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RESEARCH PAPER

A Study on the Spatial Proximity if In-Patient Departments and Movement Patterns in DHQ Hospitals for Reduction of Congestion

[1]Aisha Rafique, [2]Ubaid Ullah and [3]Zobia

1. Masters Student, Department of Architecture, University of Engineering & Technology Peshawar, Abbottabad Campus, KP, Pakistan
2. Lecturer, Department of Architecture, University of Engineering & Technology Peshawar, Abbottabad Campus, KP, Pakistan
3. Assistant Establishment, Deputy Commissioner Office Mansehra, KP, Pakistan

Corresponding Author: drubaidullah@uetpeshawar.edu.pk

ABSTRACT

This study aims to explore the impact of spatial configuration on usage patterns of healthcare facilities in DHQ's of Khyber Pakhtunkhwa Province to look for suitable ways to alleviate traffic. One of the healthcare system's main responsibilities is to provide timely, affordable, and accessible healthcare services. However, hospital overcrowding has been made worse by the growing demand for healthcare. Hospitals are complicated spaces that need to be moved around efficiently for visitors, employees, and patients; nevertheless, many of them suffer from traffic because of inadequate spatial arrangements. This research applies space syntax to assess how hospital buildings are arranged, especially the spatial proximity of inpatient departments (IPDs). The results show that the regions with high low mean depth values and high connectivity are appropriate for the placement of units in a hospital context. A highly comprehensible hospital reduces confusion, needless movement, and traffic by enabling people to deduce important locations from their environment. Based on the analysis spatial reconfigurations are suggested to increase overall patient and staff movement efficiency, reduce travel distances, and improve connection in order to ease traffic and raise the standard of care provided in DHQ hospitals.

KEYWORDS Hospital Spatial Layout, Movement Pattern, Congestion, Spatial Arrangement, Space Syntax Analysis

Introduction

A community's health care system has a big impact on the welfare and health of its residents. Hospitals are made up of a network of interrelated systems that operate together to meet the functional requirements of different tasks performed in a medical setting.

They are not merely an architectural envelope intended to contain therapeutic services and operations. Hospital visits are typically unpleasant for visitors, who are frequently there against their will and in a state of anxiety, pain, and discomfort, regardless of whether they are visiting a sick person or someone who needs to look after themselves. In healthcare institutions, patients and guests want to get to their destination as soon as possible, whether it's for an appointment, to see a patient in a ward, or to find the emergency department. In the physical environment, hospitals might be difficult to navigate because there aren't many obvious signs (Khatami, 2020).

Emergency departments (ED), intensive care units (ICU), and in-patient units (IPD) are among the functional units of hospitals that provide a range of services. Hospital congestion brought on by ineffective coordination between these units mostly impacts patient admissions through the emergency room. In the past decade, overcrowding has become a significant problem in hospitals. Patients require treatment from several hospital departments. Ineffective coordination across functional units is a serious problem that increases costs, causes delays in patient care, and disrupts patient flow. Due to inefficient arrangement, which also significantly affects how users perceive the space, patients may have a bad impression of the setting, and travel and waiting times will increase (Khan,2012). Proximity is essential for efficiency, reducing traffic, and ensuring patient comfort and safety in healthcare facilities.

In-patient departments (IPDs) are a vital feature of medical facilities because they offer vital services to patients who need to be admitted. Wards appear to be the most pertinent areas since they have the most floor area of any hospital department and patients spend the majority of their time there (Alalouch, 2009).

Visitors are exposed to stressful or inconvenient situations due to the current placement and spatial arrangement of I.P.Ds, which also impairs their capacity to effectively contact and engage with hospitalized family members, employees, and other users. Their experience can be improved by a thoughtfully planned spatial layout that impacts their usefulness and efficiency while offering comfort and support during their hospital stay. New users move and direct their paths toward locations with more direct connections in a medical setting.

Literature Review

Extensive research has been conducted on health-care environments. A first-rate healthcare center consists of administration, research labs, training facilities, and patient departments both indoors and outdoors. The physical connections between different departments largely dictate how a hospital is organized. Most of the research conducted so far has focused on individual patient care units or the interactions between a limited number of patient care units (Kim, 2023).

The health of a nation's citizens has a significant impact on both its stability and rate of development. Poor management techniques and inadequate layout lead to overcrowding, postponed admissions, and longer wait times for patients (Aljohani, K., 2019). A hospital facility that is well-designed improves user accessibility to locations, physical comfort, safety, and social interactions (Brunye, 2018).

Spatial legibility is the extent of a building's arrangement that makes sense to visitors by being clear, simple, and well-organized (Koseoglu, E., & Onder, D. E., 2011). It depends on a number of variables, including scale, accessibility, connectivity, and how simple it is to identify a noteworthy landmark for orienting (Anacta, 2017).

In healthcare facilities, it must be planned to maximize space use while taking patient accessibility, floor area, and building footprint into account (Shah, D. A., 2019). Spatial proximity in hospital design describes the architectural arrangement and separation of departments to improve patient outcomes, reduce traffic, and increase mobility. Mobility may be facilitated or hindered by a patient's travel, depending on the quality of the environment (Meka, 2023).

According to van der Zwart and van der Voordt, the relevance of these locations' characteristics is found in their interdependence. Numerous research have shown that wayfinding behavior is highly dependent on human movements, cognitive capacities, and social interactions in the environment, as well as spatial layout (Dalton, 2019).

The Australasian College for Emergency Medicine (ACEM) in 2014 stated that, "Any care model should aim to reduce unnecessary steps in the patient journey and to maximize the timeliness of all the essential components of the journey." The degree to which hospital layout and design affect patient behavior, however, is yet unclear (Peponis, 2012).

The use of space syntax in medical institutions

International guidelines and the World Health Organization (WHO) stress how crucial it is to connect and arrange the many hospital components to encourage fluidity, which in turn guarantees the circulation flow. Lack of this organizational element results in uneasy feelings that affect patients and visitors as they travel around the hospital, causing them to feel lost or alone, which in turn affects the hospital's overall effectiveness.

Since the 1990s, healthcare settings have utilized space syntax, which enables the quantification and optimization of spaces (Haq, & Luo, 2012). It is therefore regarded as a helpful method for designing facilities. According to Peponis et al. (1990), who were among the first to use space syntax in healthcare research, well-integrated surroundings are more accessible. Additionally, they found a connection between movement fluxes and the integration variable.

Analytical Approach

The link and accessibility patterns inside the healthcare facilities examined in this study using the integration concept. Integration allows for the measurement of a space's relative accessibility within a system. In order to directly compare systems of different sizes, Hillier and Hanson define integration as a global, relativized measure of depth (Hillier, & Hanson, 1984).

As a measure of depth distance, connectivity is the most popular analytical technique in space syntax. The number of neighbors that a region has that are directly connected to it is known as connectivity. By connecting nodes directly to one another, the connectivity value analyzes how a route can be incorporated into the complete system and displays the number of nodes that are connected to one another. The intelligibility coefficient must be used to comprehend and improve hospital mobility patterns and spatial closeness.

Material and Methods

Research starts with collection of DHQ hospitals' drawings which are subsequently recreated in Autodesk revit before axial analysis. The first method was to look at how IPDs were currently positioned in secondary level hospitals. The second, and most important, method was to use Space Syntax Depthmap software to examine how close IPDs were to other important departments like the emergency room, diagnostic unit, intensive care unit, OTs, and hospital building entrances.

Axial analysis is used to determine the hospitals' layout's primary spatial axes, integration, connectedness, and mean depth values.

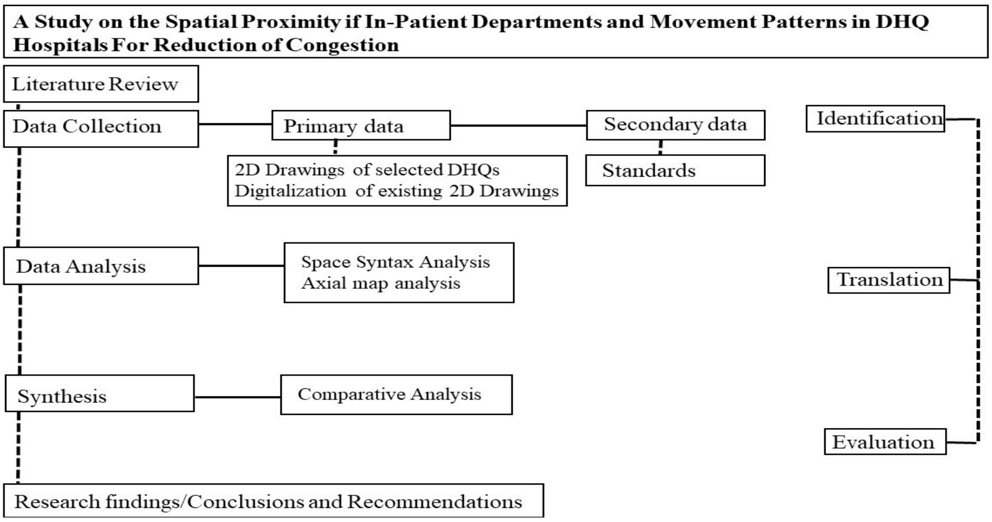


Figure 1 Research Design and Framework

Results and Discussion

In **Case-1** (H-1) both floors are typical. IPD is provided on each level and departments are connected through common corridor. However, there are no designated staff corridors, which can help ease traffic in public sections.

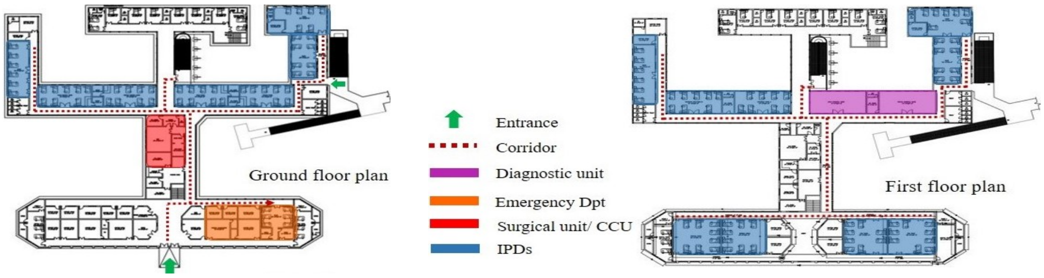
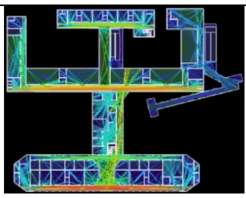
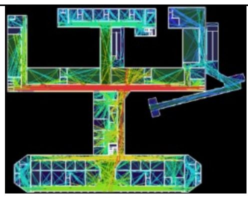
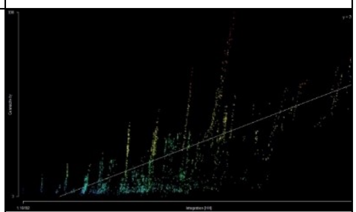
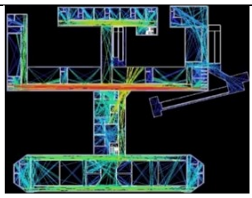
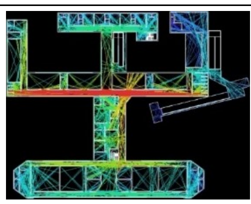
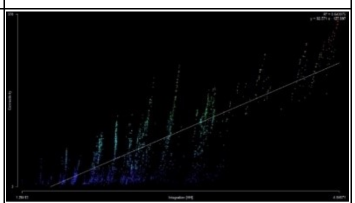


Figure 2 Floor plans of Case-1(H1)

Table 1
Axial Analysis of H1

Case -1 (H1) Axial Analysis	Connectivity	Integration	Intelligibility coefficient (R^2)
Ground floor Mean Depth = High R^2 = 0.526			
First Floor Mean Depth = High R^2 = 0.643			

The intelligibility coefficient values should be nearer 1 in order to satisfy the requirements for effective flow inside the hospital setting. The ground floor of the H1 has a 0.526 and the first floor has a 0.643, which is moderate indicating that the hospital's spatial design is not particularly intuitive but is adequately predictable.

Table 2
Comparison with Depthmap results

Case-1 (H1)	Connectivity		Integration [HH] Global Integration (Rn)		Integration [HH] Local Integration (R3)		Mean Depth	
	Low	High	Low	High	Low	High	Low	High
	3	379	1.16	4.84	2.47	6.74	2.8	8.57
Emergency	117		3.29		5.42		4.31	
Diagnostic	107		3.7		4.9		3.18	
IPD on G.F	54		2.7		4.75		4.04	
IPD on F.F	86		3.27		5.3		4.4	
Surgical suits	89		2.39		3.96		4.3	

It is evident from the table that the syntactic characteristics of the spaces have the higher values of integration and mean depth in the spatial layout but connectivity value is low.

In **Case-2** (H2) is divided into three floors. With several units, the ground level occupies the majority of the hospital's space. IPD is situated on each floor, dispersing the user flow.

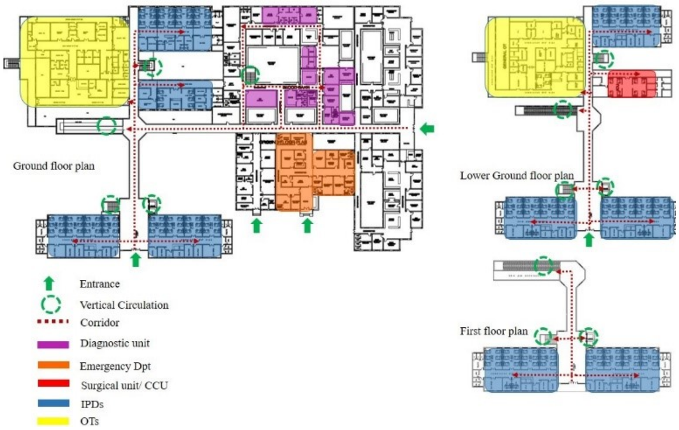
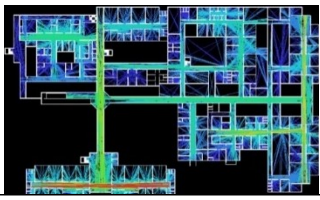
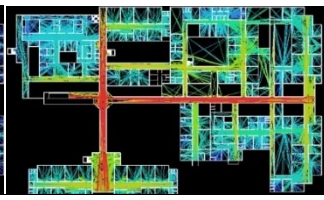
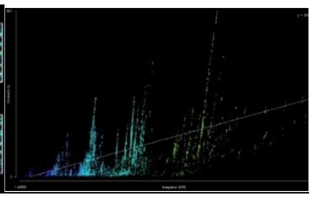
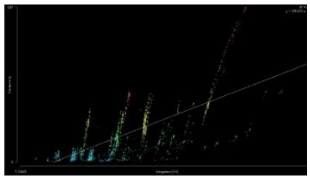
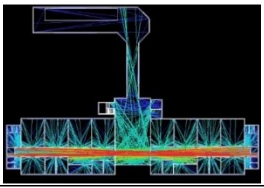
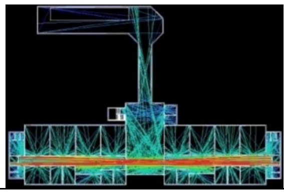
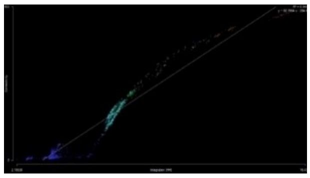


Figure 3 Floor plans of Case-2 (H2)

Table 3
Axial Analysis of H2

Case -2 (H2)	Connectivity	Integration	Intelligibility coefficient (R^2)
Ground Floor Mean Depth = High R^2= 0.343			

Lower Ground Floor Mean Depth = High R^2= 0.506			
First Floor Mean Depth = Low R^2= 0.945			

Comparing the G.F. to the L.G.F. and F.F., the intelligibility coefficient is poor which is R^2 = 0.343. G.F covers maximum area of the hospital. The F.F. has a high intelligibility of 0.945, which facilitates smoother traffic flows because movement patterns match the hospital's spatial hierarchy, while the L.G.F. has a moderate intelligibility of 0.506.

Table 4
Comparison with Depthmap results

Case-2 (H2)	Connectivity		Integration [HH]				Mean Depth	
			Global Integration (Rn)		Local Integration (R3)			
	Low	High	Low	High	Low	High	Low	High
	2	955	1.33	16.43	2.01	16.63	1.49	7.74
Emergency	324		3.1		5.98		4.51	
Diagnostic	103		2.89		5.3		3.7	
IPD on G.F	215		2.89		6.6		4.5	
IPD on L.G.F	249		3.3		6.7		3.7	
IPD on F.F	319		6.6		7.3		2.1	
Surgical suits	59		2.7		4.1		4.2	
OTs on G.F	106		3.7		5.33		3.7	
OTs on L.G.F	109		4.2		5.7		2.8	

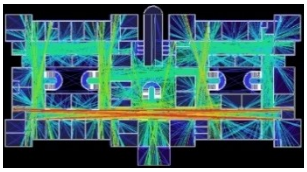
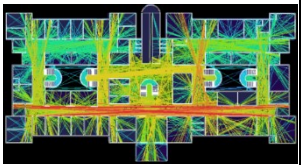
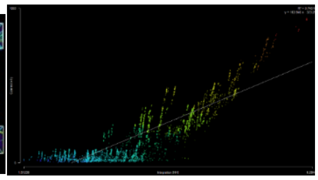
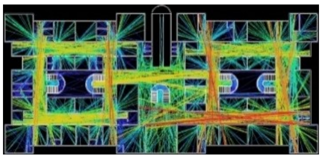
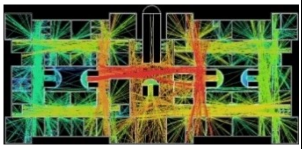
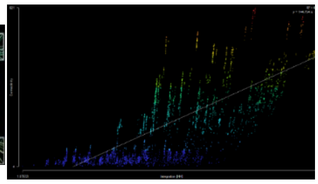
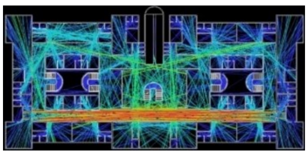
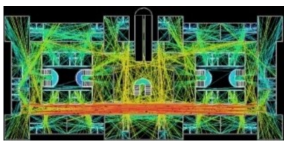
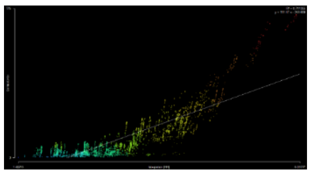
The table makes it abundantly evident that the syntactic features of the spaces have high integration values but low connectedness.

Compared to the other departments, the ground floor has a higher mean depth of IPDs, whereas the first and lower ground floors have lower mean depths. The space is more directly accessible and integrated into the layout when the mean depth is lower.

In **Case-3** (H3) is divided into three floors and each floor is typical. IPD occupies the second floor. On the first floor, close to OT, is the CCU, and on the same floor is the diagnostic unit.

Figure 4 Floor plans of Case-3 (H3)

Table 5
Axial Analysis of H3

Case -3 (H3)	Connectivity	Integration	Intelligibility coefficient (R^2)
Ground Floor R^2 = 0.7451 Mean Depth= Low			
First Floor R^2 = 0.5233 Mean Depth= Low			
Second Floor R^2 = 0.7411 Mean Depth= Low			

The high intelligibility values of 0.7451 and 0.7411 for the ground floor and second floor of H3, respectively, make traffic simpler. Inferring the general structure of the hospital from local spatial signals is challenging due to the first floor's moderate intelligibility of 0.5233, which indicates that spatial intelligibility is not particularly strong.

Table 6
Comparison with Depthmap results

Case-3 (H3)	Connectivity		Integration [HH] Global Integration (Rn)		Integration [HH] Local Integration (R3)		Mean Depth	
	Low	High	Low	High	Low	High	Low	High
	3	775	1.07	6.28	1.38	9.01	2.5	9.9
Emergency	386		5.39		7.98		3.1	
Diagnostic	443		4.4		6.6		3.41	

Surgical suits	296	4.03	6.43	3.48
OTs on First floor	314	3.9	6.1	3.2
IPD on second floor	245	4.2	5.9	3.35

From table 6, the mean depth value of IPD is regarded as low as it is less than three times the high value but more than half of the low value. Because of its strong connectivity, the second level is easily accessible and beneficial in the hospital plan, ensuring functionality without making traffic flow more difficult. It suggests a comparatively high degree of direct spatial connections between the IPD on this floor and adjacent places whereas integration value is also high.

Case-4 (H4) features spacious green fields and pathways linking its many departments. IPD is separated into four units, each of which is situated apart from the emergency unit.

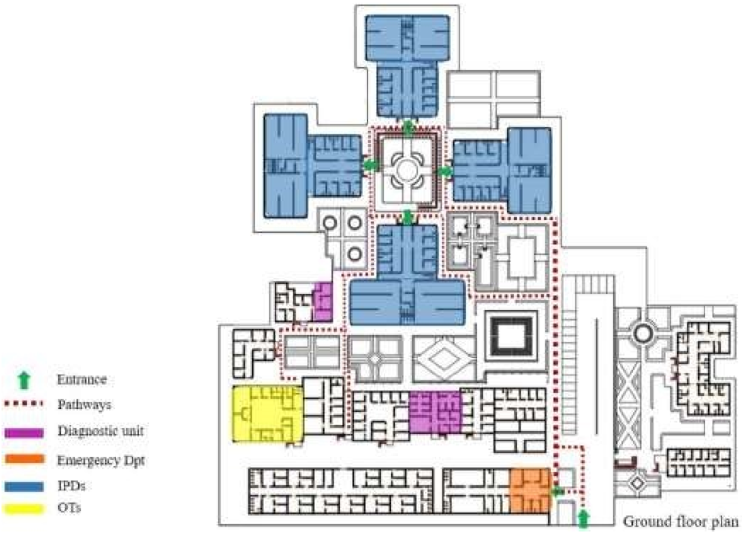
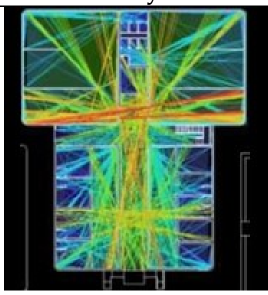
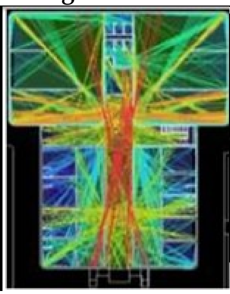
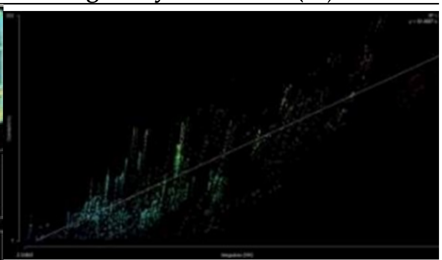


Figure 5 Floor plans of Case-4 (H4)

Table 7
Axial Analysis of H4

Case -4 (H4)	**Connectivity**	**Integration**	**Intelligibility coefficient** (R^2)
IPD plan of H4 R^2= 0.702 Mean Depth= Low			

The high intelligibility coefficient of 0.702 at H4 makes traffic flows easier because movement routes make sense given the hospital's spatial hierarchy and encourage efficiency and spatial awareness in movement patterns.

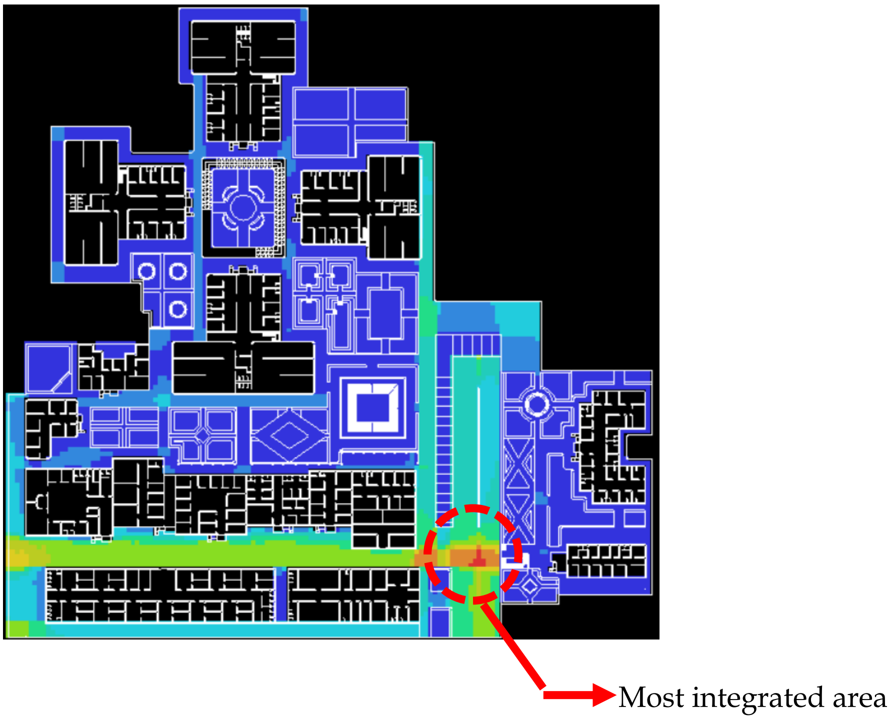


Figure 6 VGA map of Case-4 (H4)

Table 8
Comparison with Depthmap results

Case-4 (H4)	Connectivity		Integration [HH] Global Integration (Rn)		Integration [HH] Local Integration (R3)		Mean Depth	
	Low	High	Low	High	Low	High	Low	High
	1	554	0.94	3.82	0.84	8.47	3.5	11.40
Emergency	174		2.5		7.7		2.09	
Diagnostic	86		3.2		5.6		3.1	
IPD	154		3.7		5.4		3.1	
OT	118		4.8		5.3		2.6	

The table 8 indicates that the average depth of IPD from the DHQ Abbottabad entrance is 3.1, which is less than twice of the high values. IPD is well connected and integrates well with other important departments like diagnostics and OTs, however it has less interaction with the emergency unit.

Comparative Analysis

The comparative analysis identifies the primary issues at H1 and H2, with the mean depth of IPD being higher on the ground level of both locations. In H2 the ground level has a low intelligibility coefficient, making it challenging for users and visitors to traverse, while H1 has a moderate one.

All hospital facilities have a higher level of IPD integration, except of H4, where the emergency unit has a lower level of integration because of the long travel distance.

Conclusion

The primary goal of this study was to assess the significance of inpatient department placement and connectivity in medical environments.

A highly intelligible hospital plan minimizes confusion, needless movement, and traffic by enabling users to anticipate the placement of important areas based on their immediate surroundings. Interdepartmental communication between IPDs and other vital units, such as the diagnostic, emergency room, OTs, and CCUs, must be strong and efficient.

Patient transfers to care units are inefficient at H4 due to the maximum travel distance between the emergency department and IPDs. Compared to the units' existing positions in the selected buildings, the journey distance can be reduced in areas with better connectivity, integration, and depth values.

Regarding objective 3, the data analysis will help researchers, architects, and designers implement the building analysis framework to enhance the spatial arrangement of sections inside the layout.

Easy access to essential hospital units and more efficient traffic patterns are necessary to reduce congestion. The organization of the areas is determined by their functional linkages and hierarchy. The integration values for these design types demonstrate that the spatial arrangements follow a logical pattern.

The results of this study demonstrated the consistency of hospital planning. Their syntactic values share a configurational pattern, despite their highly diverse layout patterns.

Recommendations

Based on the analysis,

- Strategic placement of the IPD for optimal integration with important departments should be given top priority in spatial planning for a clear and intelligible layout. Design changes based on Space Syntax analysis to increase intelligibility and connection.
- Segregated paths or pathways and dedicated patient elevators are recommended to keep patient mobility apart from public circulation, which will cut down on delays and traffic.
- An architect can guarantee effective flow and design even before construction starts by using the framework and techniques suggested in this study to analyze his building plans and designs in relation to the placement and spatial proximity of departments.
- An interdisciplinary team of architects, legislators, and medical experts should work together to integrate space syntax into national and provincial rules, guaranteeing that hospitals are analyzed during the design stage in order to use this recommended framework.

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