

Circulation And Spatial Planning Strategies for Efficient and Biosafe Medical Research Facilities in Selected Research Institute

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Abstract- Medical research facilities require effective spatial planning and circulation systems to support efficient workflow, biosafety, accessibility, and collaboration. Poorly organized circulation can result in unnecessary movement, congestion, interaction between incompatible flows, and operational inefficiencies. As this study examined circulation and spatial planning strategies for efficient and biosafe medical research facilities, with emphasis on their application to sickle cell and blood disorders research environments. The study aims to assess circulation and spatial planning strategies for efficient and biosafe medical research facilities in selected research institute. A qualitative comparative case study approach was adopted, using the Institute for Advanced Medical Research and Training (IAMRAT), University College Hospital, Ibadan, and the Paediatric Sickle Cell Centre, Lagos State University Teaching Hospital, Ikeja, as case studies. Data were obtained through architectural observation, review of available drawings and documentation, and analysis of spatial relationships, circulation patterns, zoning and movement flows. Findings revealed that IAMRAT is constrained by shared circulation, weak clean contaminated separation, long movement routes and limited spatial flexibility, while the LASUTH centre demonstrates improved vertical zoning, functional adjacency, accessibility and partial circulation segregation, although some shared routes and expansion limitations remain. The study concludes that circulation, zoning and functional adjacency are critical to efficient and biosafe research environments. It recommends differentiated circulation routes, stronger clean contaminated separation, flexible laboratory planning, improved accessibility, effective wayfinding, dedicated service routes and planned future expansion.

Keywords: Medical Research Facilities; Circulation Planning; Spatial Organization; Biosafety; Sickle Cell Research.

I. INTRODUCTION

Medical research institutes are complex environments where the arrangement of spaces and movement routes can directly affect safety, workflow and research productivity. Unlike conventional institutional buildings, they accommodate activities such as experimentation, diagnosis, data analysis and clinical research, often requiring the movement of researchers, patients, biological specimens, equipment and waste within the same facility. For this reason, architectural planning has to go beyond providing functional spaces to consider biosafety, workflow, accessibility and user needs (Ulrich et al., 2008). The need for resilient and adaptable research environments has also become more important, particularly in response to emerging health challenges and infection-control concerns (World Health Organization, 2020).

Circulation is particularly important because different movement streams within a research facility cannot always be treated in the same way. Clean and contaminated routes, staff and public movement, specimen transportation and waste disposal require appropriate separation to reduce conflicts and cross-contamination. Poor circulation planning can result in congestion, longer travel distances and delays in laboratory processes, while appropriate adjacency between related spaces can improve workflow and reduce physical demands on staff (Ulrich et al., 2008; O'Connell, 2020). Clear spatial organization can also improve wayfinding and reduce the cognitive demands placed on users.

Facility design have increasingly incorporated visual connectivity, flexibility and spaces that encourage collaboration. Visual connections can support

supervision and interaction among researchers (Olaniran, and Adeokun, 2022), while modular layouts and adaptable service systems allow laboratories to respond to changing research requirements (Bordass and Leaman, 2022). Similarly, shared spaces and strategically positioned circulation nodes can create opportunities for interaction and knowledge exchange, which are important to research and innovation (Allen and Henn, 2007).

These concerns are particularly relevant where some medical research facilities operate in adapted buildings that were not originally designed for biomedical research. Such conditions can produce poor zoning, inefficient circulation and inadequate separation of different functional areas (Adesina and Olotuah, 2020). Environmental and infrastructural conditions, including humidity, dust and unreliable power supply, further complicate the planning and operation of controlled research environments.

Although existing studies have established the importance of circulation, zoning and spatial relationships in healthcare and laboratory design, less attention has been given to their combined application in medical research institutes, particularly facilities that bring together research, diagnostic and clinical functions. This study therefore examines the circulation hierarchies and spatial configurations of selected research institutes, with emphasis on their implications for biosafety, workflow coordination, user interaction and overall operational efficiency. The study further draws from the findings to develop spatial planning strategies for efficient and biosafe medical research facilities.

II. LITERATURE REVIEW

2.1 Circulation, Spatial Planning and Functional Organisation of Medical Research Facilities

Medical research facilities are complex environments that require careful coordination of spaces, people, materials and research activities. Circulation involves not only the movement of users through horizontal and vertical routes but also the movement of biological specimens, equipment, supplies and waste. Consequently, circulation planning has to respond to different levels of access and operational requirements

within the facility (Ching, 2023; Kandemir and Turan, 2022). The arrangement of laboratories, diagnostic areas, storage, offices and support spaces is also important, as appropriate functional adjacency can reduce unnecessary movement and improve workflow (Rashid and Zimring, 2008).

Functional zoning helps to organize these relationships by distinguishing between public, semi-restricted and restricted areas. Such zoning controls access and reduces conflicts between incompatible activities (Kandemir and Turan, 2022; Hurst and Kennedy, 2023). Circulation hierarchy further supports this arrangement by separating public, staff and service movement. In laboratory environments, the separation of clean and contaminated routes is particularly important for preventing cross-contamination and maintaining research integrity (World Health Organization, 2020; Thompson and Adebayo, 2025). Airlocks, buffer zones and gowning areas can provide controlled transitions between spaces with different levels of environmental control. Spatial planning must also balance separation with connectivity. While sensitive laboratory areas require controlled access, research environments need opportunities for interaction and collaboration. Spatial integration and visual connectivity can encourage communication and knowledge exchange, while controlled separation protects sensitive activities (Tan and Wong, 2022). Flexible and modular planning is similarly important because research activities, equipment and technologies change over time (Bordass and Leaman, 2013; National Institute of Building Sciences, 2023).

2.2 Circulation, Biosafety and Operational Efficiency in Research Environments

The quality of circulation and spatial organization has direct implications for workflow, safety and user performance. Poorly organized circulation can create congestion, increase travel distances and interfere with laboratory processes, while appropriate spatial relationships can reduce delays and physical demands on staff (Ulrich et al., 2008). Clear wayfinding and logical spatial organization are also important in complex research environments because they help users navigate the facility efficiently and reduce cognitive demands (Passini, 1996).

Biosafety remains a central consideration in the planning of medical research facilities. The separation of clean and contaminated movement, controlled access and appropriate zoning help reduce contamination risks and protect personnel, specimens and research activities (World Health Organization, 2020). Dedicated service and waste routes can further prevent hazardous materials from passing through public or clean areas, while emergency circulation supports safe evacuation and response during hazardous situations (Ibrahim and Yusuf, 2025).

Beyond safety and efficiency, spatial organization can influence collaboration. Shared spaces, circulation nodes and visual connections can encourage interaction among researchers, although these must be carefully planned so that collaboration does not compromise restricted areas (Allen and Henn, 2007; Tan and Wong, 2022). These issues are particularly relevant in Nigeria, where some medical research facilities operate in adapted buildings that were not originally designed for biomedical research, resulting in challenges relating to zoning, circulation and functional relationships (Adesina and Olotuah, 2020).

III. MATERIALS AND METHODS

The study adopted a qualitative comparative case study approach to examine circulation and spatial planning strategies in selected medical research facilities. The case studies were selected purposively from medical research and healthcare facilities that were considered relevant to the objectives of the study. The selection was guided by clearly defined criteria to ensure that the selected facilities provided an appropriate basis for assessing circulation systems, spatial organization, zoning, workflow, accessibility and biosafety provisions. In line with Yin (2018), purposeful case selection was adopted to ensure direct alignment between the cases and the phenomenon under investigation.

The selection criteria included five major considerations. First, the facility must function as a medical research institute or healthcare building with integrated laboratory and diagnostic functions, thereby providing a suitable context for examining medical research-related spatial requirements (Ulrich et al.,

2008). Second, the facility must demonstrate identifiable functional zoning, particularly the separation of public, semi-restricted and restricted areas, which is important for biosafety and operational efficiency (World Health Organization, 2020; Sailer et al., 2021). Third, the facility must have a structured circulation system with identifiable routes for staff, visitors, service movement and specimen transport, allowing the study to assess movement patterns and possible circulation conflicts (World Health Organization, 2020). Fourth, reliable architectural information, including plans, layouts, published drawings or other relevant documentation, must be available to support spatial analysis (Ching, 2023). Finally, facilities were prioritized where possible to enhance the relevance of the findings to infrastructural and operational realities (Olaniran and Adeokun, 2022).

Based on these criteria, the study considered the identified medical research and healthcare facilities within the study population from which the final case studies were purposively selected. The selected cases represented a combination of local and international contexts, allowing comparison of circulation systems and spatial organization across different settings. The final selection was based on the extent to which each facility satisfied the stated criteria, its relevance to biomedical research functions, the presence of identifiable circulation and zoning systems, and the availability of reliable architectural information for analysis. The selected cases also provided either direct physical observation or sufficient secondary information for architectural assessment.

Data were obtained through direct observation, review of available architectural drawings and documentation of the selected facilities. The assessment focused on functional requirements, spatial relationships, circulation hierarchy, zoning, movement patterns, accessibility, workflow and biosafety provisions. The circulation of personnel, specimens, equipment, supplies and waste was examined to identify possible conflicts, inefficiencies and areas of effective separation. The collected information was analysed through architectural spatial analysis, functional adjacency analysis, circulation and zoning assessment, and cross-case comparison. The findings from the case

studies were subsequently synthesized to identify appropriate design strategies for improving spatial organization, circulation efficiency and biosafety in medical research facilities.

IV. FINDINGS

Evaluation Principles for Case Study Assessment

The selected case studies were evaluated using common architectural and operational principles derived from the objectives of the study. The evaluation was structured to permit consistent comparison across the cases rather than treating each facility as an isolated description. The assessment focused on functional organization, spatial adjacency, circulation, biosafety, zoning, workflow, wayfinding,

accessibility, environmental performance, site planning and flexibility.

For each case, the identified spatial and circulation characteristics were assessed against these principles. The assessment considered the extent to which each facility provides clear functional relationships, efficient movement patterns, appropriate separation of different user and service flows, controlled access to restricted areas, adequate support for research workflow, and provisions for accessibility and future adaptation. The findings were classified comparatively as high, moderate or low, according to the degree to which each principle was demonstrated in the case study.

Table 1: Evaluation Principles Used for Case Study Assessment

Evaluation principle	Indicators assessed
Functional organization	Relationship and arrangement of laboratory, clinical, administrative, training and support functions
Spatial adjacency	Proximity of functionally related spaces and reduction of unnecessary movement
Circulation	Clarity of movement routes, circulation hierarchy and separation of user and service movement
Biosafety	Separation of clean and contaminated flows, transitional spaces and controlled laboratory access
Zoning	Differentiation of public, semi-restricted and restricted areas
Workflow	Continuity and efficiency of movement of personnel, specimens, equipment, supplies and waste
Wayfinding	Signage, visual cues and ease of orientation
Accessibility	Barrier-free entrances, ramps, accessible toilets and circulation widths
Environmental performance	Daylighting, ventilation, shading and relationship between building form and environmental conditions
Site planning	Relationship between pedestrian, vehicular, emergency and service access
Flexibility	Capacity for adaptation, expansion and changes in research requirements

Case Study 1: Institute for Advanced Medical Research and Training (IAMRAT), University College Hospital, Ibadan

IAMRAT demonstrates a basic functional organization in which laboratory, administrative and training functions are accommodated within a compact multi-level building. Laboratory and diagnostic activities are concentrated mainly on the lower levels, while administrative and training functions are located on upper floors. However, the boundaries between public, staff and restricted areas are relatively weak.

The facility relies predominantly on a shared central corridor as the main circulation spine. Researchers, students, laboratory technologists and support personnel use the same circulation routes as material and waste movement. Dedicated service and logistics routes are limited. The arrangement therefore creates potential conflicts between personnel circulation, specimen movement, supply delivery and waste removal.

The assessment also indicates limited separation of clean and contaminated flows. Transitional spaces

such as airlocks and gowning areas are limited between general circulation and laboratory areas. Functional adjacency is similarly weak in some areas, with sample reception and diagnostic laboratories

requiring additional movement, while some shared equipment areas are not centrally positioned.

Table 2: Case Study 1 – IAMRAT Assessment Matrix

Assessment area	Finding from IAMRAT	Performance	Implication for the study
Functional organization	Basic separation of laboratory, administrative and training functions	Moderate	Establish stronger functional relationships
Spatial adjacency	Some related functions are separated by considerable distances	Low–Moderate	Locate high-interaction functions closer together
Circulation	Predominantly shared central corridor	Low	Introduce differentiated circulation hierarchy
Biosafety	Limited separation of clean and contaminated flows	Low	Provide dedicated clean, dirty and service routes
Zoning	Public, semi-restricted and restricted areas exist but boundaries are weak	Moderate	Strengthen access control and spatial separation
Workflow	Long movement routes and shared circulation create inefficiencies	Low	Improve adjacency and reduce unnecessary travel
Wayfinding	Basic signage and limited visual cues	Low–Moderate	Provide clearer wayfinding and zoning indicators
Accessibility	Basic circulation arrangement with limited emphasis on barrier-free movement	Low–Moderate	Integrate universal accessibility
Environmental performance	Deep and linear configuration limits alternative environmental and circulation arrangements	Low–Moderate	Adopt climate-responsive and adaptable planning
Flexibility	Modular laboratory bays provide some flexibility, but fixed structural and service arrangements constrain major adaptation	Moderate	Provide flexible laboratory and service systems



Plate 1: Institute for Advanced Medical Research and Training (IAMRAT), University College Hospital, Ibadan, Nigerian image. Source: (Institute for Advanced Medical Research and Training [IAMRAT], 2025)

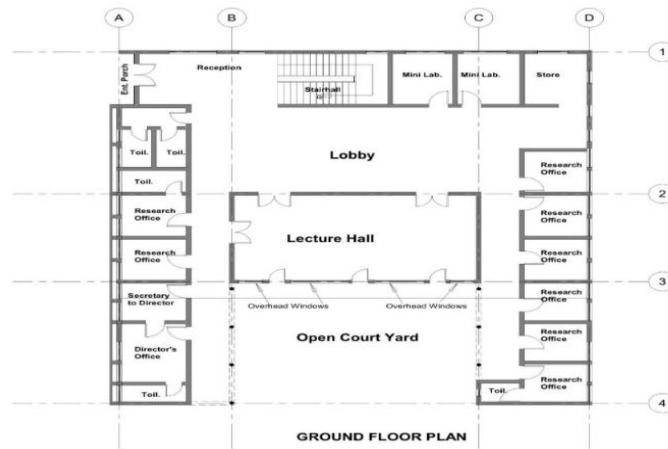


Figure 1: Ground Floor Plan: Institute for Advanced Medical Research and Training (IAMRAT), University College Hospital, Ibadan,
Source: (Institute for Advanced Medical Research and Training [IAMRAT], 2025)

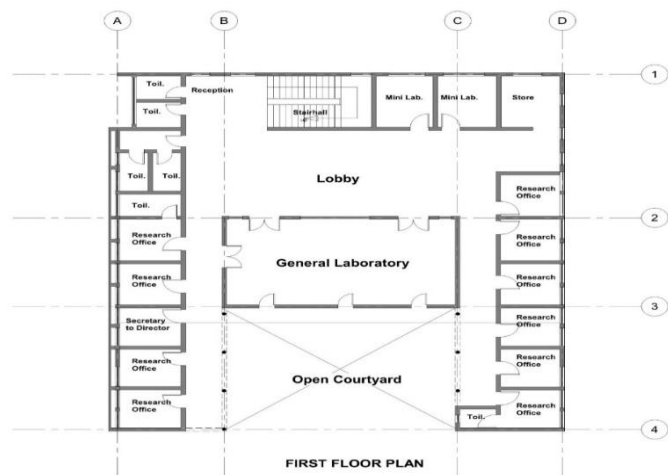


Figure 2: First Floor Plan: Institute for Advanced Medical Research and Training (IAMRAT), University College Hospital, Ibadan,
Source: (Institute for Advanced Medical Research and Training [IAMRAT], 2025)



Plate 2: Institute for Advanced Medical Research and Training (IAMRAT), University College Hospital, Ibadan, Nigerian image. Source: (Institute for Advanced Medical Research and Training [IAMRAT], 2025)

Case Study 2: Paediatric Sickie Cell Centre, Lagos State University Teaching Hospital (LASUTH), Ikeja
The Paediatric Sickie Cell Centre demonstrates a clearer functional hierarchy than IAMRAT. High-traffic clinical functions, including reception, outpatient consultation, phlebotomy and emergency access, are concentrated on the ground floor, while specialised laboratories, genetic testing suites, observation facilities and administrative functions occupy the upper levels.

The circulation system is characterized by wide corridors, ramps and barrier-free entrances, with accessible toilets and improved wayfinding through

colour-coded signage. Patient, staff and specimen movement is partially differentiated, while service and waste routes are reasonably separated from the principal patient entrance.

However, the separation of circulation is not complete. Some circulation zones remain shared, allowing possible intersections between specimens, supplies, waste and general users during periods of high activity. The facility also has limited transitional spaces and limited provision for future expansion.

Table 3: Case Study 2 – Paediatric Sickie Cell Centre Assessment Matrix

Assessment area	Finding from Paediatric Sickie Cell Centre, LASUTH	Performance	Implication for the study
Functional organization	Clear vertical separation of clinical, diagnostic, research-support and administrative functions	High	Adopt clear functional hierarchy
Spatial adjacency	Good proximity between consultation, phlebotomy and diagnostic functions, although some support spaces are less optimally located	High	Locate high-interaction functions closer together
Circulation	Wide, well-lit corridors with partial separation of patient, staff and specimen movement	Moderate–High	Provide differentiated circulation hierarchy
Biosafety	Partial separation of clean and contaminated movement, but some shared circulation zones remain	Moderate	Strengthen clean, contaminated and service/waste separation

Zoning	Relatively clear public, semi-restricted and restricted zones through vertical zoning	High	Strengthen access control and controlled transitions
Workflow	Relatively efficient relationship between clinical and diagnostic functions	Moderate–High	Optimize research and diagnostic workflow further
Wayfinding	Clearer signage and colour-coded circulation improve orientation	High	Incorporate comprehensive wayfinding
Accessibility	Ramps, wide entrances, accessible toilets and generous corridors support barrier-free movement	High	Extend universal accessibility throughout the facility
Environmental performance	Good use of glazing, daylight and cross-ventilation in many clinical and waiting areas	Moderate–High	Incorporate climate-responsive strategies where compatible with laboratory requirements
Site planning	Organized patient, ambulance and pedestrian access with reasonably separated service routes	High	Maintain clear separation of public, emergency and service access
Flexibility	Compact footprint limits future expansion	Moderate	Provide planned expansion and adaptable laboratory systems



Plate 3: Approach View showing Building Materials of Paediatric Sick Cell Centre LASUTH Ikeja. Source Paediatric Sick Cell Centre LASUTH Ikeja. (2025)

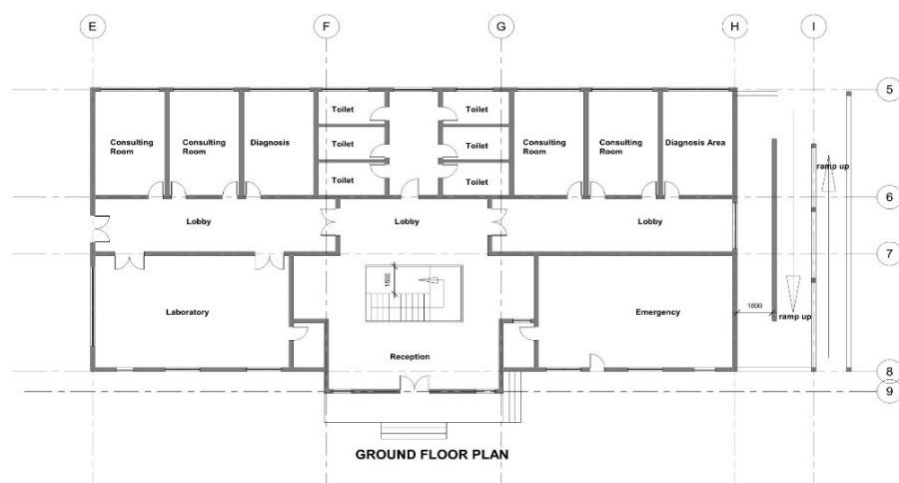


Figure 3 Ground Floor Plan of Paediatric Sick Cell Centre LASUTH Ikeja.
Source Paediatric Sick Cell Centre LASUTH Ikeja.2025)



Plate 4: Image showing Circulation System at Paediatric Sick Cell Centre LASUTH Ikeja. Source Paediatric Sick Cell Centre LASUTH Ikeja.2025)

V. DISCUSSION

The comparative assessment indicates a clear relationship between the organization of circulation, spatial adjacency, zoning and the operational performance of medical research facilities. The cases demonstrate that facilities with stronger circulation hierarchy and clearer functional relationships generally provide better conditions for research workflow and biosafety than facilities relying predominantly on shared circulation systems.

The IAMRAT case demonstrates the limitations associated with a predominantly linear circulation arrangement. Its shared central corridor accommodates different categories of users and service movement, while clean and contaminated flows are insufficiently separated. This finding validates the World Health Organization (2020) emphasis on the importance of controlling movement and separating clean and contaminated pathways in laboratory environments. It also supports the position of Ogunsoye et al. (2023) and Abiodun et al. (2024) concerning the relationship between circulation organization and operational performance. In this respect, the present findings do not contradict previous studies; rather, they provide a Nigerian medical-research example demonstrating the practical implications of the principles identified in the literature.

The Paediatric Sick Cell Centre at LASUTH provides a stronger model of functional organization and accessibility. Its vertical zoning separates high-traffic clinical functions from more controlled laboratory and research-support activities, while wider corridors, ramps, accessible toilets and clearer wayfinding improve movement. This finding validates previous work on user-centred healthcare and research environments, particularly the importance of clear zoning and accessible circulation. The case also extends previous work by demonstrating how these principles can be incorporated within a Nigerian specialized sickle-cell facility where clinical, diagnostic and research-support activities coexist.

The results on spatial adjacency further validate Ulrich et al. (2008) and the spatial planning principles

associated with functional relationships in complex healthcare environments. In the better-performing cases, related activities are positioned in closer proximity, reducing unnecessary travel between consultation, specimen collection, diagnostic laboratories, research areas and support functions. IAMRAT's weaker adjacency, by comparison, creates longer movement routes. The finding therefore suggests that adjacency planning should be treated as a functional requirement rather than simply a spatial arrangement.

The findings on circulation hierarchy extend the principles of spatial configuration discussed by Hillier and Hanson (1984) by showing that connectivity in medical research environments must be controlled according to function and risk. The objective is not simply to connect all spaces efficiently. Rather, spaces that require frequent interaction should be highly connected, while restricted laboratory areas and contaminated movement routes require controlled access and separation. SAHMRI provides the strongest example of this principle, while IHVN demonstrates a more contextually relevant approach through its multiple circulation cores and differentiated movement systems.

The results concerning biosafety also validate World Health Organization (2020) guidance on laboratory planning and movement control. SAHMRI and HMRB demonstrate stronger separation between different circulation streams, whereas IAMRAT and, to a lesser extent, the LASUTH centre retain shared movement areas. The findings indicate that the provision of corridors alone does not guarantee biosafety; rather, the relationship between circulation routes, access control, transitional spaces and functional zoning determines the effectiveness of the system.

The findings on flexibility extend the existing literature on adaptable research environments by demonstrating its importance within the Nigerian context. IAMRAT's fixed structural and service arrangements constrain major adaptation, while the more contemporary cases demonstrate greater capacity for future change. This is particularly significant for medical research facilities because

laboratory technologies, equipment and research requirements are subject to continuous change. Consequently, flexibility should be incorporated from the initial planning stage through modular laboratory spaces, adaptable service systems and provisions for future expansion.

The findings on collaboration also indicate that circulation can serve more than a movement function. In IHVN, SAHMRI and HMRB, collaborative spaces are positioned in relationship to major circulation and shared areas, creating opportunities for interaction among researchers and other users. This supports and extends Sailer et al. (2021) by demonstrating that spatial connectivity can facilitate interaction while still allowing restricted laboratory functions to remain controlled. The evidence therefore supports a balanced approach in which collaboration is encouraged in appropriate shared zones without compromising biosafety.

An important finding from the cross-case comparison is the difference between the local and international precedents. SAHMRI demonstrates a high level of integration between circulation, zoning, flexibility, collaboration and environmental performance. However, the findings extend the existing literature by emphasizing that international models should not be directly replicated without contextual adaptation. For the proposed institute in Lagos, strategies must respond to local climatic conditions, infrastructural realities, available construction resources, operational requirements and the specific research focus on sickle cell and blood disorders.

VI. CONCLUSION

The study examined circulation and spatial planning strategies for achieving efficient and biosafe medical research facilities, using selected research and clinical-research facilities as case studies. The assessment demonstrates that the effectiveness of a medical research facility depends not only on the adequacy of individual spaces but also on how these spaces are arranged, connected and accessed. Functional adjacency, circulation hierarchy, zoning, accessibility and biosafety therefore need to be considered as

interconnected components of the architectural planning process.

The findings from IAMRAT, UCH, Ibadan, indicate that older research facilities can provide durable and functional laboratory environments but may experience spatial and operational limitations as research activities evolve. The predominant use of shared central circulation, weak separation of clean and contaminated movement, limited transitional spaces and relatively long travel distances can create congestion and reduce workflow efficiency. Although the modular laboratory arrangement provides some functional advantages, fixed services and limited opportunities for adaptation constrain the facility's ability to respond to changing research requirements.

The Paediatric Sickle Cell Centre at LASUTH, Ikeja, demonstrates a more contemporary approach to specialised clinical-research planning. Its vertical zoning, improved functional adjacency, accessible circulation, clearer wayfinding and partial separation of patient, staff and service movement provide important lessons for modern medical research facilities. However, the case also shows that improved planning does not automatically eliminate biosafety and operational challenges. Incomplete segregation of clean and contaminated routes, limited transitional spaces, modest landscaping and constrained future expansion remain areas requiring further attention.

Comparatively, the two case studies show a progression from predominantly shared and linear circulation towards more clearly differentiated and vertically organized spatial systems. However, neither facility fully resolves the requirements of a highly specialized blood disorders research environment. The study therefore establishes the need for an integrated planning approach in which public, clinical, research, service and waste functions are appropriately zoned and connected through clearly defined circulation systems.

VII. RECOMMENDATIONS

The recommendations of the study emphasize the need for an integrated approach to the planning of the proposed Sickle Cell and Blood Disorders Research

Institute. The facility should provide clear functional zoning and differentiated circulation routes for patients, staff, specimens, supplies and waste to improve workflow and biosafety. Related spaces such as sample reception, diagnostic and research laboratories should be strategically located to reduce unnecessary movement, while clean and contaminated routes should be adequately separated through controlled access, buffer spaces and dedicated service routes. The design should also incorporate barrier-free access, effective wayfinding, collaborative spaces and flexible laboratory layouts that can accommodate future changes in research activities. In addition, climate-responsive design, shaded pedestrian routes, landscaping and green spaces should be provided to improve environmental comfort and user wellbeing. Overall, the institute should be planned as a flexible and future-ready facility that integrates research, clinical support, accessibility and biosafety without compromising operational efficiency.

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