



UTILIZING THE FUNDAMENTAL ELEMENTS OF CIRCULATION AND FLOW CONFIGURATIONS IN HOSPITAL CIRCULATION DESIGN

Jidefor Akubue Anselm

Baze University, Abuja, Nigeria

Email address: akjideofor@yahoo.com

Correspondence: akjideofor@yahoo.com; Tel.: +234 7060706393

Abstract

Movement paths can be conceived as the perceptual thread linking spaces of a building or series of interior and exterior spaces, relative to where we are, and where we anticipate going. Numerous studies abound in the quest for understanding the relationship between circulation as a design element and the ease of way-finding, especially in hospitals. This paper presents a practical approach for hospital circulation design by combining the values of elements of circulation as a tool for layout configurations and design of hospitals. These Circulation Elements are layers of flow patterns that define the paths of movement in buildings. The paper started by reviewing the fundamental circulation elements notable in architectural studies as the principal components of a building's circulation system in the way finding process. This is followed by a review of potential circulation patterns used in modern day hospital buildings. These theories were eventually applied in the conceptual design of the Baze University hospital (BUH) in Nigeria. For the BUH design, the looped double loaded corridor system was adopted. An analysis of the BUH circulation system using Visibility graphs showed the significance of larger carriage pathways for better visibility fields in indoor way-finding. The significance here is the application of Fundamental Architectural Design Theory in the Hospital Circulation design process.

Keywords: architectural design, design activity, circulation design, circulation configuration, Hospital design, way finding.

1. Introduction

Circulation can be defined as the ways and modes of flow through and within a building. In architecture, circulation is defined as the way people move and interact within a building. Humans by nature and behavior, 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. 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 (Ching, 2019). 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.

In hospital design, circulation plays a significant role in defining the efficiency of services. According to Hillier (1996), the spatial configuration in buildings influences human movement flows, which impacts on the behaviors of the users moving through the building space and the level of decisions they make.

Hospital designers employ different layouts and configurations as approaches for improving flow efficiency. Study has it that the quality of care, patient health and wellbeing has links with

the physical attributes of the healthcare environment (Gesler W, et al., 2004). Research identifies that by improving access and people circulation in hospitals by means of effective pathways, staff performance and productivity can be improved as well as enhancing patients' safety, privacy and rate of recovery. Likewise this can 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).

Pathways are defined as routes to locations. Psychologically, recognition of pathways is vital element of the way-finding process. This concept which was originally introduced by Edward Tolman (1948), suggests that every individual utilizes cognitive maps for way finding. 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 way-finding performance as well as user-cognitive representation of real-time spatial information, are fundamental components of the spatial cognition process. The analogy of cognitive way-finding 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 eye (Fourtassi et. al, 2014). 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. 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 (Stella et. al, 2024). More so, the definition is synonymous with such statements as 'Every person acquainted with an environment possesses a simplified cognitive structure of the environment' (Peer et. al, 2023).

Despite all studies in the way-finding process, there still exists a gap in comprehending the full relationship between 'Circulation' as a design element and the ease of way-finding for users, especially patients in hospitals. This paper focused on the process of Hospital design by integrating the fundamentals of way-finding theories as an approach for developing architectural design layouts, this is eventually used in producing the design of a prospective hospital building with intention of improving the systems by which people move and find their way.

1.1 Background of the Study

The need for efficient architectural designs of hospital layouts that benefit from the most effective system cannot be over-emphasized. Design approaches and circulation configurations that take into cognizance basic parameters for achieving ease of flows are paramount.

Studies on the human cognition values suggest that configuration process of any environment possesses significant cognitive consequences. According to Bill 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 (Hillier, 1996). Consequently, the spatial layout of every built environment influences the accuracy of cognitive representations of real-world spatial information (Ahmadpoor & Shahab, 2019). Furthermore, pathways or network structure used in our everyday spatial behavior eventually becomes critical elements of the image of a spatial environment (Paknezhad & Latifi, 2021). Lynch (1960), emphasized that 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. In buildings however, patterns of circulation define the intrinsic systems for indoor

way-finding. In order to understand the concept of way-finding in buildings, the process of circulation must be comprehended. Circulation in buildings occurs in layers, each layer representing a significant process in the structure of way finding. There are certain specific elements that make up the layers of building circulation. From the study of Form, Space and Order (Ching, 2019), these layers are identified as the Approach, Entrance, Configuration of Path, Path and Space Relationship, Form of the Circulation Space (or Configuration of the Circulation Space)

Approach

The building approach is the first layer of circulation. The three major entrance options are:

- a. Frontal approach; this is the most formal type of approach as it is directly along the straight axis towards the building entrance along the front facade of the structure.
- b. Oblique approach; is also directed towards the front of the building, placed at an angle rather than directly perpendicular. The oblique entrance type is often not immediately discernible as the path may be redirected one or more times, in order to prolong the sequence of the approach. For this purpose, it requires a more elaborate entrance structure to pronounce the entrance.
- c. Spiral approach; this form of approach prolongs the sequence of approach in order to emphasize the 3-dimensional form of the building when moving around its perimeter in search of the entrance.

Entrance

Entering a building, a room within a building, or a defined field of exterior space, involves the act of penetrating a vertical plane that distinguishes one space from another and separates "here" from "there" (Ching, 2019). A building entrance or entrance into a space marks the transition from one space to another. Traditionally, entrances are defined by the use of openings within a plane. Other options of creating entrances may utilize changes in levels, structural elements or pronounced decorations (ornamentations) that would enhance the transition from one space to another. An entrance may be projected or recessed. When projected, the entrance announces the passage prior to penetrating the opening. On the other hand, when recessed, the entrance intends to absorb the exterior into the building internal space.

Just like the approach, an entrance may be centered along the plane of opening or it can be offset from the center to create a more dynamic composition.

Configuration of Path

Fundamentally, 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 or our orientation within the building and eventually the understanding of its spatial layout (Ching, 2019). Different types of path configuration include the Linear, Radial, Spiral, Gridded, Networked, Curvilinear, Segmented, Intersected, Looped, and Composite. According to Turner et.al (2001), the design aspect plays a significant role in determining the extent of visibility in a circulation space. 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.

The grid configuration is formed by two sets of parallel paths that intersect at regular intervals. When the series of paths connect at specific points of intersection, it forms a network. Consequently, paths can be of composite configuration, with the combination of various patterns. However, when creating composite layouts, it is necessary to make a hierarchical order by applying values of scale, length, form and orientation.

Path-Space Relationships

Paths also naturally related to the spaces they link to. They may relate to the spaces as pass-by spaces, pass-through spaces or terminate in a space.

When they pass by spaces, they do so independently, and they do not affect the form or activity within the spaces. By so doing, the path configuration is made flexible.

However, when a path passes through a space or through a series of spaces, it does so without affecting the internal circulation within the physical form of the spaces. When a path cuts through a space, it creates possibilities for flow and points of rest within the space.

Conversely, when a path terminates in a space, the path is established by the location of the space itself (Ching, 2019).

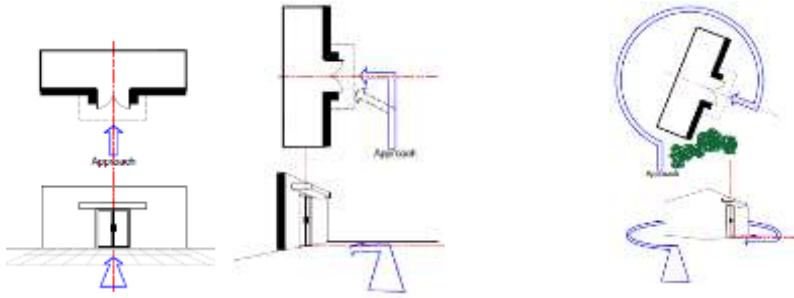
2.0 Form of the Circulation Space

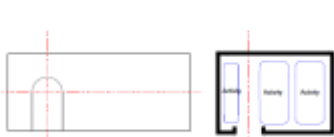
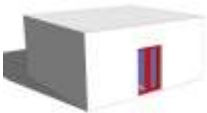
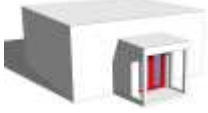
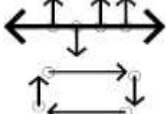
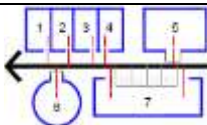
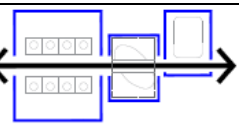
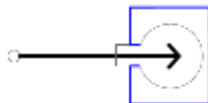
A circulation space may be enclosed, open on one side, Open on both sides or Random.

While the configuration of a space can vary from being enclosed, for corridors, it may be open-on-one side for open areas like a balcony or gallery, or totally open-on-both sides in the case of colonnade passages. In the case of large spaces, a path can be random, without form or definition, and be determined by the activities within the space. Generally, the geometrical proportion of a circulation space can be manipulated to handle the volume of circulation as well as the functional use of the space. For instance, a narrow-enclosed path naturally encourages forward directional movement, whilst wide and tall spaces tend to encourage the more random movement. Apart from the horizontal circulation spaces like corridors, circulation spaces also include the vertical forms like stairways and elevators. The size, shape and proportion of the stairway, its enclosed or open form and the angle and size of its treads or risers, all add to the overall impact of its intended circulation function (Ching, 2019).

The order of the elements of circulations is presented in Table 1 below.

Table 1. Layers of Circulation Elements in order of progression for organization of flow and way-finding

ORDER OF FLOW	LAYERS OF CIRCULATION	DESIGN SCHEMES
1st	Approach	

		Spiral	
2nd	Entrance		
		Centered along Plane of entry	Offset from Axis of Entry
3rd	Path Configuration		
		Flushed	Projected
3rd	Path Configuration		
		Recessed	
3rd	Path Configuration		
		Linear Path Configurations	
3rd	Path Configuration		
		Radial Path Configurations	Spiral Path Configurations
3rd	Path Configuration		
		Grid Path Configurations	Network Path Configurations
4th	Path-Space Connector		
		Pass by spaces	Pass through spaces
4th	Path-Space Connector		
		Terminate in a space	
5th	Circulation Element		
		Enclosed	Open on one side
5th	Circulation Element		
		Open on both sides	

Source: As adopted from Ching (2019)

3.0 Methodology

In this study, the object is to showcase the result of adopting fundamental architectural theories on circulation design. Architects are often tasked with the challenge of producing functional spaces and the success of these tasks depends largely on the design approaches. For these purposes, this paper revisits the basic theories for circulation design in architecture. Firstly, it looked at the principles of movement, flow and circulation which affect indoor way-finding. By identifying the significant layers of circulation, it utilized the identified elements in devising a design approach for Hospital building design. The identified elements and layers of circulation were carried through the design process for the Baze university hospital (BUH) building. In order to review the way-finding factor, visibility graph analysis (VGA) was done on the main circulation carriages of the BUH building. VGA analysis helps identify the significant View-sheds (visibility angles) which is a vital factor in the indoor way-finding and circulation process. In this study, the Visibility graph was utilized to represent the spatial configuration based on isovist values by illustrating the visible areas using generated points (and lines) within 360 degrees. DepthmapX 20 software was used in simulating the visibility

graph of the BUH building circulation layouts. To do this, the AutoCAD floor plans of the study building were overlaid with human-scale grid spacing; this is followed by the construction of isovists from the centre of each pixel of the grid. Afterwards, every visible pixel connected within the isovist area was assigned color values 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. 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 and move through it (Pachilova and Sailer 2020).

Circulation configuration concepts in Hospitals

In architectural practice, there is no finitely established circulation typology. While some studies suggest that simpler layouts improve way-finding cognitive process, others like Hölscher and Brösamle (2007), believe in the combination of patterns from various geometric rules or elements for navigation. In the words of Passini (1996), *“geometric forms have to be relatively simple in order to be effective in way-finding. More so, interconnected buildings, typical of large hospital buildings and educational settings, are generally not understood as forms”*. A good form of a circulation system like simple geometrical forms as Squares, Cruciform or an L-shaped form aid 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 way-finding performance (Colling et. al, 2023).

This paper identified the most fundamental circulation patterns as the primal forms mentioned in Form, space and order (Ching, 2019), which are linear, radial, circular and networks. In hospital design criteria, circulation zones are treated as the most fundamental features of the healthcare environment. Historically, different approaches and adoption of the circulation zones are presented by Verderber (2003) and Allison (2007), leading from the likes of the Roman ‘*valetudinarium*’ in western hospitals that featured a racetrack circulation system, which unveiled the first double-loaded corridors, to the Monastic medical complexes of the Middle Ages, which featured large chapel-like wards that were surrounded by an array of secular support structures. These large circulation aisles of the chapel-ward infirmary functioned as the primary means of interior circulation, as they were shared by people, equipment and supply distributions. In recent times, following the era of the modernist mega-hospitals, building have increased exponentially in size and complexity, resulting in myriads of interior spaces, undifferentiated interior circulation zones linking dozens of specialized units and departments, coupled with the development of hospital departments dedicated to the advancement of medical science through adoption of highly sophisticated medical technologies for diagnosis and treatments (Jiang & Verderber, 2016).

The complexity of hospital circulation configuration is 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:

- a. People
- b. Material Supply and distribution
- c. Ancillary Services

Table 2 below presents the groups of activities under these major traffic categories and the generalized frequency of flow within hospital buildings. Hospital designers factor these activities in the design criteria for zoning and positioning of functions, as accessibility, connectivity and safety considerations must be met in ensuring the provision of efficient logistics systems.

Table 2. Generalized flow frequency of various activity groups in hospital buildings

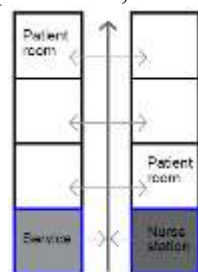
PEOPLE MOVEMENT	MATERIALS/DISTRIBUTION	ANCILLARY SERVICES
Patients	■ Medicine	■ Evacuation
Caregivers	■ Supplies	■ Emergency
Visitors	■ Equipment	■ Catering
Administrative staff	■ Accessories	■ Maintenance
Service staff	■	■ Teaching and academics
Medical/Diagnostic staff	■	■ Financial
Cleaning staff	■	■ Nursery
		■ Shopping
		■ Religious
Traffic Frequency: High ■ Medium ■ Low ■		

Source: Author's hospital zoning design proposal (2007)

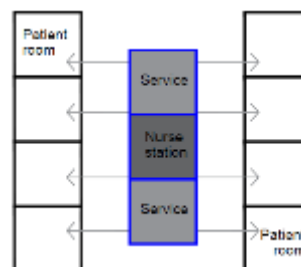
Out of the categories mentioned above, it is understandable that the most critical flow category is the Patient flow category. Hospital designers are often faced with the challenges of minimizing patient travel distances, to this end, hospital layouts are configured to ensure the reduction of operational time, which impacts on the delays in patient care/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 (Jiang et. al, 2016).

Linear Layouts

This 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 1. The linear patterns can be configured as single corridor layout, double corridor layout, straight or L-shaped 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 (Lee et. al, 2020).



(a) Single Corridor



(b) Double loaded Corridor

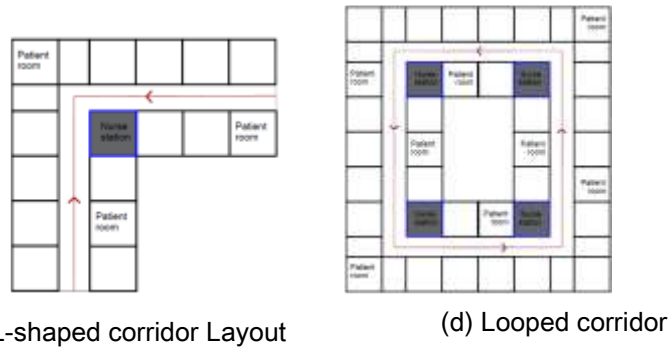


Figure 1. Linear flow configuration showing single corridor layout, double corridor layout, L-shaped and looped corridor layouts.

Source: Author's sketch illustrations

Radial Layouts

Radial layouts are configured to collect all active patient care zones to a centralized Service core and Nursing station. This option offers direct view to the central core and makes accessibility easier for the Caregivers. However, it gives rise to numerous cluster systems as only a few patient rooms can be connected to a central service core as shown in Figure 2 (Deng et. al, 2023).

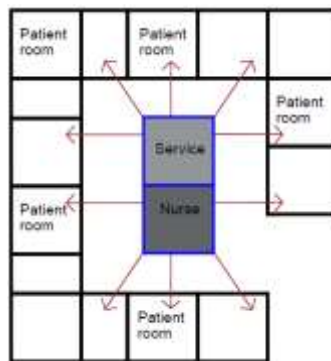


Figure 2. Radial flow configuration, showing centralized Service zone and Nursing station.
Source: Author's sketch illustrations

4.0 Results and Discussion

Review of the Baze university hospital (BUH) circulation systems.

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 culminates in the completed building. More so, in the case of hospital designs, circulation configuration is paramount among the design considerations. For the design of the Baze university hospital, the author primarily considered the use of a circulation configuration concept that will impact the entire hospital layout with a gross floor area of about 15,000m². The proposed hospital is conceived as a 150 bed capacity health care facility that will function as a teaching hospital. Table 3 shows the functional zoning concept of the facility. The hospital design comprised of majorly Outpatient, Inpatient and Emergency service units that interface with the Clinical and Para-clinical departments

Table 3. Functional zoning concept for the Baze university hospital design

OPD LEVEL	IPD LEVEL	ACADEMIC	ADMIN.	GENERAL
-----------	-----------	----------	--------	---------

				SERVICES
Ground Floor	First Floor	Ground/First Floors	Ground Floor	Basement Floor
• Radiology and Diagnostics • Laboratories • Treatment • Emergency • Surgery • Medicine • Dental • Otolaryngology • Ophthalmology • Obs/Gynaecology • Paediatrics • Pharmacy	• Surgery and Orthopaedics • Anaesthetics • Patient care admin. • Surgical wards • Medical wards • ICU wards • Staff on call lodging	• Research • Teaching • Demonstration • Library • Virtual learning	• H.R. Management • Accounts • Records • Admissions • Patient services • Staff welfare • ICT services	• CSSD • Medical Gas process plant • Laundry • Kitchen • Water treatment • Stores • Utility services units • Security/access control • CCTV/monitoring • Morgue services

The spatial distribution and zoning concept presented in Table 3, represents the preliminary level of circulation planning and way-finding organisation for the BUH project. The process of connectivity and management of circulation/way-finding is presented in Figure 3, showing the Circulation flow chart. This flow system demonstrates the conceptual idea for movements and interactivity within the hospital. The order of the Layers of Circulation Elements as discussed in (Ching, 2019), is further adopted in the design initialization for the organization of flow and way-finding optimization as seen in Table 4.

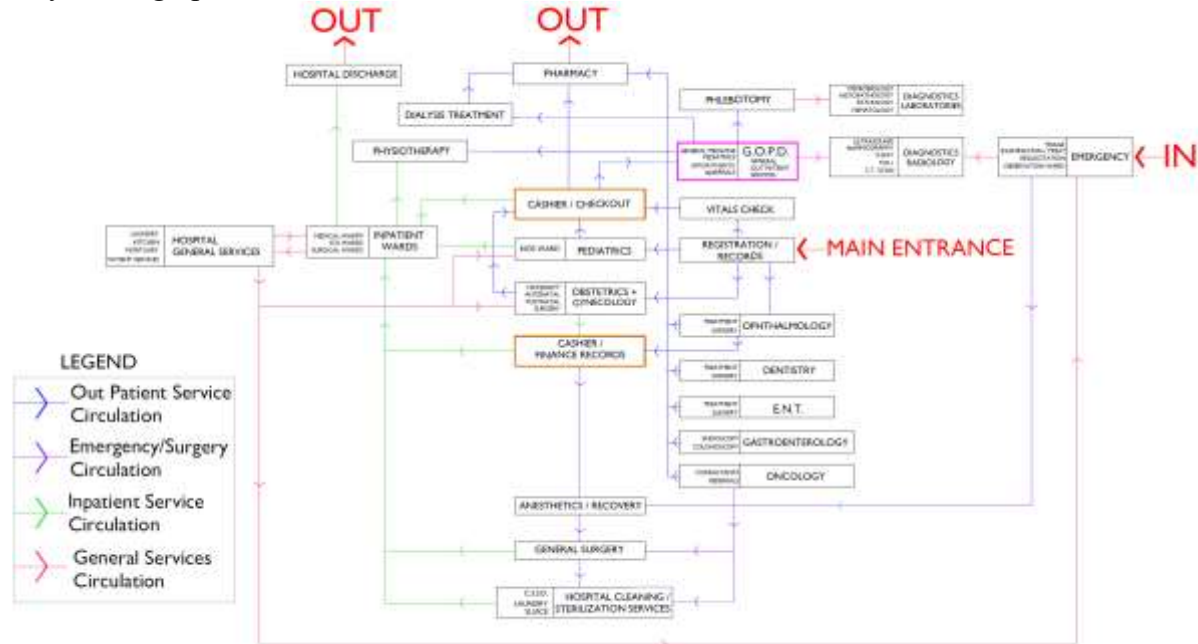


Figure 3. Baze University Hospital Flow Chart, showing major circulation paths

Organization of flow and way-finding in the BUH design using the circulation elements

4.2.1. Approach

The first layer of circulation and way-finding process begins with the “Approach”. For the

BUH design, the oblique or indirect approach was adopted as seen in Table 4. The impact of this type of approach, lies with the element of delay in reaching the building entrance, thereby permitting the visitor the chance to catch the views of the building from a distance. With this type of approach, the Entrance of the BUH is projected beyond the façade to enable clearer visibility as one approaches the building. Visitors/patients coming by foot or car can easily view the parking area as well as the driveways leading to the entrance canopy and across the parking lot as shown in the BUH Site Plan in Table 4.

4.2.2. Entrance Level

Through the approach, one arrives at the second layer of circulation, which is the entrance level. In the BUH design, the entrance is treated as a preview of the form of space being entered, by the use of the centralized symmetrical balance of the projected entrance elements (Entrance Canopy) as shown in number 2 of the order of flow in Table 4. The main entrance hall (Registration Hall) is likewise centralized, providing a view to the left, right and center wings of the hospital which is furnished with signage for easy identification of destinations.

4.2.3. Pathways

The third layer of circulation is the “Pathways” to destinations. The Path configuration adopted in the BUH is the linear type. Since Straight paths are considered as primary organizing elements for series of spaces, it thus represents the most basic form of way-finding and flow. The BUH design also utilized the Looped Corridor Layout for distribution of spaces and functions. The significance of the loop lies in the possibility of arriving at the starting point if lost, by simply walking in continuous line.

4.2.4. Path to Space Connectors

At the fourth layer lies the “Path to Space Connectors”. The BUH design also adopted the fundamental straight path system for connection to spaces. Visitors/patients and staff will find easier link to activity points by simply passing through the paths (corridors) and identifying the connectors (doorways, etc.) as shown in Table 4. Rather than passing through functional spaces which may cause disruption in activities and congestion, the option of “Passing by Spaces” is utilized in order to isolate Flow from Activity points. By so doing, restrictions can easily be implemented and separation of staff zones, patient zones and visitor zones is achieved in the BUH design. Connections to activities on other floors via elevators and stairs are provided in the BUH by means of passing-by-circulation spaces (corridors) to the lift and staircase lobbies.

4.2.5. Form of Circulation system

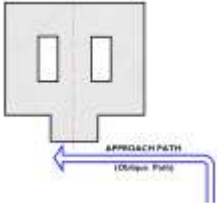
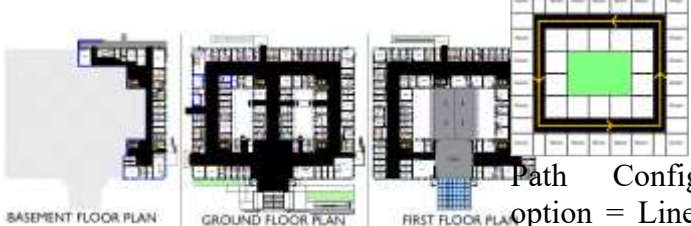
The final layer of circulation and way-finding element is the Form of Circulation system itself. The configurations, location, shape and feature of the circulation element enhances the ease in identification of destinations, flow of staff and visitors. In the design of the Primary circulation element, the BUH design adopted the double loaded corridor as seen in Table 4. The circulation corridors are thus “Enclosed” at all ends as it travels across its looped form. The secondary circulation systems adopted in the design are stairs and elevators. Strategically located at the 4 corners of the square loop, the elevators and staircases are attached to each other, hence making it easy for identification via the wide corridors. Further classifications are given to the elevators in order of assignment to critical functions like movement from Emergency to Operating theatres to Radio-diagnostics or to the Morgue, Wards to Physiotherapy floor, Wards to Radio-diagnostics and Theatres/Treatment rooms to Central Sterilization unit etc. To further enhance flow in the hospital, the design adopted a wide-corridor-form. With an 8 meter wide corridor system, visibility and flow is enhanced,

while congestion and obstruction of flows will be minimized. Figure 4 shows the typical ground floor plan of the BUH showing the size and form of the corridors.



Figure 4. Baze University Hospital Ground floor plan

Table 4. Layers of Circulation Elements in order of progression as adopted in the BUH for organization of flow and way-finding

ORDER OF FLOW	LAYERS OF CIRCULATION	BUH DESIGN OPTIONS
1st	Approach	  BUH SITE PLAN Path Option = Oblique
2nd	Main Entrance	  Entrance option = Projected + Centered along Plane of entry
3rd	Path Configuration	 Path Configuration option = Linear Path with Looped corridor layout
4th	Path-Space Connector	 Path Space Connector option = Pass by spaces

5th

Circulation Element

Circulation element type = Enclosed corridors (double loaded)

Analysis and Discussion of way-finding performance of the BUH circulation system using visibility graph

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 (Kwon et. al, 2025; 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:

- 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 5. The aim of the separation is to minimize the conflicts and interruption that occur owing to interweaving movements of the hospital users and hospital service personnel.
- 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.
- Thirdly is the location of secondary circulation elements, which are the Level connectors (Elevators and Stair cases) at visible intersections along the corridors for vertical flow across the floors.

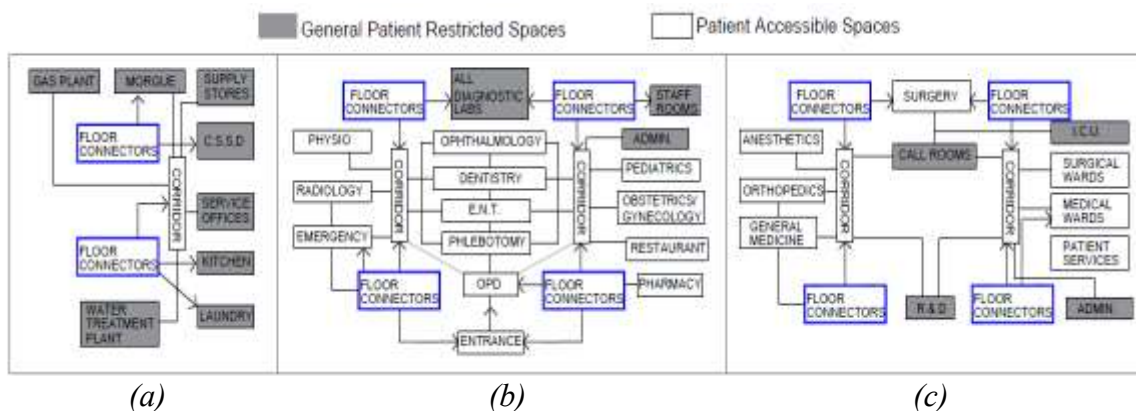


Figure 5. BUH functional and major activity-flow layouts. (a) Basement floor layout, (b) Ground floor layout, (c) First floor layout

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. Research on way-finding strategies by Hölscher & Brösamle (2007), suggests that if large parts of a building is immediately visible with mutual inter-visibility (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 behaviours (Peponis et al., 1990).

To analyse 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 represent the spatial configuration of buildings with visible values that are measurable. 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 centre 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 and move through it (Pachilova and Sailer 2020).

This paper utilized the direct observation of users in circulation spaces from the point of view of visitors. To analyse the visibility values, three sizes of circulation corridors were tested for the BUH double loaded/looped circulation design, with the aim of identifying the best corridor width for efficient circulation flow and visibility. These sizes represent the most common carriage widths, they include the 2 meter, 4 meter and 8 meter corridor widths.

Using the software 'DepthmapX 20', visibility graphs were generate and analysed for the three sizes. Afterwards, the VGA (Visibility Graph Analysis) was constructed using solid walls modelled to represent what is visible in an open circulation corridor space. The result of the VGA graphs is shown in Figure 6, which displayed a visual colour scheme ranging from Red to Blue, where the more visible areas is highlighted in warmer colours and the less visible areas in cooler colours.

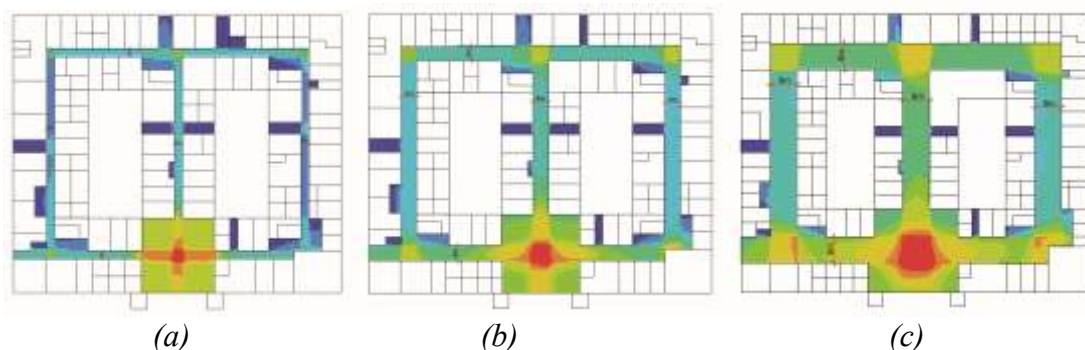


Figure 6. Comparison of the Visibility graph analysis of three different corridor widths considered in the design of the BUH double loaded/looped circulation corridor system.

(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 agrees with Turner et.al (2001) in the definition of Path Configuration, 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 colours) therefore making it more difficult for users to identify destinations or location nodes from a distance. The 4 meter wide corridors with brighter cool colours signify a much higher view-shed. However, the 8 meter wide corridors present the best visibility value, with warmer colours in display in the VGA. The BUH design thus adopted the 8 meter wide carriage pathway that supports a better visibility angle. A visibility angle signifies the range and angle that can present acceptable View-Sheds form distances. In the BUH building, the corridor lengths are up to 60 meters in length, hence higher angles are needed for higher view-sheds (see Figure 7).

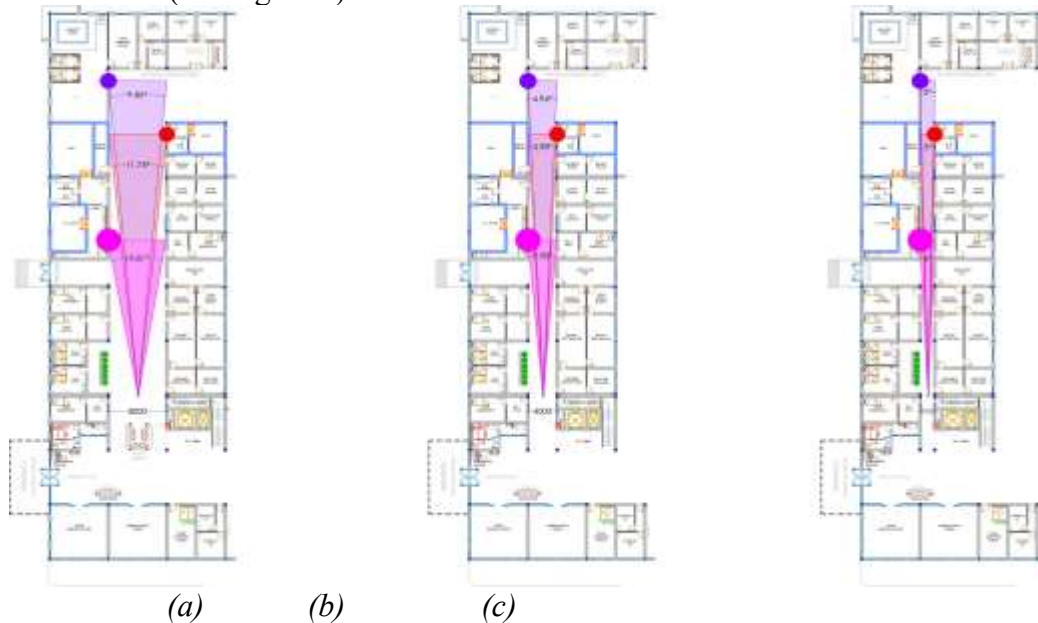


Figure 7. Comparing the view-shed angles for (a) 8 meter corridor, (b) 4 meter corridor and (c) 2 meter corridor, in a 60 meter long corridor for the BUH design.

This result is in consonant with studies by Xie et. al (2007), which focused on determining the effectiveness of signage by establishing the region from which the signage boards is most visible to occupants often referred to as the visibility catchment area (VCA). Findings indicate that the VCA is contingent of the destination distance and size of carriageway. Further studies by Natapov et. al 2019, admitted that layout which exhibit low visibility lacks a strong centre that could attract a way-finder's gaze. This further justifies the position that larger view-sheds are essential in attaining proper visibility in the process of way-finding. In conclusion, the VGA analysis in this paper presents a corridor configuration with movement and flow pattern that is dependent majorly 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 view-shed angles on key paths it provides, then 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 in (Pachilova and Sailer 2020). This in itself is a huge plus in the patient care service operations in large hospitals, as spaces with larger view-sheds allow for more interactivity among healthcare staff which in turn contribute to a productive workplace environment.

5.0 Conclusion

Way finding and circulation systems are essential components required in the building design process. In building design, the various factors that impact on these include accessibility,

visibility and connectivity. These factors simply identified as Elements of Circulation, were discussed in this paper using fundamental components like *Approach*, *Entrance*, *Configuration of Path*, *Path-Space Relationship* and *Form of the Circulation Space*. In the case of hospital designs, these factors has been identified as critical in the efficiency of services, which culminates in the reduction of risk of cross-infections, decrease delay time experienced in internal and external service delivery, achieving friendly environment for hospital visitors as well as reduction in the evacuation time in 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. This paper presented the significance of the features of a Circulation space in the hospital design process using the Baze university hospital building design; it further demonstrated the importance of visibility in circulation zones and openness of flow spaces that hospital users and healthcare workers utilize to get across functional areas.

6.0 Recommendations

Finally, these ideas demonstrated in this study may be adopted as practical approach in layout configurations and designs of hospital circulation systems with the aim of easing the challenges of way-finding and flow in buildings. The significance of Visibility graph analysis in determining the efficiency of pathway configuration has been demonstrated and found to be an effective means of predicting performance of corridors and pathways in buildings. Hospital designers may utilize this analysis system to evaluate the sizes of corridors/pathways before implementation. This will aid in attaining the efficiency required for circulation in Hospitals and other public buildings as well.

7.0 Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

- Allison D (2007) Hospital as city: Employing urban design strategies for effective wayfinding. *Health Facilities Management*, 20 (6): 61–65.
- Ahmadpoor, N. & Shahab, S. (2019). Spatial Knowledge Acquisition in the Process of Navigation: A Review. *Current Urban Studies*. 7, 1-19. 10.4236/cus.2019.71001.
- Ching F.K. (2019). *Architecture: Form, space, & order*. Hoboken, N.J: John Wiley & Sons
- Colling, J., Wollschläger, R., Keller, U., Grass, J., & Strobel, A. (2023). The relation between Self-Control, Need for Cognition and Action Orientation in secondary school students: A conceptual replication study. *PLOS ONE*. 18. e0286714. 10.1371/journal.pone.0286714.
- Deng, Q., Jiao, C., Wang, G., Song, X., & Zang, J. (2023). A Study on the Layout of Hospital Ward Buildings in Cold Regions of China Based on the Efficiency of Nurse Rounds. *Buildings*, 13(6), 1399. <https://doi.org/10.3390/buildings13061399>
- Fourtassi, M., Rode, G., & Pisella, L. (2014). Eye movements in visual mental imagery: The mind's eye revealed by ocular tracking. *Annals of Physical and Rehabilitation Medicine*. 57. e141. 10.1016/j.rehab.2014.03.1583.
- Gesler W, Bell M, Curtis S, Hubbard P, Francis S (2004) “Therapy by design: Evaluating the UK hospital building program”, *Health and Place*, 10 (2): 117-128.

- Hillier, B. (1996). *Space is the Machine*. Cambridge University Press: Cambridge
- Hölscher C, Brösamle M (2007) Capturing indoor wayfinding strategies and differences in spatial knowledge with Space Syntax. *Proceedings, 6th International Space Syntax Symposium*, İstanbul: ITU Faculty of Architecture.
- Jiang S, Verderber S (2016) On the Planning and Design of Hospital Circulation Zones: A Review of the Evidence-Based Literature. *Health Environments Research & Design Journal*, 10: 1-23.
- Kwon, J., Schmidt, A., Luo, C., Jun, E., & Martinez, K. (2025). Visualizing Spatial Cognition for Wayfinding Design: Examining Gaze Behaviors Using Mobile Eye Tracking in Counseling Service Settings. *ISPRS International Journal of Geo-Information*, 14(10), 406. <https://doi.org/10.3390/ijgi14100406>
- Lee J, Lee H, McCuskey M. (2020). Exploring the spatial arrangement of patient rooms for minimum nurse travel in hospital nursing units in Korea. *Frontiers of Architectural Research*, 9(4):711–25. doi: 10.1016/j.foar.2020.06.003.
- Lynch K (1960) *The image of the city*. Cambridge, MA: MIT Press.
- Natapov, A., Kuliga, S., Dalton, R., Hölscher, C. (2019). Linking building-circulation typology and wayfinding: design, spatial analysis, and anticipated wayfinding difficulty of circulation types. *Architectural Science Review*. 63. 10.1080/00038628.2019.1675041.
- Nazarian M, Price AD, Demian P (2011) A review of different approaches to access and people circulation within health-care facilities and the application of modelling, simulation and visualisation. *CIB-W096 Architectural Management in the Digital Arena*, Vienna, 219-231.
- Pachilova R, Sailer K (2020) Providing care quality by design: a new measure to assess hospital ward layouts. *The Journal of Architecture*. 25: 186-202.
- Paknezhad, N. & Latifi, G. (2021). Explaining the Framework of the Effect of Spatial Organization on the Citizens' Behavioral Patterns Explaining the Framework of the Effect of Spatial Organization on the Citizens' Behavioral Patterns (Comparative Study of the Zargandeh and Darrous Neighborhoods using Urban Network Analysis Method) . *Urbanism. Architecture. Constructions*. 10.22034/AAUD.2020.193706.1933.
- Passini R (1996) Wayfinding design: logic, application and some thoughts on universality. *Design Studies*. Vol. 17(3): 319-331.
- Peer M, Nadar C, Epstein R (2023). The format of the cognitive map depends on the structure of the environment. *J Exp Psychol Gen*; 153(1):224-240. doi: 10.1037/xge0001498. PMID: 37843528; PMCID: PMC10872840.
- Hillier B (1996) *Space is the Machine*. Cambridge University Press: Cambridge
- Peponis J, Zimring C, Choi YK (1990) “Finding the Building in Wayfinding”, *Environment and Behavior*, 22 (5): 555-590.
- Stella, M., Citraro, S., Rossetti, G. (2024). Cognitive modelling of concepts in the mental lexicon with multilayer networks: Insights, advancements, and future challenges. *Psychon*. <https://doi.org/10.3758/s13423-024-02473-9>
- Tolman EC (1948) Cognitive maps in rats and men. *Psychological Review*. 55 (4): 189–208.

- Turner A, Doxa M, O'Sullivan D, Penn A (2001) From isovists to visibility graphs: a methodology for the analysis of architectural space. *Environment and Planning B: Planning and Design*, 28: 103-121
- Verderber S (2003) Architecture for health-2050: An international perspective. *The Journal of Architecture*, 8: 281–302.
- Verderber S (2010) *Innovations in hospital architecture*. London, England: Routledge.
- Xie, H., Filippidis, L., Gwynne, S., Galea, E.R., Blackshields, D., Lawrence, P. (2007). Signage Legibility Distances as a Function of Observation Angle. *Journal of Fire Protection Engineering - J FIRE PROT ENG*. 17. 41-64. 10.1177/1042391507064025.