Assessing Spatial Cognition in Level 1 Hospitals using Space Syntax Theory

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Abstract: Efficient hospital design is essential for optimizing patient care, staff performance, and workflow. This study assesses spatial cognition in Level 1 hospitals using Space Syntax Theory, focusing on spatial organization, connectivity, and movement efficiency. DepthmapX was utilized to analyze visibility and connectivity, while Arena Simulation modeled patient and staff movement to identify high-traffic zones, bottlenecks, and underutilized areas. Findings highlight the importance of aligning hospital spaces with functional zoning guidelines to enhance wayfinding, workflow, and service delivery. High-visibility areas should facilitate quick access to essential services, while lower-visibility zones prioritize privacy and security. Simulation results reveal that optimizing high-utilization spaces, such as emergency and consultation areas, reduces congestion and improves efficiency. Additionally, strategic space allocation for administrative and service areas enhances operations. This study underscores the role of spatial cognition in hospital design, offering data-driven insights to guide the planning and development of future Level 1 hospitals in the Philippines.

Key Words: *DepthmapX, Arena Simulation, Workflow Efficiency*

1. INTRODUCTION

1.1 Background of the Study

The design and organization of hospitals have evolved significantly over time, with continual innovations aimed at improving patient care, workflow efficiency, and overall operational effectiveness (Lockley, 2024). In the Philippines, the development of hospital infrastructure reflects its historical colonial influences and the growing needs of its healthcare system. The Department of Health (DOH) introduced a hospital classification system in 2005, categorizing hospitals into Levels 1, 2, and 3 based on service offerings. Level 1 hospitals primarily focus on basic clinical services, primary health care, and minor surgeries, often handling general medicine, pediatrics, and obstetrics (DOH, 2005).

The Philippine Health Facility Development Plan (PHFDP) 2020-2040 highlights the urgent need to address critical gaps in healthcare infrastructure and services. By 2040, outpatient visits and inpatient bed-days are projected to rise by 60%, driven largely by the increasing prevalence of non-communicable diseases. To address these demands, the country requires an additional 400,000 hospital beds, focusing predominantly on Level 1 facilities, which play a pivotal role in primary care delivery (DOH, 2020) despite having 780 level-1 accredited hospitals in the Philippines (Balita, 2024), these challenges and opportunities underscore the importance of enhancing spatial efficiency, connectivity, and usability in the design of future Level 1 healthcare facilities.

Baguio City, as one of the highly urbanized cities in the Philippines, faces challenges related to healthcare accessibility and facility quality due to an inadequate number of healthcare facilities (Dumlao, 2021). The Department of Health in the Cordillera

Administrative Region (DOH-CAR), through its Health Facility Development Unit (HFDU), has identified an urgent need for more hospital beds to meet the city's demands (DOH CAR, 2024). Although significant efforts have been made to improve healthcare delivery, the spatial structure of hospitals remain areas of concern.

To address these concerns, the city has proposed establishing a government-operated Level 1 hospital to increase healthcare accessibility for residents and reduce overcrowding in existing facilities. This proposal aligns with the Philippine Health Development Plan 2020-2040 which identifies an unequal distribution of hospital care across provinces and regions and recommends that every province and highly urbanized city should have at least one Level 1 and Level 2 hospital (DOH, 2020). In light of these gaps in healthcare accessibility, the researchers have identified other municipalities with needs for Level 1 hospitals. These include Itogon and Tuba, Benguet, Pugo and Tubao in La Union.

Another critical issue within hospitals today is spatial cognition, which has been recognized as a major factor that contributes to delays in healthcare service delivery and creates confusion for both patients and staff (Jiang et al., 2022). Hospital layouts and navigation routes are often confusing, which frequently leads to service delays, congestion, and dissatisfaction among patients (Sanchez et al., 2018). Historically, hospitals in the early 20th century maximized bed space with narrow corridors and maze-like layouts, which caused confusion and delays (Gesler et al., 2019). With the rise of modernist design principles, hospital layouts were streamlined to enhance functional movement. However, modern and contemporary healthcare facilities still struggle with spatial cognition issues, which affects patient satisfaction, operational efficiency, and overall healthcare quality (Amato et al., 2021). Ineffective navigation within hospitals often leads to anxiety, delays in care, and operational inefficiencies (Pati et al., 2015).

To improve spatial cognition, space syntax theory will be used. Spatial cognition involves how individuals navigate environments, understand their position within a space, and effectively move toward desired locations (Youssef, 2022). Space Syntax is a method for analyzing the spatial configuration of built environments, focusing on the relationships between individual spaces and the connections that facilitate movement and visibility (Van Nes, 2014). A simple example might be that an ambulatory patient can go to an examination room only after passing through the receptionist area and by the nurses' desk. Similarly, in terms of visibility, new information is received while moving about, and previous information passes beyond visibility. These are the characteristics of the layout (Haq & Luo, 2012). In architectural terms, these features are best seen in the layout of a building, and Space Syntax is the theory that deals with layout. Fundamentally, it considers a plan drawing as a set of "connected" spaces, analyzes these "connections," and on that basis, assigns numerical measures to each space. These analyses provide quantitative measures of individual spaces and the entire layout (Haq & Luo, 2012).

Under Space Syntax, Depthmap X is utilized to analyze visual and spatial networks, contributing to developing effective hospital designs (Pachilova & Sailer, 2022). Depthmap X is primarily a computer program that is used for conducting visibility analysis within architectural and urban systems. It requires a system's floor plan as input and produces a map that highlights visually integrated areas within that space (Turner, 2004). Arena Simulation on the other hand, is a discrete-event simulation software particularly effective for modeling and analyzing hospital operations. It has been effectively utilized in healthcare settings to identify and address bottlenecks in patient flow and staffing efficiency, as demonstrated in case studies where hospitals optimized workflows to enhance patient experiences (Rockwell Automation, n.d).

The researchers assessed the floor plans of the four existing Level 1 hospitals in the province of Benguet for comparative analysis: Baguio Medical Center, Atok District Hospital, Dennis Molintas District Hospital, and Lutheran Hospital Inc, regarding their spatial cognition. The study focused on the four accredited Level 1 hospitals in Benguet for proximity. In addition to examining these hospitals, the researchers also assessed other localities that lack Level 1 hospitals. This will help determine the need for establishing such hospitals in these areas, reducing travel time for patients and providing closer access to healthcare. By applying space syntax analysis and simulation tools, this study aims to identify spatial cognition issues in Benguet's Level 1 hospitals, offering insights to improve workflow and inform the design of future government-operated Level 1 hospitals in the localities. Lastly, this research addresses the broader goals of Sustainable Development Goals 3 (Good health and well being) and 11

(Sustainable cities and communities) by emphasizing the importance of designing healthcare environments that are not only operationally efficient but also accessible and sustainable.

1.2 Objectives of the Study

The general objective of this study is to assess spatial cognition in level 1 hospitals using space syntax theory. In particular, the study aims to:

a. To identify and analyze the layout and configuration that helps to promote spatial cognition in Level 1 hospitals.

b. To assess how space syntax theory and simulation tools can be applied to evaluate spatial cognition of the existing floor plan layout of the 4 accredited Level 1 hospitals in Benguet province.

c. Utilize the simulation softwares using space syntax theory to optimize spatial cognition, hospital layout, and architectural design in the new Public Level 1 Hospitals.

1.3 Limitations of the Study

The study is limited by the availability and accuracy of spatial data from the Level 1 hospitals in Benguet namely, Atok District Hospital, Dennis Molintas District Hospital, Baguio Medical Center and Lutheran Hospital Inc., making the findings context-specific and not generalizable to other regions or higher-level facilities. It relies on Space Syntax Theory and simulation tools (DepthmapX and Arena), which do not fully account for cultural, behavioral, or emotional factors affecting hospital navigation. Time constraints, hospital policies, and staff availability prevented interviews, limiting access to qualitative insights from users.

1.4 Scope of the Study

This study examines spatial cognition in four Level 1 hospitals in Benguet using DepthmapX and Arena Simulation tool. It utilizes DepthmapX for spatial configuration analysis and Arena Simulation for modeling movement within the hospital. The analysis is limited to architectural layout and spatial relationships, excluding behavioral patterns, and emotional responses. The study is confined to Level 1 hospital facilities and aims to offer design recommendations that support the planning of more accessible and efficient healthcare environments.

2. METHODOLOGY

The study employs Space Syntax Theory to examine spatial cognition in Level 1 hospitals. This theory provides a quantitative description of the environment using tools such as DepthmapX and Arena Simulation to evaluate spatial configurations.

2.1 DepthmapX

For DepthmapX, the study utilized Visibility Graph Analysis (VGA) to analyze the floor plans of the four assessed hospitals. This approach helps to evaluate spatial configurations by analyzing visibility relationships between various spaces within the hospitals. In addition to the VGA, a corridor visibility analysis was conducted to examine how well different parts of the hospitals are visually connected, focusing on corridors that are critical for patient and staff movement. These analyses provide insights into how the spatial layout of the hospitals can influence operational efficiency and wayfinding for both patients and healthcare providers.

In space syntax analysis, visibility graph analysis (VGA) is a technique used to examine the visibility characteristics and spatial arrangement of a particular spatial environment (Turner et al., 2001).

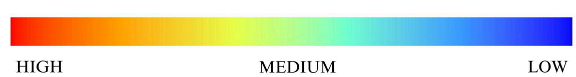

Fig. 1. Visibility Scale (Visibility Graph Analysis)

The color gradient used in the visualization provides a clear representation of these visibility levels: dark yellow to red indicates areas with high visibility, green to yellow-green represents medium visibility, and sky blue to dark blue signifies low visibility (Rauof & Al-Qemaqchi, 2022). Visibility, in the context of Visibility

Graph Analysis, refers to the ability to identify which points within an environment are visually accessible to each other without obstructions.

2.2 Arena Simulation

ARENA Simulation is a tool for modeling and analyzing complex systems, especially in healthcare (Combrink et al., 2024). It allows users to create simulations of hospital workflows to study patient flow, resource use, and efficiency. By visually showing how processes work and interact, ARENA helps spot bottlenecks and delays, making it easier to improve layouts and operations.

In this study, Arena Simulation will play a key role in analyzing and optimizing patient flow, resource allocation, and operational efficiency within selected hospital layouts. By simulating patient journeys from entry to exit within the hospital (See Fig. 2), Arena enables researchers to identify bottlenecks and understand how spatial configurations impact movement and interaction, directly.

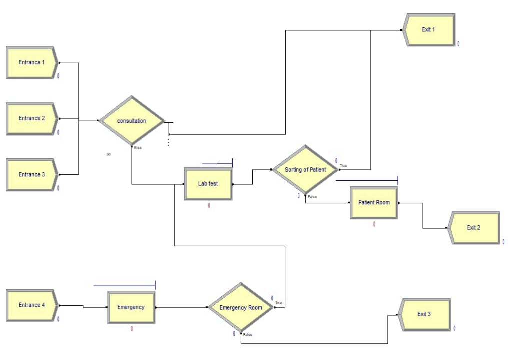

Fig. 2. Representation of the ARENA simulation model in action

First, patient flow and entities are defined within the simulation. Each patient is modeled as an entity with characteristics based on their medical needs, such as the urgency of care (e.g., emergency or outpatient services). These entities navigate through various hospital departments, including registration, consultation, diagnostics, and treatment rooms, with each patient journey representing typical scenarios found in Level 1 hospital settings.

Arena's process flow modules are used to map each step in the patient's journey sequentially—from arrival and registration to diagnostic tests and treatment (Rahman, 2022). This mapping reflects the unique spatial configurations and resource availability of each Level 1 hospital under study, allowing for an analysis of how spatial layout influences movement. By capturing the sequence of patient activities, the simulation provides insights into potential bottlenecks in patient flow and identifies areas for operational improvements.

In addition, resource allocation is modeled in Arena, where hospital resources, such as hospital staff, are integrated into the simulation to assess utilization rates. Arena's tracking capability allows researchers to observe resource availability and demand over time, identifying peak times and instances of potential overuse that could compromise patient care quality or increase staff workload (Rasidi et al., 2024)

3. RESULTS AND DISCUSSION

This section presents the study's findings, along with analysis and interpretation of the data generated. The discussions are organized according to the research objectives.

3.1 DepthmapX

The study analyzes the visibility of the hospital floors and areas. Dark yellow to red indicates areas with high visibility, green to yellow-green represents medium visibility, and sky blue to dark blue signifies low visibility (Rauof & Al-Qemaqchi, 2022). The following are the results of the analysis for the four Level 1 hospitals:

a. Visibility Graph Analysis of the hospital floor plans

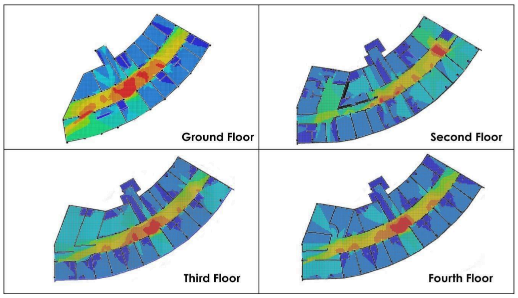

Fig. 3. Baguio Medical Center Visibility Analysis

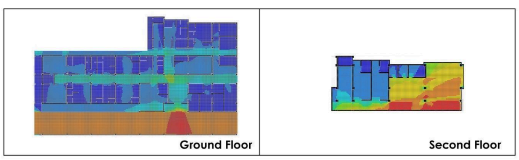

Fig. 4. Dennis Molintas District Hospital, Bokod, Benguet Visibility Graph Analysis

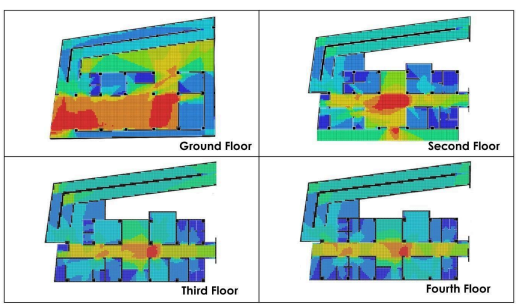

Fig. 5. Atok District Hospital, Atok, Benguet Visibility Graph Analysis

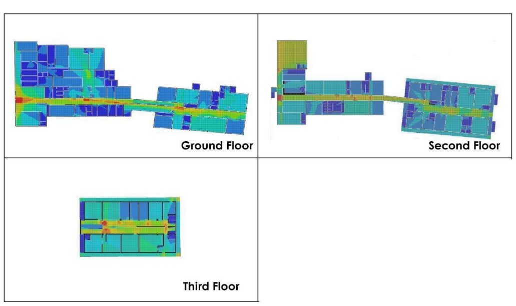

Fig. 6. Lutheran Hospital, Buguias, Benguet Visibility Graph Analysis

Based on the result of VGA, the corridors were identified as having the highest visibility among the four Level 1 hospitals analyzed. This prompted a focused Visibility Graph Analysis specifically for the corridors, as presented in Fig.7. The common areas with high visibility status are the main entrance, hallway, and lobby where primary access points are crucial for orientation and initial guidance, (Gupta et al., 2017). The areas where patients, workers, and visitors engaged the most are appropriate to have adequate spaces to have a good movement circulation to reduce congestion and improve workflow efficiency.

The areas with medium visibility from the assessed hospitals are emergency room, information area, nurse station, operating room and surgical wards. These areas require a degree of privacy to protect patient information and maintain confidentiality and need to be accessible but also require a level of separation from high-traffic zones to create a more supportive environment for both patients and staff.

The areas with low visibility from the assessment of hospitals include laboratories, records offices, administrative offices, patient wards, recovery rooms, pharmacies, clinics, private rooms, doctors' offices, dental clinics, stock rooms, and chief offices. However, Karki in 2023 suggests that patient rooms should ideally fall under medium-visibility areas to balance privacy with accessibility, allowing nurses to monitor patients effectively while maintaining a sense of seclusion. Similarly, Sheila et al., (2016) argue that pharmacies should also be in medium-visibility areas, strategically positioned along primary corridors to ensure convenient access for both patients and visitors. Clinics, laboratories and labor rooms, these areas are often designed with closed doors and limited visibility to control infection and provide patient privacy

Harris and colleagues' study on "healthcare facility design also supports the idea of restricted visibility for infection control", they found that limiting visibility and access to rooms where invasive or close-contact procedures take helps reduce exposure to potential contaminants, promoting a cleaner and safer environment for both patients and staff.

Using Depthmap X, the researchers were able to evaluate the visibility and access within hospital environments by providing detailed data on how accessible or isolated certain areas are and address key considerations like privacy, security, infection control, and productivity.

Since most of the High Visibility Areas come from the hallways. The researchers also assessed the Visibility Graph Analysis (VGA) of the corridor types within hospitals.

b. Visibility Graph Analysis of hospital corridor layouts

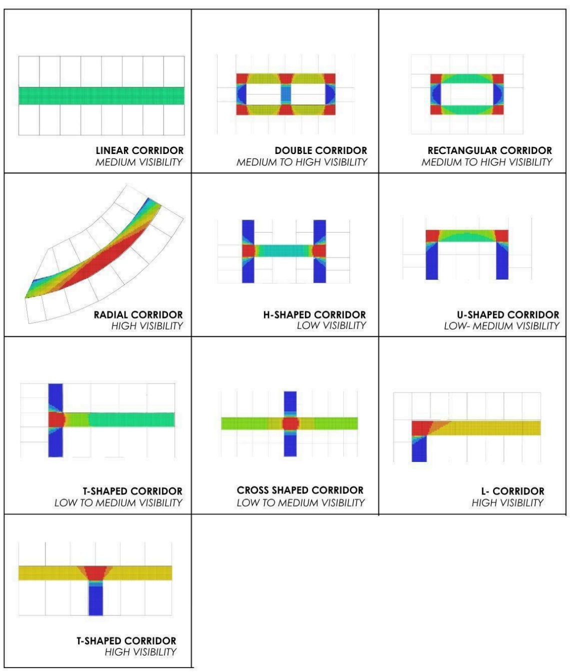

Fig. 7. Visibility graph analysis of the different Hospital Corridor Types

Research underscores the critical role of corridor visibility in enhancing spatial cognition, defined as the ability to understand and navigate environments effectively (Kaplan, 1995). From the results shown in Fig.7, high-visibility corridors, such as Radial/Arc, L-shaped, and T-shaped layouts, provide clear sightlines and ease of navigation, significantly improving wayfinding and spatial awareness. These layouts are beneficial in public zones, where efficient circulation and visibility are paramount for patient and staff navigation.

Medium-to-high visibility corridors, including Linear, Double, and Rectangular layouts, support seamless movement and maintain balanced visibility, often used in spaces requiring moderate accessibility. In contrast, low-to-medium visibility corridors, such as H-shaped and Cross layouts, are suitable for private spaces.

c. Depthmap Analysis Findings and Alignment with DOH Zoning Guidelines

The Depthmap analysis highlights that spatial configurations promoting visibility and connectivity are crucial for wayfinding, workflow efficiency, and hospital functionality. Each zone's corridor layout is designed to align with visibility requirements and the zoning principles set by the Department of Health (DOH). DOH hospital zoning consists of five zones namely: Outer zone, second zone, Inner zone, Deep zone and Service zone. This zones consist of the following spaces for Level 1 hospitals according to DOH guidelines:

1. Outer Zone: Emergency services, outpatient services, and administrative offices.
2. Second Zone: Laboratories, radiology rooms, and pharmacies.
3. Inner Zone: Patient rooms and nursing stations.
4. Deep Zone: Surgical suites, delivery rooms, recovery rooms, and intensive care units.
5. Service Zone: Dietary services, housekeeping services, maintenance, and mortuary.

These zones follow specific visibility needs that support hospital operations. In the Outer Zone, high visibility aids public navigation. The Second Zone requires medium-to-high visibility for efficient staff movement and communication. The Inner Zone benefits from low-to-medium visibility to maintain patient privacy while ensuring caregiver access. Lastly, the Deep Zone has low visibility to preserve sterility and restrict access, aligning with DOH zoning standards. For the Service Zone, low-to-medium visibility is ideal. This supports discreet movement of support staff and services like dietary, housekeeping, maintenance, and mortuary functions—ensuring they operate efficiently without disrupting patient care areas.

3.2 Arena Simulation

The simulation results highlight the impact of spatial planning on patient flow and staff efficiency in Level 1 hospitals:

High-Utilization Areas – The Triage and Nurse Station in the ER are accessed by 100% of patients. In the OPD, the Nursing Units show a 125.89% usage rate, while the Consultation Area is the busiest, with 200% patient usage, reflecting frequent follow-up visits. The Lobby is the most utilized staff area, with 100% usage.

Moderate-utilization areas - The Emergency Complex (60.19%) and Surgical & Obstetrical Facilities (71.17%) exhibit moderate patient flow.

Low-Utilization Areas – The Resuscitation Room (5.77%) and Resuscitation Desk (11.72%) have limited patient flow. The Pharmacy shows low usage, with 9.15% in the ER and 16.15% in the OPD. Imaging and Laboratory areas also have lower usage—28.83% in the ER and 20.5% in the OPD.Other areas such as the Cadaver Holding Room, Waste Room, and Dietary Room all record usage below 40%. High patient volumes in the Nursing Unit and Consultation Area highlight the need for additional consultation rooms and more spacious layouts in the Nursing Units to accommodate the demand efficiently. Areas with high and moderate results require larger spaces to improve spatial cognition.

4. CONCLUSIONS

Designing an efficient Level 1 hospital requires a deep understanding of spatial cognition. This study applied Space Syntax Theory through the use of DepthmapX and Arena Simulation tools to assess how spatial layout influences visibility, accessibility, and user flow in healthcare environments. DepthmapX evaluated hospital floor plans for visual connectivity, while Arena Simulation modeled patient and staff movement to identify high-traffic areas, congestion points, and underutilized zones requiring layout optimization.

Findings from DepthmapX revealed that visibility is most effective when aligned with the Department of Health's Planning and Design Guidelines, which divide hospital spaces into five zones: Outer, Second, Inner, Deep, and Service. High-visibility corridors—such as Radial/Arc, L-shaped, and T-shaped layouts—enhanced spatial awareness and should be placed in high-traffic zones like Emergency Services and Administrative Offices. Meanwhile, low-visibility areas suited to the Inner and Deep Zones help preserve privacy and control access such as patient wards and surgical suites.

The Arena Simulation results reinforced the importance of strategic spatial planning. High-utilization areas such as triage, nurse stations, and consultation rooms require well-integrated and flexible layouts to manage patient loads and reduce bottlenecks. Moderate-use areas like the Emergency Complex and Surgical & Obstetrical Facilities need adaptable designs to handle fluctuating demand.

Future research could explore the integration of real-time data tracking, patient feedback, and post-occupancy evaluations to further validate spatial strategies. Extending this approach to higher-level hospitals would also help establish broader, adaptable design standards for the Philippine healthcare system.

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