Spatial Orientation and Wayfinding

Architectural Strategies for Improving Circulation in Buildings

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ISBN: 978-81-69822-18-3

Cover design: Aafiya Saifi
Typesetting: Namrata Saini

First Edition: December 2025

Acknowledgement

My sincere appreciation goes to my family, whose support over the years provided me the break to do this book. I also extent my special gratitude to Dr. Adekoyejo B. Jolaoso (Rector, Moshood Abiola Polytechnic, Abeokuta), whose reviews and constructive criticism assisted in the revisions that aided in getting to the final copy of this book.

Akubue Jideofor Anselm

Baze University, Abuja, 2023.

Foreword

This book is a concise and accessible introduction to the Challenges of wayfinding in buildings. The book focuses on research that is capable of inspiring and understanding of fundamental ways of overcoming disorientation, circulation, and efficiency of human flow in the built environment.

Disorientation is a common phenomenon that affects every human, especially when visiting new places. Often described as the condition of having lost one's sense of direction, this phenomenon is a common occurrence experienced in mostly large-sized buildings. In order to achieve adequate orientation, the human body depends on accurate perception and cognitive integration of these systems. This book presents the premise that the collective systems of visual, vestibular, and proprioceptive stimuli differ in magnitude, direction and frequency, and the inappropriate coordination of these systems results in spatial disorientation.

This five-chaptered book commences with a brief introduction of the subject, followed by the discussion of the underlying Spatial Cognizance Principles, then presented a review of Circulation and Flow Patterns in large Buildings (especially Hospitals), and ended with strategies for Solving Wayfinding Problems while presenting techniques of improving wayfinding and its application in building designs. Furthermore, it presented case studies and analysis of selected building types as means of identifying efficient methods of circulation and movement within critical building types like Hospitals. This is done with design strategies and touches on the practical demonstrations with explanatory illustrations and case studies.

The book thoughtfully concluded with a justification towards generating evaluation systems within the Nigerian environment through the selection of cases from localized regions in an integrated manner.

The initiative and efforts deployed in writing this book is highly commended, which is bound to be of immense benefit for the advancement of knowledge in the subject area.

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Abeokuta, Ogun State, Nigeria. 2024

Prologue

The process of building design, spatial layout, and arrangement provides information about the organization ability of an Architect or Planner. Circulation has been defined as the relative easiness and modes of flow through and within a building, mostly in the network of spaces or routes. Studies on environmental cognition theories identify a general problem in the structuring of communication and transaction between individuals brought about by co-presence in space. This situation is largely determined by local visual fields in common spaces and perception of users, which aligns movement routes through that visual field. All living creatures rely on spatial orientation to navigate through familiar environments. For humans, everyday activities depend on spatial orientation for navigating routes from outside locations to final destinations. Study suggests that the larger the buildings get, the more the challenges of spatial orientation for its users. Likewise, building forms and configurations impact significantly on the course of wayfinding. Finding one's way in spatially extended environments is essential for survival and requires a wide range of cognitive abilities. Pre-eminent among these is the ability to make use of long-term spatial memory to guide wayfinding. An understanding of how we might mentally represent large-scale space has been gained from a variety of tests, such as sketching maps, direction pointing, and giving route descriptions.

Studies on the human cognition values suggest that configuration process of any environment possesses significant cognitive consequences. According to Hillier, spatial configuration on its own could become constraints on spatial experience because its elements may improve or impede aspects of human activities through spatial cognition and behaviors.

Wayfinding is about the first step towards efficient flow and movement in buildings. Wayfinding around public buildings such as airports, museums, hospitals, office buildings, or university buildings often proves to be challenging and frustrating. The studies adopted in this book, amongst other things, also aim at developing appraisal techniques which could be applied as a tool for assessing the wayfinding performance and circulation efficiency in notable public buildings like hospitals, where primary human comfort in terms of wayfinding is vital.

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CHAPTER 1

Introduction

Wayfinding design and spatial orientation may be viewed as the critical system that translates architecture into intuitive human movement. Without this system, complex built environments may become stressful to users as well as alienating functional spaces; hence resulting in huge losses in time and costs of place identification.

A typical scenario may be perceived in the condition of a frantic traveler at a huge airport or a first time visitor trying to navigate a massive/complex hospital maze like the Lagos University Teaching Hospital (LUTH), where patients and visitors frequently become disoriented in labyrinthine hallways and confusing signage. These experiences create immense anxiety for visitors or patients as major medical appointments are missed or delayed.

Understanding the process of wayfinding entails looking at both its academic perspective and the everyday applications. This chapter thus provides fundamental definitions of the concept of wayfinding relative to buildings and spatial orientation. It elucidated the psychological and physiological components as well as listing the major principles that assist in successful wayfinding process.

Spatial Orientation

Disorientation is a common phenomenon that affects every human, especially when visiting new and unfamiliar places. Often described as the condition of having lost one's sense of direction, this phenomenon is a common occurrence experienced in mostly large spaces. While disorientation is a common terminology in aviation owing to the vastness of the sky and space where pilots are meant to navigate, same experiences are likewise predominant in built environments, especially in large-sized buildings.

According to the psychology of the human system, there exist four (4) physiologic systems that interact in order to enable humans to orient themselves in a space. They include:

- **Vision:** regarded as the most dominant sense for orientation;
- **Vestibular system:** regarded as the system that functions to detect the human head position and movement in space. This system is responsible for coordination of eye movements, posture, and equilibrium;
- **Proprioceptive system:** regarded as the system that provides sense of body awareness, detects and controls force and pressure, as well as assists the body in controlling responses to sensory stimuli and
- **Auditory system:** regarded as the system that processes sounds within the environment.

According to Rachel K. Meeks et al, in order to achieve adequate orientation, the human body depends on accurate perception and cognitive integration of these systems. Study also agrees that the collective systems of visual, vestibular, and proprioceptive stimuli differ in magnitude, direction and frequency, and the inappropriate coordination of these systems results in spatial disorientation (Meeks *et. al,* 2023). Study of the human body interaction also justifies the relationships of these systems for appropriate spatial orientation. While the human eye provides visual and spatial orientation with about 80% of the sensory inputs required for maintaining spatial orientation, other systems like the vestibular system, which lies in the inner ear, contributes about 15%, the proprioceptive sensory system, composed of receptors located in the skin, muscle, tendons, and joints, is responsible for the remaining 5% of the total sensory information required to establish spatial orientation (Stott, 2013). The interactions of these systems also produce near to complex coordination between all the sensory inputs, which are relatively translated and interpreted by the human brain, and the case of misinterpretation or inaccuracy resulting from three sources of information consequently produces sensory mismatch, resulting in varieties of visual or vestibular illusions, hence disorientation (Ponzo, *et Al.*, 2018).

Human ability to maintain body orientation and posture relative to his surrounding environment (in the physical space), whether at rest or when in motion, is regarded as Spatial orientation (Hunt & Waller, 1999). Naturally, all living creatures rely on spatial orientation for navigation. In the case of humans, everyday activities depend on spatial orientation for navigating accustomed routes from outside locations to our homes, etc. Likewise, the action of positioning oneself within an environment, as well as the representation of the position of environmental features and objects relative to one another and the process of continuous updating of this assimilated knowledge, are regarded as the key elements in spatial orientation.

According to Van den Brink & Janzen (2013), there exists a general agreement (of two systems) for physical location to be represented in two fundamental forms in order to allow the attainment of a successful orientation and navigation process (Newcombe & Huttenlocher, 2000).

(a) One of the systems involves the mental representation of object positions relative to an observer, termed egocentric coding. This system is often employed when the observer in a space is stationary or able to track movements based mainly on optic flow, vestibular, and proprioceptive signals, otherwise referred to as path integration.

(b) The next is the system referred to as allocentric coding, which is independent of the observer's current position and is dependent on additional externally referenced spatial coding drawn from inter-object interactions.

Studies show that these two-system models of parallel spatial representation generated by body and environment in object-location memory are largely evident in adult humans (Mou *et. al,* 2004), (Nadel & Hardt, 2004), (Burgess, 2006), (Waller & Hodgson, 2006). Humans adopt these systems in their senses to situate themselves in their environment. Equally, the discernment of space is not always the same for everyone and often differs according to other mental factors. Conversely, the process of finding one's way in our spatially extensive environments is essential for survival and thus requires a wide range of cognitive abilities to actualize. Dominant among these abilities is the use of long-term spatial memory to guide wayfinding. Findings on the human cognition abilities suggest that the configuration process of any given environment possesses distinctive cognitive consequences (Hillier, 1996). Invariably, the process of spatial configuration on its own could become constrained on spatial experience, as its elements may improve or hinder components of human activities through the aspects of spatial cognition and behaviors. Research identified the human ability to mentally represent large-scale space through a variety of tests, such as sketching maps, direction pointing, and practical route descriptions (Hugo & Eleanor, 2008). Studies further suggest that several qualitatively different spatial representation types may also support wayfinding process, which may include actions such as route knowledge, i.e., the knowledge of directions to turn at locations or landmarks, as well as the combined knowledge of the spatial relationships between locations and landmarks, referred to as survey-like knowledge (Siegel & White, 1975). This survey-like knowledge is believed to also represent the descriptions for spatial cognition and wayfinding principle referred to as cognitive maps, which provide humans with such abilities to take shortcuts in familiar environments (Tolman, 1948).

Wayfinding

Wayfinding can be defined as the process people adopt for purposes of orientation, route selection, navigation through spaces, and recognizing arrival at destinations (Al-Alwan & Al-Azzawi, 2014). This process goes beyond just the use of signages; rather, it functions as the complete system that adopts signage, maps, colors, symbols, and in modern times, it includes digital tools that make navigation instinctive

The term was first created by Kevin Lynch in his book "The Image of the City" in 1960 and has since expanded to accommodate other aspects of the built environment, especially public spaces like hospital corridors, university campuses, and other smart buildings.

Historically, Wayfinding can be associated with the ancient human navigation system. One of the earliest documented instances of wayfinding is attributed to Polynesian navigators, who crossed thousands of miles of open ocean with no maps or compasses, but rather used stars, patterns of sea waves, and bird migration as means of location and bearing (Inman, 2022).

Modern concepts of wayfinding became formalized in 1960 when Architect and Planner Kevin Lynch published The Image of the City, in which he identified five fundamental elements adopted by humans for mental mapping of surroundings as illustrated in Figure 1. These he described as:

i. paths,
ii. edges,
iii. districts,
iv. nodes, and
v. landmarks.

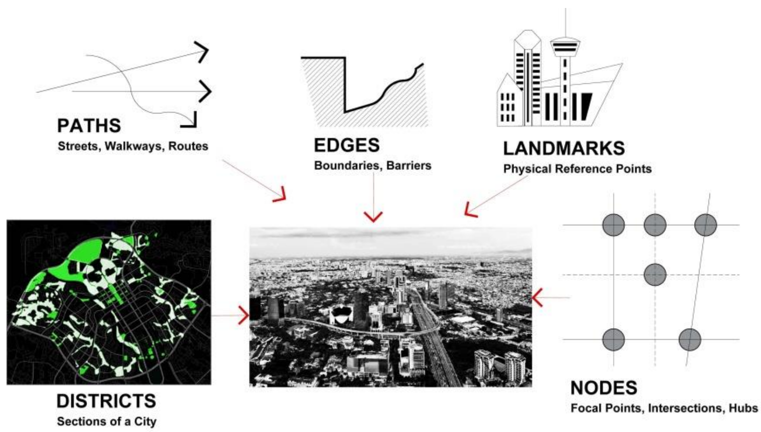

Figure 1. *Kevin Lynch's framework showing the five elements of urban design paths, edges, districts, nodes, and landmarks*

In 1981, it was expanded by researchers like Romedi Passini into a formal framework that thus defined wayfinding as a cognitive process rather than just a set of signs (Romedi, 1984). In contemporary times, wayfinding has advanced into the combination of cognitive principles with physical designs and digital technologies to aid in guiding humans through advanced complex spaces.

Wayfinding performance in buildings can be attributed majorly to circulation and spatial configurations. Successful wayfinding only occurred when the navigator makes correct navigation decisions that may take him/her from present location to a final destination which must fulfill the intended purpose of movement [21]. According to studies from [22], other principles that assist in successful wayfinding are listed as follows:

i. Location Distinctiveness
ii. Landmarks and Orientation
iii. Pathways or circulation configuration
iv. Zoning (Areas of Different visual characters)
v. Signage with Decision Points
vi. Sight Lines for Visibility

These principles all play intrinsic roles in assisting the wayfinding process. However, the dominant element of spatial configuration must firstly be established appropriately in building design before the adoption of assisted principles like signage. This is critical, as not all information is available in signage designs. This dominant element (spatial configuration) is the primary tool utilized by designers principally in defining the wayfinding process at the point of design and configuration of building layouts. The study of spatial configurations for purposes of improving wayfinding in building and city designs has evolved over the years. Modern tools and concepts like Space syntax theories (from where axial analysis and isovists are generated) are amongst the most popular tools used for analyses of spaces and layout configurations. Space syntax utilizes a set of theories and techniques for the analysis of spatial and layout configurations. It incorporates both evaluation of the applications and the adoption of the analytical techniques and theoretical ideas associated with the syntactic study of architectural spaces. According to Bill Hillier, space should be translated into graphical measures. However, in order to apply graph theoretic measures, geometries of a space must be read firstly and then translated into patterns that would support the type of analysis to be executed. This process encompasses the formation of spatial networks, which invokes syntactic properties of global and local spatial systems with the aid of syntactic axial and convex maps. The three fundamental concepts that enable assessment of spatial circulation effectiveness in space syntax include:

i. Axial lines; defined as straight sightlines and possible paths.
ii. Convex spaces; defined as inhabitable voids where no line between two of its points goes outside its perimeter.
iii. Isovist fields; which are referred to as view-sheds or visibility polygons, indicating field of view from any particular point in a space.
iv. This study utilizes the first concept (Axial analysis) to analyze the performance of layout configurations relative to spatial orientation and the wayfinding process.

Why This Book Matters

It is evident that the larger the buildings get, the more the challenges of spatial orientation for its users. Likewise, building forms and configurations impact significantly on the course of wayfinding. Even in hospitals, spatial configuration has been identified as significant in influencing human movements, performances of users and the efficiency of services. This book thus provides strategies that could be adopted by scholars and building designers for analyzing layout configurations relative to spatial orientation and wayfinding process. This is intended to assist in building design processes while aiming to reduce the challenges of spatial disorientation for building users, visitors and patients.

CHAPTER 2

Spatial Cognizance Principles

The process of wayfinding in and around built environments is the first step towards efficient movements and flow within spaces. In the case of large public buildings such as institutional buildings, airports, hospitals, museums, malls, and office buildings, wayfinding challenges often pose frustrating experiences, resulting in mental and psychological stresses, which may translate into disorientation. Studies on human behaviors in built up spaces show that orientation problems do not often originate at the front doors; rather, orientation challenges starts long before people enter a facility and may often continue long after they have arrived at their destination again. This is due to the fact that wayfinding capabilities are shared across numerous mediums, including through visitors who eventually pass on their experiences (emotionally) to friends and relatives, and the process continues downwards until each individual, in turn, develops their own expectations (Ullas & Aju, 2014; Hashim & Said, 2013). One of the most common principles for successfully navigating through the course of wayfinding is the generation of pathways. Tolman defined Pathways as routes to locations. This concept suggests that every individual employs cognitive maps for wayfinding. This concept defines 'Cognitive Maps' as mental representations which are utilized to obtain, store, memorize, code, and decode spatial information about the relative locations and features of phenomena in the environment. Analyses of the impact of layout organization on wayfinding performance, alongside user-cognitive representation of real-time spatial information, identify pathways as fundamental components of the spatial cognition process. The analogy of cognitive wayfinding describes the human ability to make use of long-term spatial memory to guide wayfinding. The process describes the originated mental map that resides in the head and examined by the mind's eye, as functionally identical to the graphical map that is inspected in the physical environment (Russell et. al, 2017). Kuipers (1982) suggests that cognitive map information is likewise isomorphic to data held in a graphical map; further information added to, or retrieved from, the cognitive map is considered same as that processes used for the adding and retrieval of information from a physical graphical map. Although this characterization does not imply the existence of a region in the physical brain where the entire environment is physically mapped, nevertheless, it indicates the availability of correspondence between the products of information input and output behaviors of the storage (visual data) and retrieval functions (Osman & Suliman, 1994). When related to wayfinding in built environments, it is believed that the layout of spaces influences the accuracy of the actual cognitive representations in real-world spatial configurations (Brunye *et al,* 2018). These layouts of spaces eventually form pathways or network structures used in our everyday spatial activities, and they, in turn, develop into critical elements of the mental image of the spatial environment (Golledge & Stimson, 1997).

Fundamental Principles of Spatial Cognition

Spatial cognition comprises the human brain's capability to process, encode, decode, and mentally manipulate spaces in terms of location, size, distance, and movement of objects within the space. The principles of spatial cognizance are initiated from fields like cognitive psychology, which guides how humans navigate environments and interact with digital or physical spaces/systems (Werner *et al*, 1997).

Core Cognitive Skills

These are the fundamental mental processes that are applied during the process of human interaction with spaces. They includes the process of acquisition, organization, usage, and alteration of information about spatial environments. The basic cognitive skills adopted when interacting with the environment are discussed below:

Mental Rotation:

Mental rotation is described as the capacity to visualize, as well as rotate, 2-dimensional and 3-Dimensional objects in the mind's eye in order to understand how they look from different angles. This is demonstrated in the sample task presented in Figure 2, where two sample items presented on the left are described using the four figures on the right to depict the figure on the left in alternative positions. Originally established by psychologists Roger Shepard and Jacqueline Metzler, mental rotation is a core skill for basic spatial reasoning, mathematics, and navigation. This is a basic skill required in modern times as the task of spatial recognition evolves into more complex understanding of built environments.

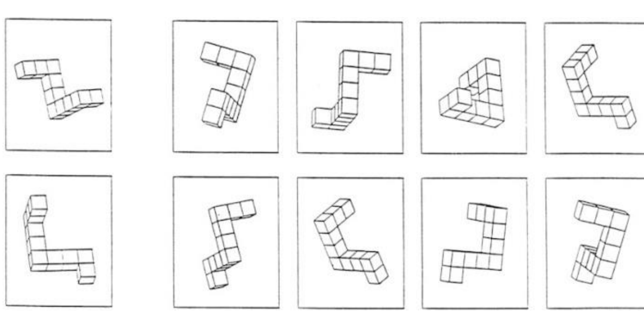

Figure 2. *Two sample items from a mental rotation test. (Source: Silverman, et. al, 2000)*

Spatial Perception:

Spatial perception involves the exteroceptive and interoceptive process. While the exteroceptive process is the ability of humans to be aware of their relationships with the environment around them, the interoceptive processes, on the other hand, relates to the awareness of the relationship with oneself. This awareness is comprised of representations about our space through feelings, and representations about our body as with respect to position or orientation. Spatial perception aids in the accuracy of gauging distances, relative positions, and the spatial layout of your surroundings (Gori *et al,* 2026).

The core components of Spatial perception include the following:

i. **Depth & Distance Perception:** Where the brain estimates how far away objects are and how they move through space. This component heavily relies on visual cues, sound localization, and tactile reactions.
ii. **Mental Rotation:** The ability to visualize and manipulate 2D or 3D objects in the mind's eye without physically touching them. This basic component enables the understanding of objects through mere visual contact.
iii. **Navigation & Orientation:** This is regarded as the process of mentally mapping routes, understanding topographical maps, and orientation within an environment.

Spatial Visualization:

This component is defined as the ability to imagine the actual look of an object or a complex 3D shape when its parts are disfigured, rotated, or folded. This involves the mental simulation of the real natures of objects when undergoing multi-step changes. Such skills are used in the arrangement of furniture to fit into rooms or arrangement of puzzle pieces to fit into accurate forms. A basic spatial visualization skill is experienced in the arrangement ability utilized in the game of "Tetrix," as seen in Figure 3.

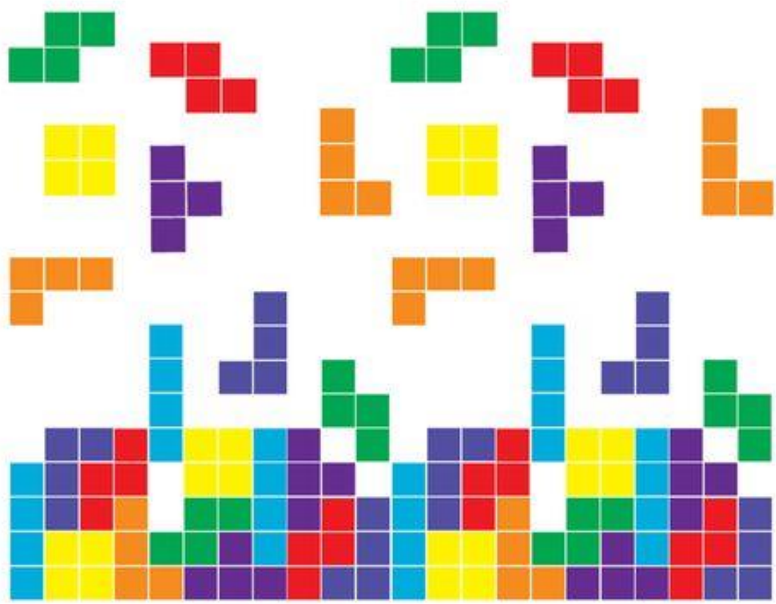

Figure 3. *Tetrix used to exemplify the Spatial Visualization skill*

Spatial Memory:

This is described as the ability to temporarily hold, while at the same time processing, the locations of various objects or landmarks in one's head while conduction other daily tasks. Such skills are exemplified in the activities like the tracking a set of directions without the use of a map. This skill assists in remembering locations of stored objects, the creation of cognitive maps, or the use of landmarks to navigate through spaces. The primary principles associated with this process as shown in Table 1 include the **Allocentric Memory,** which is utilized in remembering the location of objects relative to external landmarks, irrespective of current location; **Egocentric Memory,** which deals with the process of recollecting object locations relative to one's current bodily position and perspective: as well as the **Visuospatial Working Memory,** which is used for temporarily holding and manipulating visual and spatial information (McAfoose & Baune, 2009).

Table 1. **Comparison between the Allocentric and Egocentric cognitive memory paths**

Feature	Egocentric Memory	Allocentric Memory
Definition	Locations are coded in relation to observer's body, head, or eyes.	Locations are coded based on external landmarks or relative to objects.
Perspective	Perceived as "To my left", "behind me", "within arm's reach"	Viewed as "North of the park", "between the building and the tree".
Navigation Style	Follows a memorized sequence of turns based on individual's perspective, thus **Route based**.	Understanding a broader layout of an area, independent of individual's current position, thus **Map based**
Brain Networks	Relies mainly on the precuneus, dorsal visual stream, and parieto-frontal networks.	Relies mostly on the hippocampus, right parietal lobe, and ventrolateral occipito-temporal cortex.
Typical Application	In actions like reaching, pointing, or walking directly to a specific object.	In activities like General navigation, spatial planning, and learning complex layouts.

Spatial working memory is illustrated in Figure 4, with the Visual depiction of the Brooks spatial working memory task.

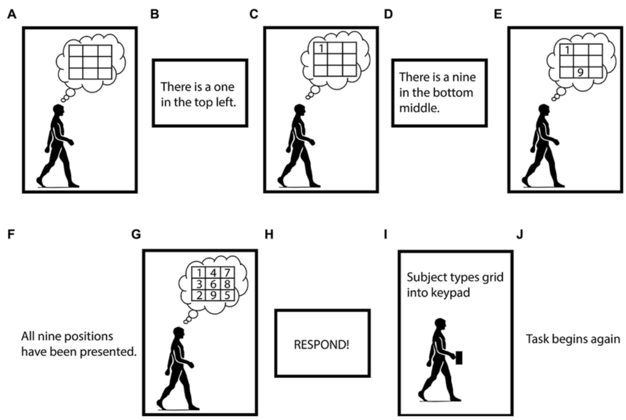

Figure 4. *Visual depiction of spatial working memory task.*
(Source: Kline, et. al, 2014)

Challenges of spatial Cognizance and Disorientation in Buildings

Spatial orientation in a large space is attributed as fundamental for the organization of all meaningful behavior within the space. Since wayfinding is defined as the process of identifying locations and navigating to a destination using mental environmental information, the ability to comprehend one's environment by way of spatial cognizance is the first principle towards successful wayfinding spaces. Degrees of place capacity or volumes of functional spaces affect people's capabilities to mentally grasp the composition of the environment. Studies show that the ability to control space is achieved either through the process of habitual occupation, by personalization, or by mere marking (Gifford, 1997). The composition of modern large buildings has evolved over the years, resulting in complex environments comprising lengthy and confusing pathways and corridor systems with bends, turns and confusing signage systems (Rooke, 2012). These types of settings pose enormous challenges as well as frustrations for visitors and building users. Most significant in the classification of modern large buildings are Hospital buildings. Figure 5 illustrates the comparative value of building space weights to wayfinding cum-spatial-orientation difficulty levels. As shown in the illustrations, when building spaces grow larger, the spatial orientation and wayfinding difficulty grows.

Figure 5. *Building sizes relative to Spatial Orientation difficulty levels*

According to Rachel K. Meeks et al (Meeks *et., al*, 2023), in order to achieve adequate orientation, the human body depends on accurate perception and cognitive integration of these systems. Study also agrees that the collective systems of visual, vestibular, and proprioceptive stimuli differ in magnitude, direction and frequency, and the inappropriate coordination of these systems results in spatial disorientation. The Study of human body interaction also justifies the relationships of these systems for appropriate spatial orientation. While the human eye provides visual and spatial orientation, with about 80% of the sensory inputs required for maintaining spatial orientation, other systems, like the vestibular system, which lies in the inner ear contributes about 15%, the proprioceptive sensory system, composed of receptors located in the skin, muscle, tendons, and joints, is responsible for the remaining 5% of the total sensory information required to establish spatial orientation (Stott, 2013). The interactions of these systems also produce near to complex coordination between all the sensory inputs, which are relatively translated and interpreted by the human brain, and the case of misinterpretation or inaccuracy resulting from three sources of information consequently produce sensory mismatch, resulting in varieties of visual or vestibular illusions (hence disorientation).

According to studies (Carlson, *et al*, 2014), (Mastrodonato, *et. al*, 2016), Major architectural and cognitive factors that drive Spatial Disorientation in buildings include:

i. **Complex or Symmetrical Layouts:** Extremely complex building layouts often severely inhibit user's ability to predict navigation routes. Likewise, the application of geometric symmetry without unique architectural features in building design has been identified to cause building users to revolve repeatedly in an attempt to orient themselves within built spaces.
ii. **Poor Visual Accessibility:** Similarly, the lack of clear sightlines or destination points from locations and decision-making nodes often causes disorientation, thereby compelling users to depend exclusively on signage rather than natural navigation skills.
iii. **Vertical & Inferential Disorientation:** In environments with Multi-level spaces, poorly positioned staircases often heavily disrupt spatial memory. Users of such buildings often struggle to align mental images as they arrive on

different floors, thereby getting lost as they transition between different levels.

iv. **Feature Similarity & Repetitiveness:** The adoption of identical-looking corridors (circulation pathways), elevator lobbies, or undistinguished lengthy walls, as mostly observed along lengthy hospital corridors, is known to deny the environment distinctive reference points, thereby resulting in failures in the cognitive mapping process (hence disorientation).

Factors that may predict successful navigation in buildings, as illustrated in Figure 6, includes correspondence between the building and the cognitive map; compatibility between strategies, individual differences, and building; completeness of the cognitive map as a function of strategies and individual differences; and finally, the complexity of the interaction between the structure, map, strategies, and spatial abilities (Carlson, *et. al*, 2014).

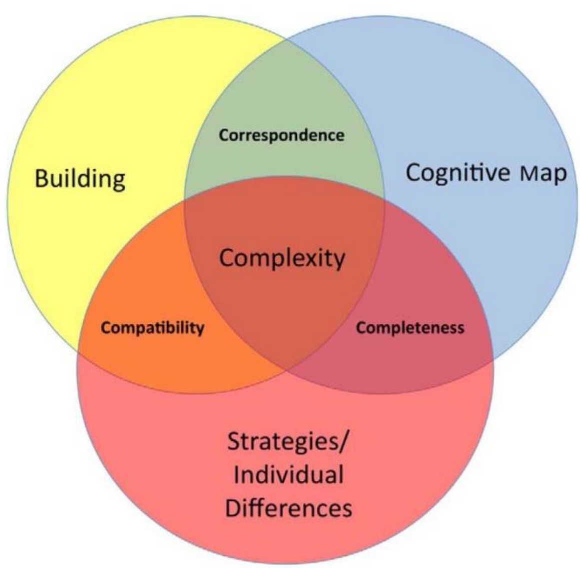

Figure 6. *Factors predicting navigation in buildings*
(Source: Carlson, *et. al*, 2014)

CHAPTER 3

Understanding Circulation and Flow Patterns in Buildings

The process of building design, spatial layout, and arrangement provides information about the organization ability of an Architect or Planner. Spatial Circulation is generally defined as the relative easiness and modes of flow through and within a building, mostly in the network of spaces or routes. Studies on environmental cognition theories identify a general problem in the structuring of communication and transaction between individuals brought about by co-presence in space. This situation is largely determined by local visual fields in common spaces and perception of users, which aligns movement routes through that visual field. By nature and behavior, humans ultimately define their paths through spaces by way of choice and convenience. The natural human behavior in built-up spaces is often determined by the building form and layouts. In other words, circulation describes how people make their way through a building. Do users respond to designed plans for circulation and flow? What pathways do users take? Do visitors circulate the way the designers intended, or do they deviate? As the form and space in architecture is distinguished according to the function and structure of the building, so is the flow within the building. The different flow systems observed in buildings are referred to as Circulation Patterns. In reality, paths of human movement through buildings are actually the element that links different spaces together. When circulation occurs in architecture, it is a combination of these natural tendencies of people to flow in one direction or another. The essence of design to guide flow patterns in Architecture is fundamental in the definition of navigation, orientation, and way-finding. The interdependent relationships between the building itself and the people who move within it is what creates the dynamic flow that is referred to as Circulation.

Wayfinding is about the first step towards efficient flow and movement in buildings. Wayfinding around public buildings such as airports, museums, hospitals, office buildings, or university buildings often proves to be challenging and frustrating. According to studies, orientation problems do not start at the front door. They rather begin long before people enter a facility and often continues even long after they arrive home again, as wayfinding capability is shared through visitors who pass on their experiences (emotionally) to their friends and relatives, who in turn develop their own expectations (Hashim & Said 2013).

To successfully navigate through the course of wayfinding, pathways are developed. Pathways are defined as routes to locations. Psychologically, recognition of pathways is a vital element of the wayfinding process. This concept was originally introduced by Edward Tolman in 1948, which suggests that every individual utilizes cognitive maps for wayfinding. The concept suggests that cognitive maps are mental representations which are utilized to acquire, store, recall, code, and decode information about the relative locations and traits of phenomena in the environment (Tolman, 1948). Study shows that the impact of layout organization on wayfinding performance, as well as user-cognitive representation of real-time spatial information, are fundamental components of the spatial cognition process. The analogy of cognitive wayfinding is such that the map that resides in the head and examined by the mind's eye, is functionally identical to the graphical map that is inspected by the physical (Russell, *et. al,* 2017). This indicates that cognitive map information is likewise isomorphic to information held in a graphical map, and thus, any information added to, and retrieved from the cognitive map is similar to, or same as the processes used to add and retrieve information from a graphical map (Kuipers, 1982). This definition does not signify that there exists a region in the physical brain to which the entire environment is physically mapped, however, it connotes that there will be a correspondence between the products of input and output behaviors of the storage and retrieval functions (Kuipers, 1983).

In building design, especially hospitals and public buildings, circulation plays a significant role in defining the efficiency of services (Dalton, *et al,* 2019). According to Hillier (1996), the spatial configuration in buildings influences human movement flows, which impacts the behaviors of the users moving through the building space and the level of decisions they make. Reviews on the state of healthcare facilities globally, revealed the existence of assiduous appraisal systems across the various sectors. Prominent amongst these are evaluation works in the areas of management and planning of these facilities. In the past, such systems like "Descriptive event stimulation was utilized in assessing the performance of public buildings like hospitals in the area of operations management. Through the years, it's been observed that one of the biggest challenges in healthcare facility development and management are highly dependent on architectural planning. Although, in developing countries like Nigeria, the challenges of healthcare administration, coupled with the uncoordinated development of facilities, most times leave a range of conflicts in the planning and management of the facilities (Osefoh, 2013). This, in effect, affects all spheres of functions, including management of staff, patients and equipment services.

Public building designers often employ different layouts and configurations as approaches for improving flow efficiency. Study has it that the quality of care, patient health, and wellbeing in hospital buildings has links with the physical attributes of the healthcare environment (Parsia & Fadzline, 2018), (Gesler, *et al,* 2004). Likewise, Research identifies that by improving access and people circulation in hospitals, staff performance and productivity can be improved as well as enhancing patients' safety, privacy, and rate of recovery. These consequently reduce the risk of cross-infections, decrease delay time experienced in external service delivery, achieve friendly environment for hospital visitors, as well as reduction in the evacuation time in emergency services (Nazarian, *et. al,* 2011).

Despite all studies in the circulation and wayfinding process, there still exists a gap in comprehending the full relationship between 'Circulation' as a design element and the ease of wayfinding for users. Thus, the assessment of circulation efficiency required understanding the critical elements that form the circulation component of a facility. Identifying these elements then becomes the most critical action towards resolving the ensuing conflicts in the patterns of patient traffic and staff circulation.

In modern times, the evaluation techniques employed in the appraisal of public buildings and associated facilities range from spatial theories combined with activity patterns. One of these theories is the Space Syntax Theory by Bill Hillier. Using this theory, the essential patterns of flow within public facilities can thus be predetermined through the evaluation of variables in the range of movement patterns, circulation, and Isovist.

Spatial Theories

Spatial theories in architecture involve the application of traditional theories and normative theories, respectively. Whilst traditionally, space is interpreted as a homogeneous structure of its own and exists independently of things, absolute space serves as the ultimate framework for the positions and motions of objects and the relative space within it. A metaphor normally used to describe this interpretation of space is a “container” or “arena”;, objects and events occur “in” space, but space itself is independent of them (Arisaka, 1996). In the normative sense, however, space is mathematical and can be controlled (Campbell, 2016). Hillier et al., believes that, in order to design harmonious buildings, designers should aim for the mathematical order found in nature. This offers a method of calculating proportions to serve as a technique for realizing this aim in architectural terms (Hillier & Hanson, 1984). The Space Syntax approach quenches the most common architectural theories that leaned more on the normative. It rather presents a stronger analytical approach, which is lacking in most spatial theories of the past.

Studies on the human cognition values suggest that configuration process of any environment possesses significant cognitive consequences. According to Hillier, spatial configuration on its own could become constraints on spatial experience because its elements may improve or impede aspects of human activities through spatial cognition and behaviors. Consequently, the spatial layout of every built environment influences the accuracy of cognitive representations of real-world spatial information (Brunye *et. al,* 2018). Furthermore, pathways or network structure used in our everyday spatial behavior eventually becomes critical elements of the image of a spatial environment (Golledge & Stimson, 1997). More so, images of spatial environments can be achieved only if they are configured as patterns of high continuity with a number of distinctive but interconnected parts (Lynch, 1960). In the case of buildings, patterns of circulation define the intrinsic systems for wayfinding, and to understand the concept of wayfinding in buildings, the process of circulation must be comprehended.

Space Syntax Theory

Space syntax encompasses a set of theories and techniques for the analysis of spatial configurations. This involves both exploration of the applications and extension of the analytical techniques and theoretical ideas associated with the syntactic analysis of architectural spaces. The major objective of Space syntax is providing a systematic and quantitative account of building configuration in order to support the understanding of how buildings function.

In application, space must be translated into graphical measures. But in order to apply graph theoretic measures, the geometry of a space must first be read and translated into a pattern that supports the type of analysis to be performed, for example, the process of intersecting lines of movement, connected 2-D convex spaces, or intersecting visual polygons. This involves the establishment of spatial network invoking syntactic properties of the global and local systems with the aid of axial map and convex maps.

Space syntax applications involve three basic elements of space:

i. **Isovist,** referred to as viewsheds or visibility polygon. This is the field of view from any particular point in a space.
ii. **Axial space,** which is mostly a straight sight-line and possible path.
iii. **Convex space,** which is an inhabitable void where (if imagined as a wireframe diagram), no line between two of its points goes outside its perimeter; in other words, all points within the polygon are visible to all other points within the polygon.

The most popular Space Syntax analysis methods include Integration, Choice, and Depth Distance. The circulation system in buildings can be compared to the veins of organisms. The veins create a network in the body, and it arranges the flow of blood through pressure. In Space Syntax analysis, the shape of these veins and their integration with cells is compared to the spaces in a building. Be it a linear or circular architectural geometry, the shape of the building affects the legibility of the spaces. The justified graph developed from the layout of the building, the architectural form, the space and circulation relationship, the linearity or centrality of spaces is interpreted with the language of Space Syntax using depth or shallowness as "relative asymmetry" (Hillier & Hanson, 1984). According to studies on space syntax (Osman & Suliman, 1994), the fundamental formula for calculation of the Relative asymmetry is generated as follows:

Mean depth (md) = I/ (K - 1). ∑ (all depth values between a point & all other points in a graph) **(1)**

The depth value between two points in a graph is equal to the minimum number of connections that must be taken to reach from one point to the other (the shortest path). K is the total number of nodes in a graph, including the outside node.

Relative Asymmetry (RA) = 2 (md - 1)/ (K - 2) **(2)**

Circulation and Movement Configurations within Public Buildings

Configuration simply means a set of relationship among things, all of which are interdependent in an overall structure. Understanding the idea of relationship is to redefine spatial relation as existing when there is any type of link, adjacency, or permeability between two spaces. Subsequently, configuration only exists when relations between two spaces are changed according to how we relate one to the other or both to at least one other space [16]. Additionally, it is possible that our normal experience of buildings is affected by the way in which spaces are connected to each other. The changes of direction imposed by the circulation system, the creation of room sequences, the distribution of branching points, the availability of alternative routes, and the relations of visibility between and across spaces all sum up the define the configuration (Peponis, 2012), (Lynch & Hack, 1984).

Any interaction with a space begins with the access. Accessibility is the prerequisite to using any space; thus, without the ability to enter or move within it, or to receive and transmit information or goods, space is of no value, however vast or rich it may be. In architectural practice, there is no finitely established circulation principle. While some studies suggest that simpler layouts improve way-finding and cognitive process, others believe in the combination of patterns from various geometric rules or elements for navigation (Hölscher & Brösamle, 2007). Conversely, interconnected buildings, typical of large hospital buildings and educational settings, are generally not understood as forms. A good form of a circulation system, such as simple geometrical forms like Squares, Cruciform, or an L-shaped form, aids in understanding the complexity of layouts as soon as the cognitive response of a person recognizes or notices the specific shape as an underlying principle in the order of its configuration. This action, in turn, can inform and consequently support wayfinding and circulation performance (Passini, 1996).

Primarily, all paths of movements are linear in nature. Likewise, all paths emanate from a starting point, from which we are taken through a sequence of spaces to a destination. Nonetheless, paths can also be segmented or curvilinear. they can also intersect to branch into other paths, or form a loop. The type of configuration of a path influences and is impacted by the organizational pattern of the spaces it is made to link. The configuration of a path often reinforces a spatial organization by reiterating its pattern. It may also contrast with the form of the spatial organization and serve as a visual counterpoint to it. By so doing, we are able to cognitively map out in our minds the overall configuration of the paths in a building, our orientation within the building, and eventually the understanding of its spatial layout (Ching, 2007). A path may be made radial when multiple paths culminate or extend from a shared central point. It may also be a continuous path revolving around a central point, forming a spiral. Path networks can take one of several general forms, such as the grid, radial and linear.

Illustrations of Circulation Configurations using Healthcare Buildings

As a factor of fundamental criteria in public building design, like hospitals, circulation zones are treated as the most fundamental features of the functional environment. A typical instance in this case is the hospital Building design, where the fundamental features relate to the healthcare environment. The complexity of hospital circulation configuration is often compounded by the variety of users/traffic (movements) with interweaving paths of flows. Volume of circulation activities in hospitals are determined primarily by the following category of traffic:

i. People;
ii. Material Supply and distribution;
iii. Ancillary Services.

Hospital designers are often faced with the challenges of minimizing patient travel distances to this end, hospital layouts are configured to ensure the reduction of operational time, which impacts delays in patient care and patient flow. Studies identified that the most common circulation design layouts employed in modern hospital designs, especially in the wards and patient care zones, are the Linear and Radial configurations.

Linear Layouts

The linear configuration in hospital design typifies the corridor layout design, where the Service zones and Nursing stations are accessible to active patient care zones by a linear flow, as shown in Figure 7. The linear patterns can be configured as single-corridor layout, double-corridor layout, straight or L-shaped layouts, and looped corridor layouts. The option of single-or double-loaded corridor system provides the potential for collecting larger numbers of patient rooms to strategically located Service zones and Nursing stations.

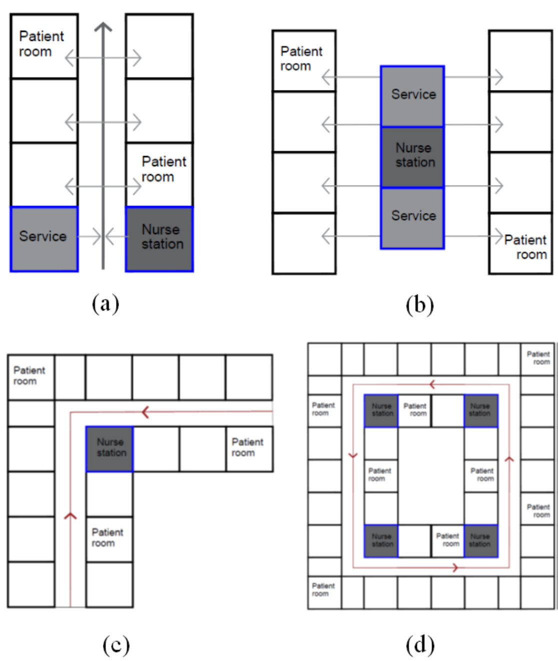

Figure 7. Linear flow configuration showing (a) single corridor layout, (b) double corridor layout, (c) L-shaped, and (d) looped corridor layouts

Radial Layouts

Radial layouts (Figure 8) are configured to collect all active patient care zones to a centralized Service core and Nursing station. This offers direct view to the central core and makes accessibility easier for the Caregivers. However, this gives rise to numerous cluster systems, as only a few patient rooms can be connected to a central service core.

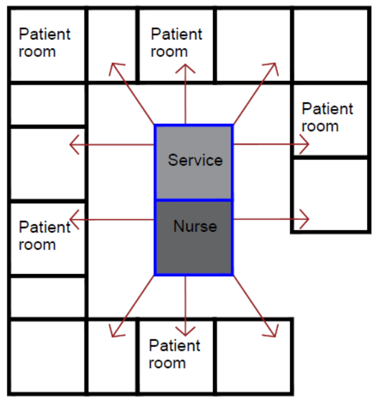

Figure 8. *Radial flow configuration, showing a centralized Service zone and Nursing station.*

Evaluating the Circulation Efficiency of Different Circulation Configurations in Healthcare Buildings

In order to evaluate the performance of circulation configuration in public buildings, this section of the book focuses interest on the internal circulation within hospital buildings. This is because a hospital building possesses a complicated setting comprising many functions and variety; therefore, wayfinding in such a configuration depends highly on the capability of occupants. The legibility of the building and the means of wayfinding are important aspect of circulation in such a complicated building type. The parameters affecting the legibility of hospitals may be considered as the geometric shape of the corridors, the ergonomics of the spaces, as well as characteristics of occupants (Unlu *et al*, 2005).

To further demonstrate the effective theory of circulation in hospital design, a selection of cases is analyzed. The main factors considered in the spatial and circulation analysis are as follows:

iv. **Geometry:** Shape of building as a whole, or the configuration of the buildings.
v. **Path:** Routes of circulation system within the buildings.
vi. **Cells:** Activity spaces around the routes.
vii. **Flow:** Pattern of movement within the routes.

The Above-stated factors are the general factors considered in spatial circulation analysis. The syntactic analysis approach employed in this study identified two major parameters that summarized the four spatial principles stated above. These parameters, in this case, are used in calculating and deriving the circulation efficiency (CE). They include;

- **Real Integration:** Used to calculate the asymmetry value, with the equation:

$$RA=2(MD-1)/(K-2) \qquad \textbf{(3)}$$

- **Visibility:** The VGA representation of the flow patterns within a building, employed to determine visibility values from points in the buildings.

For the purpose of the evaluation exercise, three hospitals are selected for analysis of spatial configurations as well as the circulation efficiency.
The three selected hospitals include the

i. Enugu State University of Technology Teaching Hospital Parklane **(ESUTH),**
ii. University of Nigeria Teaching Hospital **(UNTH),**
iii. Baze University Hospital Abuja **(BUH).**

Investigative measurements were carried out in these hospitals. The required information generated was:

- The existing building layout and real-time floor plans (this was required to determine the building form, both the layout and archetype utilized in the design). These will be used for the analysis of the Visibility values, which justifies the wayfinding performance of the circulation system adopted in the designs.
- Patterns of movement of the patients from the egress point (main entrance carriage) to the outpatient unit, consulting rooms, treatment, and diagnosis labs. These were collected using a data-logging graph, which measured time and population.

For the Circulation Efficiency **(CE)** analysis, the two major factors, (i) Real integration and (ii) Visibilities (Isovist of sights), were determined for each hospital. Visibility isovists are used to represent the spatial configuration. They are spatial representations based on isovists, often used to illustrate the visible areas around generating points in space occurring at 360 degrees. This representation provides a description of space from the interior of the building. It also describes space from the point of view of users of a building, as they view, interact with, and move through it (Pachilova & Sailer, 2020).

Furthermore, the buildings were subdivided into cells, and space depths were assigned to each cell as a function of dimension. Values were generated for all entrance point in all the cells (nodes). Through these, the relationship between cells & nodes were determined. These space syntax parameters were employed to establish the permeability of the spaces through the geometry of the buildings. The real integration (RI) values were calculated for each hospital buildings using asymmetry equations and the values generated from the analysis. For data collection, the following was employed:

- Direct observations of movements of patients in the outpatient departments of the hospitals under review.
- The as-built Architectural floor plans of the outpatient departments of the respective hospitals were obtained.
- Recorded pattern of visits and exits of patients for the periods of the day under review.

With the outcome of the study in each hospital, it is possible to evaluate the relationships of these parameters with each other and with the total Circulation Efficiency (CE) factor, CE = RI + V (where RI is the Real integration values and V is the Visibility isovist).

For the purpose of the assessment, Investigative measurements were carried out with the primary objective centered on synthesizing the behavioral phenomenon associated with real-life context into patterns analyzable through space syntax. In order to do this within the research objectives, the study is set to process information gathered during fieldwork surveys and the experimentation process undertaken within the selected study cases.
The selected hospitals are presented according to their Circulation configuration, as identified below:

CASE 1 – The University of Nigeria Teaching Hospital (UNTH), Ituku, with the Linear Circulation Pattern
CASE 2 – The Enugu State University Teaching Hospital (ESUTH), with the Multilateral Circulation Pattern
CASE 3 – The Baze University hospital Abuja (BUH), with the Looped (Linear) Circulation Pattern.

CASE-1

Investigation and Analysis of the Linear Circulation Pattern (UNTH Hospital)

The survey was carried out at the University of Nigeria Teaching Hospital (UNTH), Ituku. The survey was restricted to the outpatient departments, which are the busiest section in most hospitals in Nigeria. The aim of the survey was to firstly investigate the patterns of movement of patients and visitors from the main carriage point to various facilities. To do this, frequency-of-flow data were collected, measuring time and population. Furthermore, the existing building layout was substantiated, and the building form and archetype documented. This would help in generating the necessary space depth information for determining the degree of Circulation efficiency in the hospital.

Evaluation of the Pattern and Frequency of Patient traffic flow in the Linear Pattern:

During this exercise, the main entrance point of the building was regarded as the major carriage point. From this point, visitors were studied and counted, while their paths were documented as they crossed from one activity area to another until their final departure from the department. Figure 10 shows the typical pattern of movement observed during the study.

Figure 9. Picture of the main carriage corridor (linear path) of the outpatient department, UNTH, showing the direct visibility along the corridors.

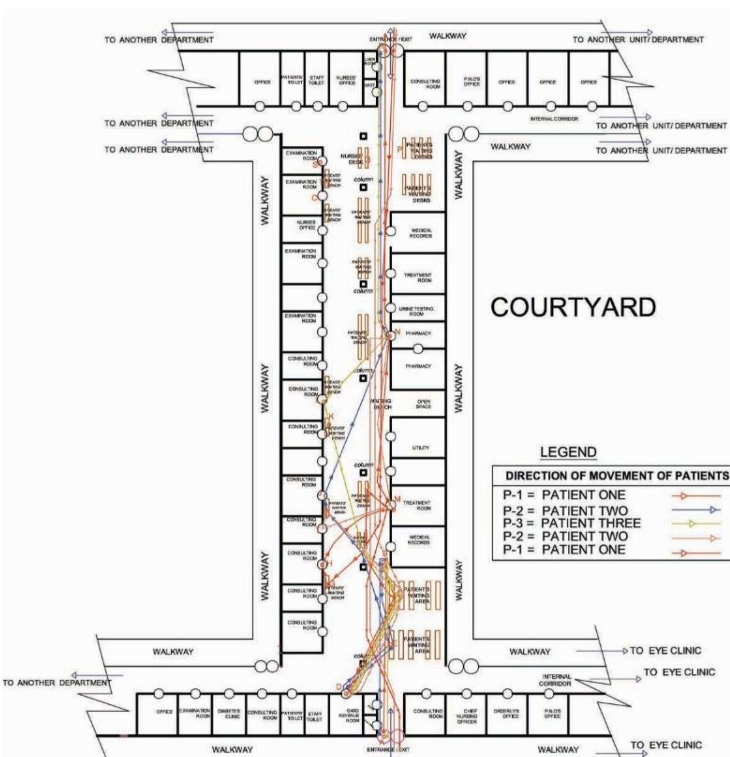

Figure 10. *Movement patterns of Patients/visitors observed at the UNTH hospital*

Analysis of the Circulation Efficiency of the Linear Pattern:
For the analysis of the Circulation efficiency (CE) of the Linear Circulation Pattern, the two major factors, (i) Real integration and (ii) Visibilities (isovist of sights), necessary for establishing (CE), are determined. This process involves subdividing the various spaces in the outpatient department into cells. These cells (as shown in Figure 11) will be assigned space depths as a function of dimension to aid in calculating the Real Asymmetry value (value of Integration) and the Isovist factor (visibility). The spaces covering 0 to 28 cells are used for this study.

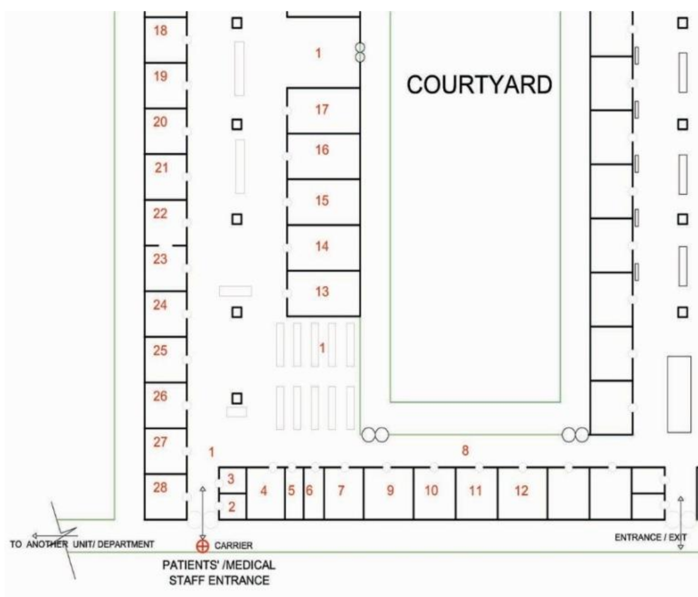

Figure 11. *Floor plan of the UNTH Linear Circulation Pattern showing the different spaces as Cells, with 0 to 28 (29 depths in all)*

Deriving the Real Integration (RI) value of the Linear Pattern:
With the formula for calculating Real Integration (using the Real Asymmetric value)

$$RA = 2(MD-1)/K-2 \qquad \textbf{(4)}$$

Where K = 29

The RI for the Linear pattern [UNTH] calculation is derived as seen in the Table 2 below.

Table 2. *Tabulation of space cells and space depths for Real Integration calculation of the UNTH Linear Circulation pattern. The RI value =0.074*

CEL		1	2	3	4	5	6	7	8	9	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	
	0	1	2	2	2	2	2	2	2	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
1	1	0	1	1	1	1	1	1	1	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
2	2	1	0	2	2	2	2	2	2	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
3	2	1	2	0	2	2	2	2	2	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
4	2	1	2	2	0	2	2	2	2	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
5	2	1	2	2	2	0	2	2	2	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
6	2	1	2	2	2	2	0	2	2	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
7	2	1	2	2	2	2	2	0	2	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
8	3	2	2	2	2	2	2	2	0	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
9	4	3	3	3	3	3	3	3	1	0	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	
10	4	3	3	3	3	3	3	3	1	2	0	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	
11	4	3	3	3	3	3	3	3	1	2	2	0	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	
12	4	3	3	3	3	3	3	3	1	2	2	2	0	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	
13	2	0	2	2	2	2	2	2	2	3	3	3	3	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
14	2	1	2	2	2	2	2	2	2	3	3	3	3	2	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
15	2	1	2	2	2	2	2	2	2	3	3	3	3	2	2	0	2	2	2	2	2	2	2	2	2	2	2	2	2	
16	2	1	2	2	2	2	2	2	2	3	3	3	3	2	2	2	0	2	2	2	2	2	2	2	2	2	2	2	2	
17	2	1	2	2	2	2	2	2	2	3	3	3	3	2	2	2	2	0	2	2	2	2	2	2	2	2	2	2	2	
18	2	1	2	2	2	2	2	2	2	3	3	3	3	2	2	2	2	2	0	2	2	2	2	2	2	2	2	2	2	
19	2	1	2	2	2	2	2	2	2	3	3	3	3	2	2	2	2	2	2	0	2	2	2	2	2	2	2	2	2	
20	2	1	2	2	2	2	2	2	2	3	3	3	3	2	2	2	2	2	2	2	0	2	2	2	2	2	2	2	2	
21	2	1	2	2	2	2	2	2	2	3	3	3	3	2	2	2	2	2	2	2	2	0	2	2	2	2	2	2	2	
22	2	1	2	2	2	2	2	2	2	3	3	3	3	2	2	2	2	2	2	2	2	2	0	2	2	2	2	2	2	
23	2	1	2	2	2	2	2	2	2	3	3	3	3	2	2	2	2	2	2	2	2	2	2	0	2	2	2	2	2	
24	2	1	2	2	2	2	2	2	2	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	0	2	2	2	2	
25	2	1	2	2	2	2	2	2	2	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	0	2	2	2	
26	2	1	2	2	2	2	2	2	2	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	0	2	2	
27	2	1	2	2	2	2	2	2	2	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	0	2	
28	2	1	2	2	2	2	2	2	2	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	
29	2	1	2	2	2	2	2	2	2	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
MD.	2.28	1.28	2.08	2.03	2.1	2.1	2.1	2.1	1.76	2.69	2.69	2.69	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	RA=0.074

Deriving the Isovist (Visibility) value for the Linear Pattern:
The visibility map shows the level of Isovist of sight, or range of Visibility, across spaces. The numbers indicate the level of obstruction between sights (sight depths). Figure 12 shows the Visibility mapping of the UNTH Linear Circulation pattern.

To calculate the Visibility function *(V)*, the mean of the sight depths is divided by the total number of Cells (spaces) under evaluation.

Mean sight depths = 1.96
Number of Cells = 29
Visibility function = 1.96/29 = 0.067

In the case of the Linear Circulation pattern, V = **0.067**

Figure 12. *Visibility mapping of the UNTH Linear Circulation pattern, with sight depths 1, 2 and 3 represented with warm color schemes.*

Deriving the Circulation Efficiency (CE) for the Linear Pattern:
With the visibility value derived as 0.067, the circulation factor of the Linear Circulation system can be derived as follows:

Circulation Efficiency (CE) = $RI + V$
CE = 0.074 + 0.067 = **0.141**

Therefore, the CE for the Linear Circulation pattern in this case is stated as 0.141

CASE-2

Investigation and Analysis of the Multilateral Circulation Pattern (ESUTH):

The measurement of the frequency of flow in the Enugu State University Teaching Hospital (ESUTH) was carried out following the same process as with the first case above. Likewise, the existing building layout was confirmed, and the building form and archetype documented for the purpose of generating the necessary space depth information and determining the degree of Circulation efficiency in the hospital. Unlike the Linear circulation system observed in case 1 above, the ESUTH hospital layout showed multiple carriage points connecting to each other along smaller corridors as carriageways different from that observed in the case of the Linear Circulation System (hence adopting the title of multilateral).

Evaluation of the Pattern and Frequency of Patient traffic flow in the Multilateral Pattern:
The main entrance point of the building was regarded as the major carriage point. From this point, visitors were studied and counted, while their paths were documented as they crossed from

one activity area to another until their final departure from the department (Figure 14).

Figure 13. *Picture showing the narrow carriage corridors in the outpatient department at ESUTH (multilateral circulation pattern)*

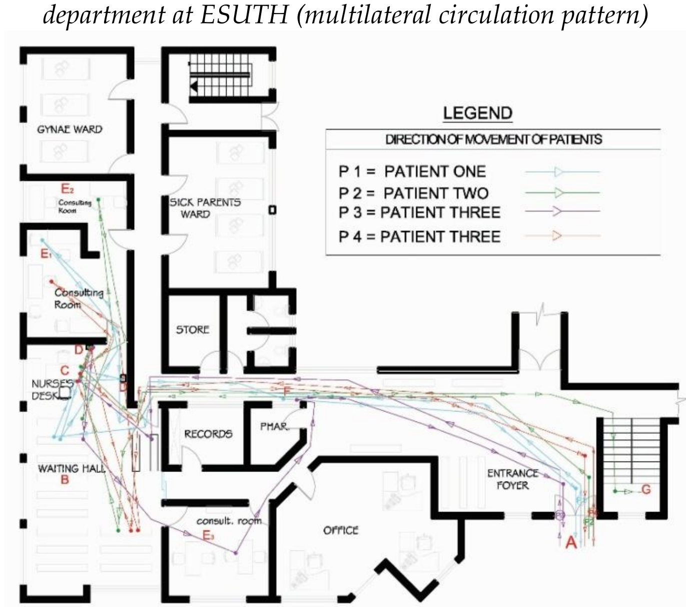

Figure 14. *Movement patterns of Patients/visitors observed at the ESUTH hospital*

Analysis of the Circulation Efficiency of the Multilateral Pattern:

The investigation of the Circulation efficiency of the multilateral circulation pattern also involves the two major factors: (i) Real integration and (ii) Visibility (isovist of sights), necessary for establishing (CE). This process, as well, involves subdividing the various spaces in the outpatient department into cells (as shown in Figure 15), which are assigned space depths as a function of dimension to aid in calculating the Real Asymmetry value (value of Integration) and the Isovist factor (visibility).

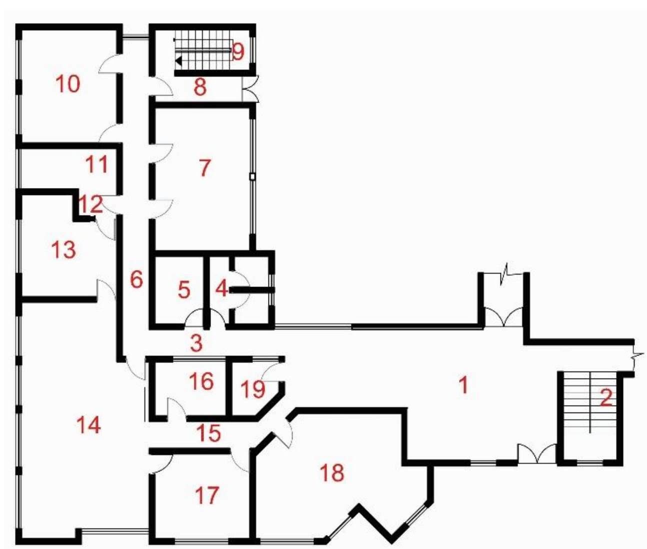

Figure 15. *Floor plan of the ESUTH Multilateral Circulation Pattern showing the Different Spaces as Cells with 0 to 19 (20 depths in all)*

Deriving the Real Integration (RI) value of the Multilateral Pattern:

With the formula for calculating Real Integration (using the Real Asymmetric value)

$$RA = 2(MD-1)/K-2 \qquad \textbf{(5)}$$

Where K = 19

The RI for the multilateral pattern [ESUTH] calculation is derived as seen in the Table 3 below.

Table 3. *Tabulation of space cells and Space Depths for Real Integration calculation of the ESUTH Multilateral Circulation pattern.*
The RI value =0.25

CELLS		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	
	0	1	2	3	4	4	3	3	4	4	4	4	5	5	4	5	3	3	3	2	
1	1	0	1	2	3	3	2	2	3	3	3	3	4	4	3	4	2	2	2	1	
2	2	1	0	1	2	2	1	1	2	2	2	2	3	3	2	3	3	3	3	2	
3	3	2	1	0	1	1	2	2	3	3	3	2	4	4	3	3	4	4	4	3	
4	4	3	2	1	0	2	3	3	4	4	4	4	5	5	4	4	5	5	5	4	
5	4	3	2	1	2	0	3	3	4	4	4	4	5	5	4	4	5	5	5	4	
6	3	2	1	2	3	3	0	2	3	3	3	2	4	4	3	3	4	4	4	3	
7	3	2	1	2	3	3	2	0	1	1	1	1	2	2	1	2	3	2	3	3	
8	4	3	2	3	4	4	3	1	0	2	2	2	3	3	2	3	4	3	4	4	
9	4	3	2	3	4	4	3	1	2	0	2	2	3	3	2	3	4	3	4	4	
10	4	3	2	3	4	4	3	1	2	2	0	2	3	3	2	3	4	3	4	4	
11	4	3	2	3	4	4	3	1	2	2	2	0	1	1	2	3	4	3	4	4	
12	5	4	3	4	5	5	4	2	3	3	3	1	0	2	3	4	5	4	5	5	
13	5	4	3	4	5	5	4	2	3	3	3	1	2	0	3	4	5	4	5	5	
14	4	3	2	3	4	4	3	1	2	2	2	2	3	3	0	1	2	1	2	3	
15	5	4	3	4	5	5	4	2	3	3	3	3	4	4	1	0	1	1	2	2	
16	6	5	4	5	6	6	5	3	4	4	4	4	5	5	2	1	0	3	2	3	
17	5	4	3	4	5	5	4	2	3	3	3	3	4	4	1	1	2	0	2	3	
18	6	5	4	5	6	6	5	3	4	4	4	4	5	5	2	1	2	3	0	3	
19	2	1	2	3	4	4	3	3	4	4	4	4	5	5	4	2	3	3	3	0	
MEAN	**3.8**	**2.9**	**3.3**	**2.9**	**4.4**	**3.8**	**3.1**	**2**	**2.9**	**2.5**	**2.9**	**3.6**	**3.6**	**2.9**	**2.5**	**2.8**	**3.1**	**3.1**	**3.4**	**2.7**	**RA=0.2**

Deriving the Isovist (Visibility) value for the Multilateral Pattern:

The visibility map of the multilateral circulation system indicates the level of Isovist of sight, or range of Visibility, across spaces. Also, the numbers indicate the level of obstruction between sights (sight depths), as shown in Figure 16. The sight depths 1, 2, and 3 are represented with warm color schemes, which turn cooler as visibility decreases.

__Figure 16.__ Visibility mapping of the ESUTH Multilateral Circulation pattern, with sight depths 1, 2 & 3 indicated with warm color schemes

To calculate the Visibility function *(V),* the mean of the sight depths is divided by the total number of Cells.

Mean sight depths = 2.26

Number of Cells = 20

Visibility function = 2.26/20 = 0.113

In the case of the Multilateral Circulation pattern, $V = 0.113$

Deriving the Circulation Efficiency (CE) for the Multilateral Circulation Pattern

With the visibility value derived as 0.113, the circulation factor of the Multilateral Circulation system is calculated as follows:

Circulation Efficiency (CE) = $RI + V$

CE = 0.25 + 0.113 = **0.363**

Therefore, the CE for the Multilateral Circulation pattern in this case is stated as 0.363

CASE-3

Investigation and Analysis of the Looped Circulation Pattern

The development of an architectural project is often regarded as an extensive process, which must consider numerous factors that integrates the process of site utilization/layout planning and finally culminating into the completed building. More so, in the case of hospital designs, circulation configuration is paramount among the design considerations. For this purpose, the design of the Baze University hospital (BUH), primarily considered the use of a circulation configuration concept that will impact the entire hospital layout housed in one single building, with a gross floor area of about 15,000m2.

As stated above, the spatial distribution and zoning concept represent the preliminary level of circulation planning and way-finding organization. The location and size of access points, main carriage corridors, as well as activity points, becomes vital in achieving an optimized Circulation efficiency. These considerations were utilized and adopted for the BUH design. The process of connectivity and management of circulation/way-finding for the BUH is presented in Figure 16 below, illustrating the Circulation flow chart. This flow system demonstrates the conceptual idea for movements and interactivity within the hospital, which was driven by the order of layers of Circulation Elements (Ching, 2007).

Evaluation of the Pattern and Frequency of Patient traffic flow in the Looped Circulation system:

Following the study of the first two circulation patterns examined in this study and noting the characteristics and challenges that may occur in the orderly flow of patients/visitors, staff/equipment and the inherent conflicts therewith, the design of the BUH circulation system aimed at not only producing efficient circulation values but also providing the necessary potential for conflict-free integration between staff and patient/visitors access and flow patterns. The design thus adopted a double loaded corridor layout (as shown in Figure 18), with large carriage corridors of up to 8m in width running across all functional areas (Figure 20). The advantage of the large carriageways pertains to visibility, wayfinding, and ease of movement.

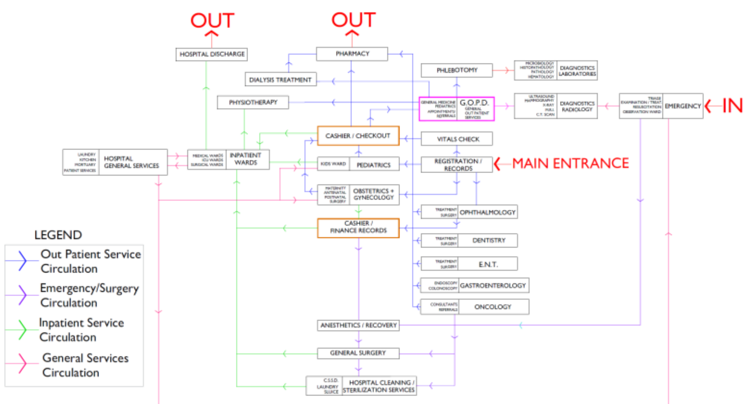

Figure 17. *Baze University Hospital (BUH) Flow Chart, showing major circulation paths*

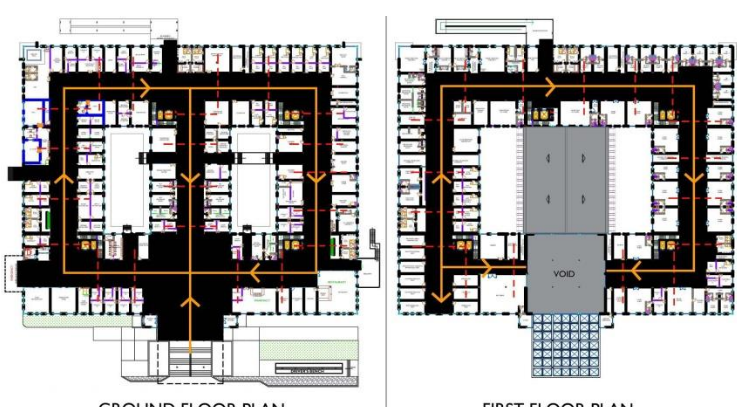

Figure 18. *BUH Looped circulation paths*

Figure 19. *Picture showing the large sized central entrance lobby in the BUH (Looped Circulation pattern)*

Figure 20. *Picture showing the large (8m wide) carriage corridor in BUH (Looped circulation pattern)*

It is established that the functionality and efficiency of movement in hospitals are dependent majorly on the openness/size of circulation spaces that patients and healthcare workers traverse to get from one key zone to another, irrespective of the sizes of the patient service rooms (Lynch & Hack, 1984). The BUH represents the intent to develop a circulation system that considered the efficiency of movement.

Using the (CE) potentials of the Linear circulation pattern, the Looped circulation system combines continuous linear layout with extended projections for possible accessibility of other functions without interjection from the busy patient traffic; hence, it provides room for additional carriage routes for separating distinctive carriage routes and accesses to functions. Figure 21 shows the movement patterns of Patients/visitors observed at the BUH outpatient wing.

Figure 21. *Movement patterns of Patients/visitors observed at the BUH hospital*

Analysis of the Circulation Efficiency of the Looped (Linear) Circulation Pattern:

To calculate the Circulation efficiency of the Looped circulation system, the two major factors: (i) Real integration and (ii) Visibility (isovist of sights), necessary for establishing (CE), are derived for the Outpatient wing as well. This process, as well involves subdividing the various spaces in the outpatient department into cells (Figure 22), which are assigned space depths as a function of dimension to aid in calculating the Real Asymmetry value (value of Integration) and the Isovist factor (visibility).

Deriving the Real Integration (RI) value of the Looped Circulation system:
Using the Real Asymmetric value, the RA is calculated as;

$$RA = 2(MD-1)/K-2 \qquad \textbf{(6)}$$

Where K = 45

The RI for the Looped pattern [BUH] calculation is derived as seen in the Table 4 below.

Figure 22. *Floor plan of the BUH Looped Circulation Pattern showing the different spaces as Cells with 0 to 44 (45 depths in all)*

Table 4. *Tabulation of space cells and space depths for Real Integration calculation of the UNTH Linear Circulation pattern.*
The RI value =0.045

CELLS S/N		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	
	0	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
2	2	1	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
3	2	1	2	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
4	2	1	2	2	0	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
5	2	1	2	2	2	0	2	2	2	2	2	2	2	2	2	2	2	2	3	3	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
6	2	1	2	2	2	2	0	2	2	2	2	2	2	2	2	2	2	2	3	3	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
7	2	1	2	2	2	2	2	0	2	2	2	2	2	2	2	2	2	2	3	3	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
8	2	1	2	2	2	2	2	2	0	2	2	2	2	2	2	2	2	2	3	3	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
9	2	1	2	2	2	2	2	2	2	0	2	2	2	2	2	2	2	2	3	3	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
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MD.	1.93	0.98	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	2.9	2.9	1.93	1.93	1.93	1.93	1.93	1.93	2.96	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	RA=0.045

Deriving the Isovist (Visibility) value for the Looped Circulation Pattern:

The visibility map of the Looped circulation system indicates the level of obstruction between sights (sight depths), as shown in Figure 23. Likewise, the sight depths 1, 2 and 3 are represented with warm color schemes, which turn cooler as visibility decreases.

Figure 23. *Visibility mapping of the BUH Looped Circulation pattern, with sight depths 1, 2 and 3 represented with warm color schemes.*

To calculate the Visibility function *(V)* in this case, the mean of the sight depths is divided by the total 45 Cells (from 0-44 cells).

Mean sight depths = 2.06
Number of Cells = 45
Visibility function (*V*) = 2.06/45 = **0.046**

In the case of the Looped Circulation pattern, *V* = 0.046

Deriving the Circulation Efficiency (CE) for the Looped Circulation Pattern:

With the visibility value derived as 0.046, the circulation factor for the Looped system is calculated as follows:

Circulation Efficiency (CE) = RI + V

CE = 0.045 + 0.046 = **0.091**

Therefore, the CE for the Looped Circulation pattern in this case is 0.091

Summary of Evaluation of the three Different Circulation Configurations (Cases 1,2&3):

The analysis of the three circulation patterns assessed is summarized in Table 5.

Table 5. *Summary of Circulation Efficiency analysis for the Linear, Multilateral, and Looped circulation layouts.*

Circulation Configuration	Real Asymmetry /Integration Value (*RI*)	Visibility/ Isovist of Sight (*V*)	Circulation Efficiency (*CE*)
Linear Circulation	0.074	0.067	**0.141**
Polygonal Circulation	0.25	0.113	**0.363**
Looped Circulation	0.045	0.046	**0.091**

From the summary shown in the Table 4, the Linear circulation system presented an (RI) value of 0.074, whereas the Multilateral system gave a Real integration value of 0.25. Studies show that a lesser value indicates a better integrated space function, hence more permeable. The Looped circulation system, in this case, presented the lesser value with an (RI) value of 0.045. This indicates that the looped circulation model offers a more integrated spatial distribution system, signifying that spaces link to each other more freely and thereby improves way-finding and thus reduces the potential for congestion in flow within the spaces and carriages.

On the visibility function *(V)*, the Multilateral system gave an Isovist of sight with a range of 0.113, while the Linear circulation system gave 0.067. The lesser range of sight indicates enhanced permeability of spaces within the overall complex. With a value of

0.046, the Looped circulation system also offers the potential for easier perception of the various spaces and activity points in the building, better than the other two. This is attributed mostly to the wide corridors used for circulation carriageways. With 8 meters-wide corridors, the visibility angles in this configurations provides better 'View-sheds' than the narrower corridor systems. By combing the two functions *(RI+V)*, the circulation efficiency (CE) for Multilateral circulation system was determined as 0.363, while that of the Linear system was 0.141. The combined values are meant to indicate efficiency in the movement of patients and visitors to the outpatient department of the hospitals used in the study. A zero CE value is taken as perfect circulation efficiency (and this can only occur in a non-demarcated space); however, the closer to zero the value of CE is, the better the efficiency.

With a circulation efficiency value of 0.091, the Looped circulation pattern presents a more efficient way-finding system, with better circulation flow potential and less significant possibility for congestion due to its improved circulation efficiency value, compared to the Multilateral and Linear patterns.

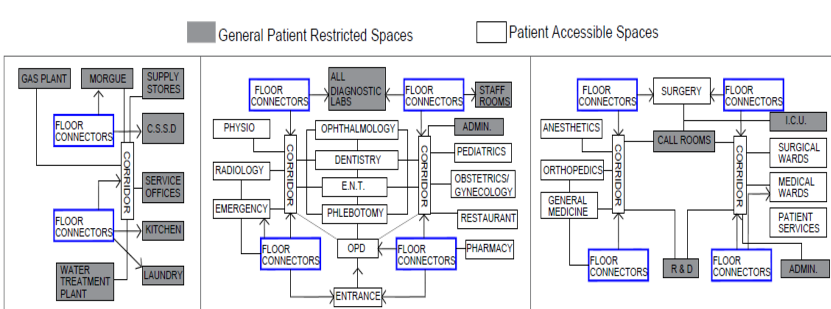
Evaluating the Performance of Circulation Configurations in Buildings Using Visibility

Way-finding is a major design issue that deals with the potential spatial organization of a setting, the circulation system, and the applied architectural cum graphic communication. While the design layout and the circulation paths outline way-finding challenges, applied architectural solutions and integrated graphic communication towards good visibility provide users with the information to solve these imposed problems (Passini, 1996). The ease of way-finding and circulation within a building contributes immensely to building efficiency and has both mental and psychological impacts on users, especially patients, as discussed earlier. This also affects productivity of operators who must function within the facility while traversing other functions and users. Curtailing these challenges entails adopting unsophisticated building forms, layouts and circulation elements that allow for visibility of activity points. In the design of the Baze University Hospital, a three phased circulation element is implemented for improving circulation and way-finding; these include:

i. In the first phase, the activities are set in a 3-level building unit, with each floor/level operating as a separate functional zone, as shown in Figure 24. The aim of the separation is to minimize the conflicts and interruptions that occur owing to the interweaving movements of the hospital users and hospital service personnel.

ii. The second phase is the use of looped double-loaded corridors as the major circulation element and architectural solution for ease of flow and effective way-finding. The sizes of the corridors are enlarged in the design in order to improve the visibility factor in way-finding.

iii. Thirdly is the location of secondary circulation elements, which are the Level connectors (Elevators and Staircases), at visible intersections along the corridors for vertical flow across the floors.



(a) (b) (c)

Figure 24. *BUH functional and major activity-flow layouts. (a) Basement floor layout, (b) Ground floor layout, (c) First floor layout*

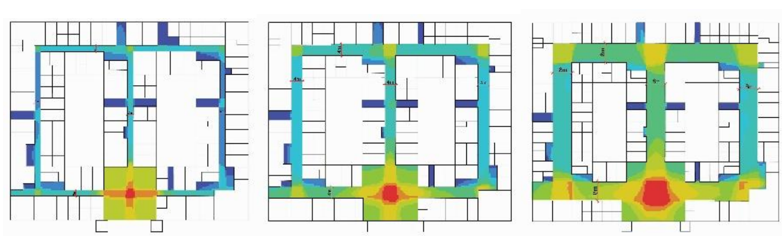
Studies show that the first stage in the process of the way-finding and movement is Visibility. Finding one's way around public buildings often proves to be exasperating; however, this is made easier by the visual accessibility within and around buildings. Hölscher & Brösamle (2007) suggests that if large parts of a building are immediately visible, with mutual intervisibility (or vistas) connecting the parts of the building, then people have to rely less on stored spatial knowledge and can rely on information directly available in their field of vision. Calculations based on this impression expresses the connective structure of rooms and circulation areas in a building, and these are strongly associated with route choices of hospital visitors, both in unguided exploration and in directed search based tasks relative to way-finding behaviors (Peponis *et al.,* 1990).

To analyze the efficiency of the circulation system adopted in the BUH, a space syntax study using Visibility graphs is carried out in order to ascertain the way-finding factor relative to visibility in the double loaded/looped system.

Visibility graphs are used to represent the spatial configuration. They are spatial representations based on isovists, often used to illustrate the visible areas around generating points in space occurring in 360 degrees. Visibility graphs work by overlaying a human-scale grid spacing on top of an architectural floor plan, then constructing an isovist from the center of each pixel of the grid, and connecting every pixel to the pixels that can be seen within the isovist area, thus assigning values to every pixel. This graphical representation provides a description of space from the interior of the building. It also describes space from the point of view of users of a building, as they view, interact with and move through it (Pachilova & Sailer, 2020).

Considering the direct observation of users of circulation spaces, three sizes of circulation corridors were tested for the BUH double loaded-looped circulation design, in order to identify the best corridor width for efficient circulation flow and visibility. They are the 2 meter, 4 meter and 8 meter corridor widths.

Using the software **'DepthmapX 20'**, visibility graphs were generate and analyzed for the three sizes. Afterwards, the VGA (Visibility Graph Analysis) was constructed using solid walls modeled to represent what is visible in an open circulation corridor space. The result of the VGA graphs is shown in Figure 25, which displayed a visual color scheme ranging from Red to Blue, where the more visible areas is highlighted in warmer colors and the less visible areas in cooler colors.



(a) *(b)* *(c)*

Figure 25. *Comparison of the Visibility graph analysis of three different corridor widths from the double loaded/looped circulation system.*

Where:

(a) *is the result of the VGA when a 2 meter wide corridor is used*
(b) *is the result of the VGA when a 4 meter wide corridor is used*
(c) *is the result of the VGA when an 8-meter wide corridor is used*

From the visibility graphs presented above, the results suggests that design factor plays a huge role in determining the value of visibility in a circulation space. The 2 meter-wide system presents a lower visibility angle (illustrated by the darker cool colors), therefore making it more difficult for users to identify destinations or location nodes from a distance. The 4-meter-wide corridors, with brighter cool colors, signify a much higher viewshed. However, the 8-meter wide corridors present the best visibility value, with warmer colors displayed in the VGA. A visibility angle signifies the range and angle that can present acceptable ViewSheds form distances. In the BUH building, the corridor lengths are up to 60 meters; hence, higher angles are needed for higher viewsheds (see Figure 26).

(a) *(b)* *(c)*

Figure 26. *Comparing the viewshed angles for (a) 8 meter corridor, (b) 4 meter corridor, and (c) 2 meter corridor.*

VGA analysis of hospital circulation suggests that the functionality and efficiency of movement in hospitals depend largely on the openness/size of circulation spaces that healthcare workers traverse to get from one key zone to another, irrespective of the sizes of the patient service rooms. Likewise, it is also evident that the larger the sizes of the circulation area that links one major function to another, combined with the large viewshed angles on key paths it provides, the higher the chances of running into another healthcare personnel along the circulation space and having an informal or quick conversation concerning patient information, as stated by Pachilova & Sailer (2020). This in itself is a huge plus in the patient care service operations in large hospitals, as spaces with larger viewsheds allow for more interactivity among healthcare staff, which in turn contribute to a productive workplace environment.

CHAPTER 4

Solving Wayfinding Problems

Humans depend hugely on spatial orientation to navigate through familiar environments. Everyday activities depend on spatial orientation for navigating routes from outside locations to final destinations.

Studies shows that the gaze bias identifies that people pay attention to structural elements in the built environment. According to Martinez-Conde *et al* (2019), study of visitors' behavior in memorized spaces identified that tiny gaze shifts disclose people's familiar locations in a memorized space rather than that of visual space. This discovery indicates that the oculomotor system may be engaged in the process of focusing attention within the internal space of memory. These studies are in line with the suggestions for the use of axial lines and Isovists fields in analyzing perception in the wayfinding process.

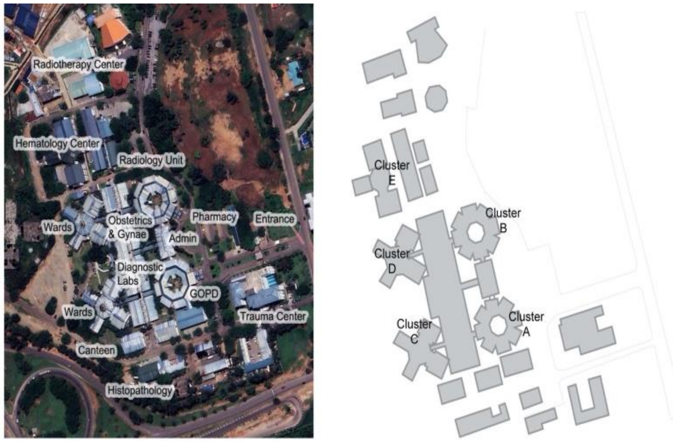
This chapter presents some of the strategies for analyzing and improving wayfinding performance in the built environment. It used real-life cases of existing building (large hospital buildings) to demonstrate techniques such as axial analysis and the adoption of color coding for reducing wayfinding challenges.

Reducing Wayfinding Challenges in Buildings using Axial Analysis

This section reviews the spatial orientation and wayfinding difficulties in large hospital buildings in Nigeria. As identified in Figure 4, the larger the size of a building, the more complex the spatial orientation and wayfinding process within it becomes.

Owing to the large sizes and spatial distribution concepts adopted in the design of these large hospital buildings, patients and visitors often find challenges in locating destination areas.

A typical example is the case of the National Hospital in Abuja, Nigeria (Figure 27). Designed to function as both a general and teaching hospital, the national Hospital provided the service of a comprehensive training center for medical graduates in affiliation with Ahmadu Bello University, Zaria, as well as general healthcare services for the Abuja community. A review of the building layout indicates the presence of multiple functional units, with about 28 departments distributed in Blocks and Cluster pattern that originates from the entrance gate, leading through the Trauma and Emergency center down to the Radiotherapy center. The departments/units includes: Psychiatry, Hematology, Trauma Centre, Dietetics, Pharmacy, Chemical Pathology, Histopathology, In vitro Fertilization (IVF), Health Records, Library Services, Nuclear Medicine, Radiotherapy and Oncology, Pediatrics, Dental and MFU, Anesthesia, Intensive Care, Family Medicine, Medical Physics, Obstetrics/Gynecology, Ophthalmology, Otorhinolaryngology/Head and Neck Surgery, Physiotherapy, Radiology Surgery, Internal Medicine, Nursing Services, Plastic Surgery Unit, Medical Microbiology, and Medical Record. With the combination of Cluster layouts and combined building blocks, the complex on first view presents a visitor with a feeling of disorientation.



(a) Google map/layout National Hospital Abuja (b) Outline/layout of National Hospital Abuja

Figure 27. *Google map of the National Hospital Abuja (NHA), showing the major spatial units/functions*

Real-time view of the National Hospital Abuja (NHA) environment from the entrance indicates the lack of vistas to destination points from any point of location during the process of wayfinding. Even the general directory signage (Figure 28), which presents a guide to users and visitors, requires extensive mental mapping to acquire satisfactory spatial cognizance for recognition of destinations within the facility.

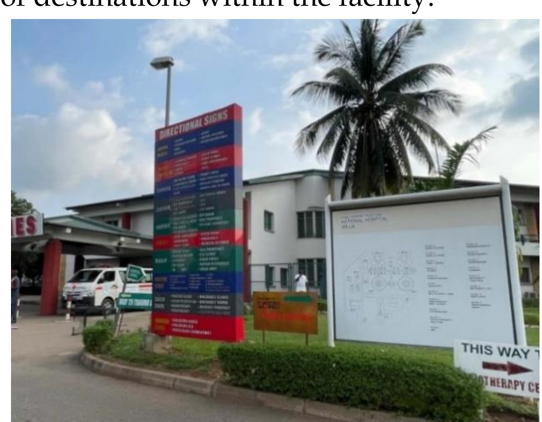


Figure 28. *General Directory of Departments and Units in the National Hospital Abuja*

The Axial Analysis technique utilizes axial map analysis as an instrument. Spatial layout characteristics of each case are identified, and the significant impact analyzed in order to identify the performance of each configuration in the wayfinding process. Three (3) selected hospitals, which make up the crux of the major (large) tertiary healthcare institutions in Nigeria, are used for this study. The significance of this is to ascertain the effects layout configurations have on spatial orientation and wayfinding. Visual axial analysis, which is a way of analyzing a spatial layout represented by an axial map with simplified connections between spaces in urban or architectural morphology (Klarqvist, 1993), is used to ascertain the longest visibility lines between convex spaces within the selected hospitals.

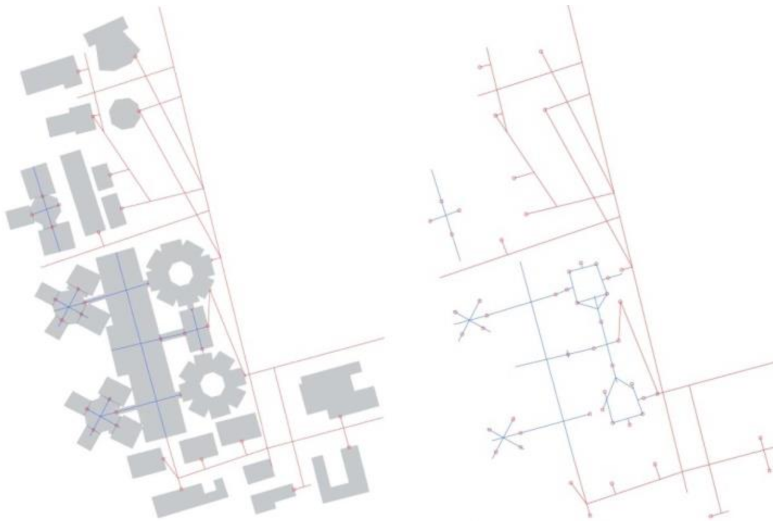
Previous studies identified that the axial map is an alternative representation of spatial and urban networks for measuring levels of accessibility across layouts. This process is defined as "spatial integration". Over the years, this method of representation has been adopted by space syntax analysis, and numerous researches have been built upon this method. This analysis method is seen to function as the fundamental spatial unit through which the interaction of society and spaces are observed and interpreted. In the past, hand-drawings are generally used in creating the axial map. However, the process of over-laying raster image maps is applied afterwards to complete the process. The procedure is such that the user draws the lines that represent the longest accessible and visible point. In the early years, this process was formerly completed by using tracing paper superimposed on a paper map with the axial line model. These axial lines are analyzed by visual assessment of their connectivity to identify the spatial integration and connectivity factors (Dhanani *et al,* 2012). In this exercise, AutoCAD (CAD) drawing tools are utilized to outline the building forms in order to identify the layout configurations used in design, followed by the drawing of axial lines across each nodes in the layout to connect visibility lines across various location/destination points. This is followed by the visual assessment of each generated axial map to identify the spatial integration and connectivity factors in each case.

The process of this analysis begins with the generation of the axial map of each hospital layout. The axial maps of each selected hospital outlines the Visibility context (using axial lines to indicate lines of sight) when one travels along pathways in the layouts. The connections of the red lines (lines of sight) in the analysis signify the effectiveness of each type of "building form" and layout in organizing the flow of visitors along these pathways.

The key principle of drawing an axial map is to minimize the number of lines and the angular change between any pairs of lines. The procedure of drawing axial map is such that the number and distances of connectivity in straight/linear unobstructed lines of sight observed in each case indicates the level of difficulty visitors will face in seeing or identifying the next nodal point (functional location and destination).

Axial analysis of the National Hospital Abuja (NHA)

Figure 29 shows the axial map of the National Hospital Abuja. The significant axial lines are the external lines represented in red color, while the blue color indicated the internal axial lines. The pattern of the external axial lines indicates the level of disconnected lines of sight and dispersed connectivity between each of the blocks and Cluster units in the Hospital's Layout. The complexity of its connectivity further signifies the challenges of connecting from one destination (node) point to another (represented in red circles).



(a) Axial map of NHA layout showing the External Axial lines in Red and internal Axial lines in Blue

(b)Axial map of NHA showing the External Axial lines in Red and internal Axial lines in Blue

Figure 29. *Axial analysis of the National Hospital Abuja*

Axial Analysis of the University of Nigeria Teaching Hospital (UNTH), Enugu

To further observe the impacts of building layout configuration on spatial orientation and wayfinding, the axial map of the University of Nigeria Teaching Hospital (UNTH) was developed. Figure 30a shows the Google map/Layout of UNTH, while 30b and 30c presents the axial map and analysis of the layout. The significant axial lines are the external lines represented in Red color, while the Blue color indicates the internal axial lines. The pattern of the external axial lines indicates more linearly connected lines of sight and pathways between each of the hospital blocks. The external axial lines indicates less unobstructed (clear) direct sight connections from one destination (node) point to another, with less turns than that of the NHA

Figure 30*(a) Google map/layout of UNTH*

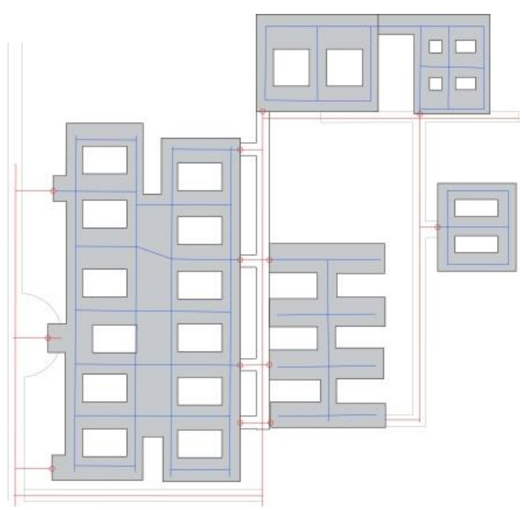


Figure 30*(b) Axial map of UNTH layout showing the External Axial lines in Red and internal Axial lines in Blue*

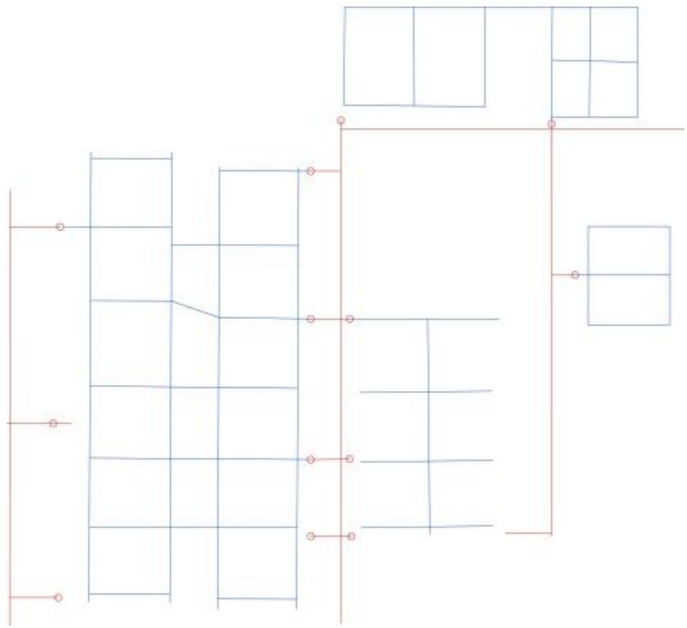


Figure 30(c) Axial map of UNTH showing the External Axial lines in Red and internal Axial lines in Blue

Axial analysis of the University College Hospital (UCH), Ibadan

In the case of the analysis of the UCH layout configuration, spatial orientation and wayfinding, the axial map of the UCH was developed. Figure 31a shows the Google map/Layout of UCH, while 31b and 31c presents the axial map and analysis of the layout. Likewise, the significant axial lines are the external lines represented in red color, while the blue color indicates the internal axial lines. The pattern of the external axial lines in this case indicates a rather scattered lines of sight and pathways between each of the hospital blocks. The external axial lines indicate obstructed and indirect sight connections from one destination (node) point to another, requiring more turns than that of the UNTH. Owing to these scattered lines, the spatial orientation course will likewise follow cumbersome process.

Figure 31*(a) Google map/layout of UCH*

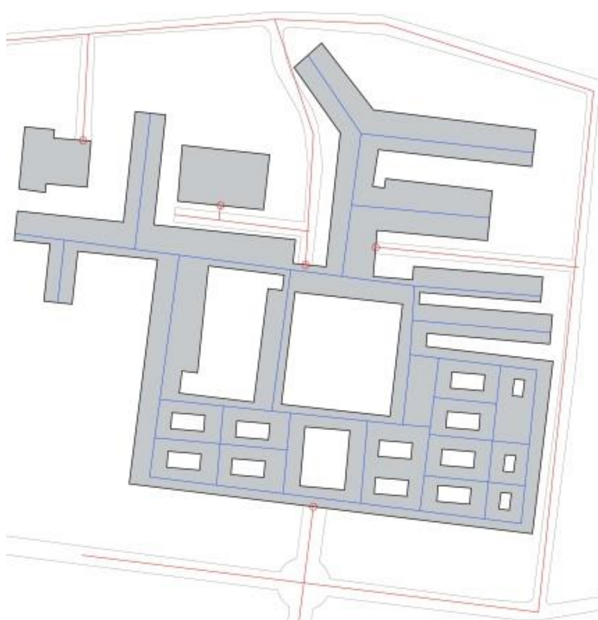


Figure 31*(b) Axial map of UCH layout showing the external axial lines in Red and internal axial lines in Blue*

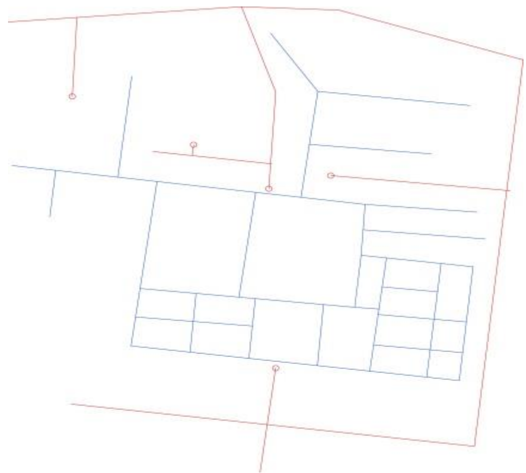
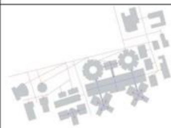
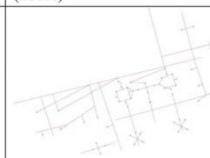
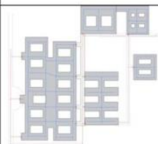
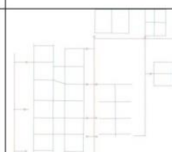
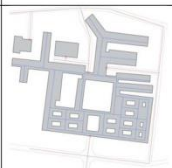
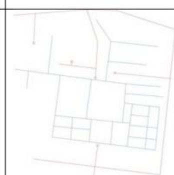


Figure 31*(c) Axial map of UCH showing the external axial lines in red and internal axial lines in Blue*

A comparative summary of the three hospitals in the study is presented in Table 6, suggesting that the less complex hospital layout presents lesser spatial disorientation outlook. While the NHA is made up of dispersed sightlines and connection to access points of the numerous blocks and clusters, thereby making wayfinding more challenging, the UNTH presents a less complex layout and more linear sightlines with fewer turns that enable visual connectivity to destination points, thus indicating fewer challenges for wayfinding. The UCH layout, on the other hand, presents limited sightlines to the scattered access points to various blocks in the hospital. This presents a medium challenge to spatial orientation on the external axis, with even more challenges envisaged in the internal pathways, as the building exists as a massive unit with integrated blocks. While the experience of spatial orientation may be minimal from the external axis, the internal wayfinding process in the UCH is expected to be highly disorienting.

Table 6. Analysis of disorientation levels in the three selected hospitals

Hospital	Axial map	External Axial connection to Pathways and Access points (nodes)	Connectivity level	Disorientation level
National hospital Abuja (NHA)			Dispersed connection to numerous access points (nodes) owing to multiple building units	High
University of Nigeria teaching hospital (UNTH)			Lineal sightlines as indicated by external axial lines, ensuring ease of connection from locations	Low
University college hospital (UCH)			Scattered connection to controlled access points (nodes), limited sightlines from external axial lines	Medium

From the comparative analysis of the three hospitals in Table 6 above, it could be asserted that simplified architectural morphology (building forms) and layout/arrangement of building units, if adopted in the organization and composition of the hospital building layout, would improve the connectivity of axial lines (sight lines), which in turn will increase the potential of spatial orientation and wayfinding process for visitors and users. Architectural designs that consider the problems of spatial disorientation often adopt simplified patterns of hospital building layouts for the benefit of patients and users. Previous study confirms that the quality of patient care and well-being are linked with the physical attributes of the healthcare environment (Gesler, *et al*, 2004). Also, spatial configuration has been identified as significant in influencing human movements and this impact on the performance of the users within the space and the quality of decisions they make. For hospital buildings, spatial configuration and ease of wayfinding play major roles in determining the efficiency of hospital services and thus, in order to understand the concept of wayfinding in hospital buildings, the process of spatial orientation, flow and visual connectivity must be comprehended (Edgett & William, 2004).

Improving Wayfinding and Spatial Cognition in Buildings Using Color Coding approach

Wayfinding and circulation systems are essential components required in the building design process. In building design, the various factors that impact these include accessibility, visibility and connectivity.

In the case of hospital designs, these factors has been explained as critical to the efficiency of services, which culminates in the reduction of the risk of cross-infections, decrease delay time experienced in internal and external service delivery, the achieving of a friendly environment for hospital visitors, as well as reduction in evacuation time during emergency services. Furthermore, by improving accessibility, visibility, and people circulation in hospitals by means of effective pathways, factors such as staff performance and productivity can be improved, coupled with enhancing patients' safety, privacy, and rate of recovery.

Color coding in wayfinding may be utilized to instantly communicate location, direction, and zoning of major functional areas without the need to read signage boards. Its primary objective often lies in the reduction of navigation confusion, as well as enabling the speeding up of task completion by up to 95% through the innate creation of a cognitive map while in locations with color coding (Zhang, *et al,* 2022).

To further improve the place identity aspect in the process of way-finding and spatial cognitive experience, the option of color coding is advisable. In this case, significant activity zones are captioned by the color of the corridors, level, core activity lobbies, or doorways on every floor. Figure 31 below shows the color schemes adopted in each significant zone in the Baze University Hospital (BUH) building.

(a) *(b)* *(c)* *(d)*

Figure 32. *Different color schemes used on doors and entrances, differentiating the major functional areas in the BUH building.*

(a) Purple is used for the General entrance Hall & Registration lobby

(b) Blue for the Outpatient zone,

(c) Green for the Inpatient wards,

(d) Orange for the Surgery and Operating theatres.

These color-coding ideas can be adopted as a practical approach in layout configurations and designs with the aim of easing the challenges of wayfinding and flow in large buildings.

CHAPTER 5

Conclusion

Studies in the past identified significant relationship between architectural design parameters, circulation designs, spatial and layout configurations, circulation efficiency, and wayfinding. Since building and urban environment designers are often challenged with the tasks of producing functional spaces, the success of which depends largely on the design implications, this study is thus tailored towards showcasing the values and importance of adopting fundamental concepts/principles of circulation design for generating appropriate building layouts focused towards on optimizing wayfinding and spatial orientation right from the conceptualization stages of design. The impacts of spatial orientation in buildings and ease of wayfinding can be attributed to general building safety and-post occupancy experiences of users.

The values of wayfinding play key roles in problem-solving practices mostly associated with emergency evacuations, or with simple spatial cognitive attitudes that impact on user orientation.

Key Findings and Recommendations

Professionals, especially Architects and Urban Planners, rely on several fundamental concepts of wayfinding to make buildings and urban environments legible to common users.

In this book, the principal findings are hugely relevant in the following areas:

a. Identification of effective patterns of circulations in buildings,

b. Strategies for wayfinding improvements in large buildings like hospitals,
c. Axial analysis methodology application system for assessing wayfinding performance in buildings and large spaces,
d. Effective building forms for improving wayfinding,
e. Identification of less complex user-cognitive representations of spatial information in buildings with components intended to improve indoor spatial cognition process

While the analyses of patterns of circulation presented in this book portray that each type has its potentials and limitations in terms of circulation flow, visibility and wayfinding, the results from this discussion can be useful in the design process and consideration for effective circulation systems to be adopted by designers in critical buildings like hospitals.

Consequently, since spatial disorientation in built environments is attributed mostly to layout configurations which originate from the building conceptualization and design stages, architects and designers of spaces like large hospitals may reduce these negative impacts by adopting measures like:

i. Establishing spatial configuration as the dominant element in the design for eliminating spatial disorientation and improving wayfinding process.
ii. Application of pre-design axial analysis of conceptual building layouts prior to design development.
iii. Adoption of more linear building forms (configurations) that provides visitors and users with extended lines of sight and networks for ease of visual connectivity to destination points in large buildings, especially large hospitals where the effects of spatial disorientation may impact on the mental well-being of users.
iv. Employment of the additional principles for effective wayfinding, such as location distinctiveness, visual

characterization, adaptive sightlines, and signage with decision points.

v. Adoption of spatial configurations that provides easy user-cognitive representation of spatial information, with components intended to improve indoor spatial cognition process, such as colors and textures.

Building layouts, forms, and spatial configuration has been identified as significant in influencing human movements, performances of users, and efficiency of services, especially in hospitals. This book also analyzed the layout configurations of selected large hospital buildings in Nigeria using axial maps and relates the analysis with spatial orientation and the wayfinding process. The aim of the study was to identify the extents of the impact of building layout configuration on spatial orientation and the wayfinding process. The three selected hospitals (National Hospital Abuja, University of Nigeria Teaching Hospital, and the University College Hospital) all represent the basic standard larger-scale hospital buildings in the country. Through the axial map analysis of these selected hospitals, different scenarios were observed, whereas the more complex layout configurations presented more disconnected axial lines (limited sightlines). On the other hand, the more simpler building layout configurations presented better axial-line connectivity with linear sightlines, which ensured easier wayfinding process for visitors and users. The findings from this study provide insight into the potentials of building layout configurations in influencing wayfinding. With this insight, further studies and analysis of various building forms, layouts, and configurations may be undertaken in order to discover better options for adoption in both hospital and general building designs, in order to reduce the challenges of spatial disorientation for patients and building users.

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