts different user groups, patients, visitors, medical staff, and emergency personnel, resulting in operational delays, reduced

privacy, and increased stress within the hospital environment. Patients, visitors, medical staff, and service personnel frequently share the same pathways, increasing delays, compromising privacy, and potentially affecting infection control measures. Additionally, poorly positioned vertical circulation cores (elevators and staircases) can intensify congestion and disrupt workflow continuity.

Wayfinding challenges are also closely linked to circulation inefficiencies. Where spatial layouts lack visual clarity and intuitive directionality, users experience disorientation, which further strains circulation systems.

Collectively, the findings indicate that existing circulation patterns in many teaching hospitals in Lagos are functional but not optimized. There is limited integration of analytical tools or smart planning strategies to evaluate and refine movement networks. As a result, circulation inefficiencies persist, affecting both patient experience and staff productivity.

4.3 Integration of Smart Design Strategies

The analysis of peer-reviewed studies and institutional guidelines highlights the growing role of smart design strategies in optimizing hospital performance. These strategies extend beyond traditional layout planning to include evidence-based design principles, digital modeling tools, and flexible spatial systems.

A key finding across the literature is the importance of adjacency planning informed by systematic analysis. Smart design approaches utilize spatial modeling and simulation techniques to predict movement flows, identify potential congestion points, and evaluate alternative layout configurations before implementation(Akubue et al, 2024). Such tools enable designers to evaluate circulation networks and zoning efficiency during the planning stage, rather than after construction.

However, the literature also indicates that integrating smart design strategies in developing contexts faces challenges, including financial constraints, limited technical expertise, and the need to retrofit older infrastructures (Talabi et al., 2022). In Lagos teaching hospitals, where many facilities were constructed incrementally, applying smart design principles may require phased redesign strategies rather than complete structural overhauls. The findings suggest that smart design strategies provide a viable pathway for improving zoning and circulation efficiency. When

contextually adapted, these strategies can enhance workflow, reduce congestion, improve user orientation, and strengthen the dual healthcare and educational functions of teaching hospitals.

4.4 Synthesis of Findings

The synthesis of literature and institutional publications highlights several interconnected insights regarding zoning and circulation efficiency in teaching hospitals. Effective zoning must reflect clear operational hierarchies and well-defined functional adjacencies, with careful consideration of the movement patterns of patients, staff, and students. Where these spatial relationships are weak, circulation inefficiencies and congestion are likely to occur.

Efficient circulation networks require structured, and where possible, separate movement pathways to reduce bottlenecks and enhance safety. Similarly, wayfinding should not rely solely on signage but integrate both physical spatial clarity and supportive digital navigation tools to improve user orientation within complex hospital environments.

The findings further demonstrate that smart design strategies, including digital modeling, simulation techniques, and modular layouts, provide evidence-based approaches for optimizing hospital performance. However, their successful implementation in Lagos teaching hospitals depends on contextual adaptation, particularly in response to space limitations, existing infrastructure, and high patient volumes. The synthesis reinforces the need for an integrated spatial strategy that aligns zoning structure, circulation hierarchy, wayfinding systems, and smart planning methodologies to enhance efficiency in teaching hospitals.

5.0 Conclusion

This research analyzed intelligent design approaches to improve zoning and circulation effectiveness in chosen teaching hospitals in Lagos via a qualitative systematic review of literature and organizational documents. Concerning the first goal, which aimed to analyze current spatial zoning and circulation patterns, the results indicate that numerous teaching hospitals display disjointed functional groupings, intersecting movement patterns, and mainly linear circulation systems that lead to overcrowding and challenges in navigation. Insufficient division among

public, clinical, and academic areas further diminishes operational effectiveness and spatial transparency.

Regarding the second objective, aimed at suggesting intelligent design strategies for enhancement, the analyzed studies consistently highlight the significance of evidence-driven adjacency planning, organized circulation hierarchies, enhanced spatial clarity, and the incorporation of digital modeling along with adaptable design frameworks. These approaches offer practical and flexible solutions that can tackle recognized inefficiencies.

In general, the research shows that although current layouts function, they are not optimized. Context-sensitive smart design methods present considerable opportunities to enhance workflow efficiency, minimize congestion, and bolster the healthcare and educational roles of teaching hospitals in Lagos. While confined to qualitative secondary analysis, the study lays the groundwork for upcoming empirical research on spatial performance in Nigerian hospital settings.

5.1 Recommendations

This section presents recommendations derived from the findings of the study and insights gained from the reviewed literature. It proposes practical and context-sensitive strategies aimed at improving zoning and circulation systems in teaching hospitals. These recommendations are intended to guide architects, planners, and stakeholders in designing more efficient, functional, and user-centered healthcare facilities.

5.1.1 Zoning and Spatial Arrangement

Lagos teaching hospitals ought to enhance effective clustering by strategically situating interrelated departments nearby to minimize unnecessary internal movement. Distinct vertical and horizontal spatial hierarchies ought to direct the positioning of high-traffic clinical zones, administrative departments, and educational areas. Moreover, implementing adaptable and modular zoning frameworks will enable hospitals to respond to evolving healthcare needs, technological progress, and variations in patient numbers while maintaining effective circulation efficiency.

5.1.2 Circulation Mechanisms

Circulation networks need to be intentionally designed to facilitate seamless and continuous movement throughout hospital areas. Where possible, corridor systems ought to include alternative routing choices to minimize congestion, especially in emergency and outpatient zones. Distinct separation of pathways for staff, patients, and visitors is crucial to reduce congestion, improve infection control, and boost workflow efficiency. Vertical circulation components like elevators and staircases must be strategically located to enhance effective interdepartmental connectivity.

5.1.3 Navigation and Spatial Clarity

Wayfinding enhancements must go beyond signage to incorporate intuitive spatial designs that improve visibility and orientation. Well-defined nodes, recognizable areas, and uniform visual indicators can greatly alleviate navigation anxiety for patients, visitors, and students. The incorporation of digital navigation systems, where feasible, can further boost accessibility and elevate the overall user experience in extensive teaching hospital settings.

5.1.4 Intelligent Design Incorporation

Intelligent design approaches, such as evidence-driven planning, spatial modeling, and simulation tools, must be incorporated in both new construction and renovation activities. These methods allow for the assessment of adjacency connections and movement trends before execution, decreasing long-term inefficiencies. Institutional dedication to recognized healthcare design guidelines, coupled with regular evaluations of spatial performance, will guarantee that zoning and circulation systems continue to address operational requirements in Lagos teaching hospitals

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