Ain Shams University
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Evaluation of Space Layout Planning of General Hospitals Using Algorithms

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Statement

This thesis is submitted as a partial fulfillment of Master of Science in Architectural Engineering Engineering, Faculty of Engineering, Ain shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

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Abstract

The evaluation of an architectural building in the healthcare sector is dependent upon its capacity to fulfill the expectations of various user groups, including patients, patient families, and medical staff.

The research was conducted by studying the definition of general hospital facilities according to international organizations and Egyptian design standards, as all of the case studies are located in Egypt, and the organizational zoning among the departments of the general hospital. Specifically, studying the inpatient department zoning with the goal of knowing the space layout planning basics for the department and the different typologies of nursing units that can be included inside the department.

Also, the research introduced the concepts of space layout planning and the aspects that should be considered during the process. How this process affects the user experience within the physical environment of spaces they use, studying how to improve the space quality to enhance the spatial experience for all of the users inside the inpatient departments in general hospitals.

The research introduced the integration of algorithms in the post-occupancy evaluation process for different typologies of nursing units in inpatient departments, analyzing the effect of spatial configuration on user behaviors according to the different users based on factors such as wayfinding, accessibility, privacy,.. etc. studying how the use of algorithms could be efficient in creating a post-occupancy evaluation for the departments in the general hospital facility.

Keywords:

General Hospitals - Inpatient Departments - Evaluation Process- Space Quality - Spatial Experience - Physical Environment - Post-Occupancy Evaluation - Algorithms.

List of Abbreviation:

- **S.L.P.:** Space Layout Planning.
- **P.O.E.:** Post Occupancy Evaluation.
- **I.C.U.:** Intensive Care Unit, (I.C.U.) deals with patients who are critically ill.
- **M.I.C.U.:** Medical Intensive Care Unit, (M.I.C.U.) deals with patients who are less critically sick but still require more care than they would get in a general ward.
- **P.C.U.:** Progressive care unit, (P.C.U.) provides a level of care intermediate between intensive care units and medical-surgical units.
- **C.C.U.:** The Cardiac Care Unit, (C.C.U.) is a specialized ward designed to accommodate patients experiencing cardiac arrest or other heart conditions necessitating immediate medical intervention.
- **O.B. / GYN. Unit:** Obstetrics and Gynecology Unit.

Software Used:

- **Rhino:** It is computer-aided design software. Rhino CAD is used primarily in architectural trades and industrial design. A 3D development platform for specialty modelling, rendering, analysis, and fabrication tools across a wide variety of disciplines.
- **Grasshopper:** It is a visual programming language and environment that runs within the Rhinoceros.
- **Decoding Spaces:** De-Coding Spaces Toolbox for Grasshopper is a collection of analytical and generative components for algorithmic architectural and urban planning as: Visibility analysis, Street network analysis, Plot generation, …. Etc.

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Introduction

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i. Preface

Using their expertise, design principles, and adherence to legal requirements, architects frequently design hospital facilities with a focus on creating spaces that act as a healing environment for the patients and an easily accessible space for the medical staff and visitors. Nevertheless, the arrangement of facilities and resources also plays a significant role in determining the operational effectiveness of healthcare services.

However, there is an intersection between the planning of space configurations and the user behaviors within these spaces. In the healthcare field, many studies focus on the role of the physical environment in improving the healing environment for patients. And how the post-occupancy evaluation plays a crucial role in improving the existing configurations of different buildings according to the developed technologies in construction and also in avoiding the repetition of mistakes in the planning of new projects.

provide a comprehensive and detailed description of the research:

Chapter 1:
Discuss the inpatient department planning guidelines in general hospitals through explaining the definition of hospital facilities from different points of views. Define the zoning configuration of the inpatient department and the main users, and the spatial relations between them. Also, the different typologies of nursing units in the inpatient department.

Chapter 2:
The chapter discusses the role of space layout planning in healthcare facilities, focusing on its role in the design process and spatial configuration. It emphasizes the importance of transforming patient care factors into space quality factors, thereby improving the physical environment for users.

Chapter 3:
The chapter discusses the evaluation methods in healthcare facilities, particularly the post-occupancy evaluation process, and reviews theories integrating sight and visibility analysis to explore the impact of spatial configurations and physical environments on user behaviors in hospital facilities.

Chapter 4 (Case Studies):
Evaluating the space layout planning of inpatient department with different layout configurations by using algorithms based on Isovist theory, testing the aspects derived from the literature of space layout planning and space quality factors that directly affect the behaviors of users in space layout planning.

Chapter 5:
Finally, the concluding chapter discusses the results from the use of algorithms in inpatient department space layout planning, its impact on user behavior, and its integration in post-occupancy evaluation, aiming to improve and develop existing configurations for new projects.

ii. Research Problem

Despite the growing interest in research studies on how the physical environment influences users behaviors, especially in hospital facilities, Investigating how the space configurations affect medical performance and patients' satisfaction in healthcare facilities, many studies focus on exploring the users behaviors based on their visual fields using various theories such as space syntax and visibility graph analysis. Few studies focus on the integration of using a tool that is based on the field of sight of the observer in evaluating the spatial configuration of a space during the post occupancy evaluation process of buildings, which directly translates how the behavior of users in that space is. Depending on this analysis, as an alternative to the conventional way of post-occupancy evaluation that can be applied in the inpatient departments of general hospitals or any other departments.

iii. Research Aim

Utilization of algorithms in the evaluation of space layout planning in general hospitals. especially in inpatient departments, as a case study for exploring applying algorithms in the post-occupancy evaluation process of general hospital departments.

iv. Research Objectives

The research attempts to bridge the gap between the use of post-occupancy evaluation in analyzing the functionality of certain layout configurations and the use of visibility analysis research that focused on using the field of sight of users in exploring the effect of spatial configuration and the physical environment of the space on the users behaviors. Also, to assess the validity of using developed tools based on the visibility analysis theories (Isovist) in the evaluation of the space layout planning of inpatient departments based on aspects that should be considered during the design stage to formulate an analysis, helping to avoid the repetition of mistakes in future projects by the experts and architects. The following figure (0–1) represents a detailed map of the research's main aim and the secondary objectives.

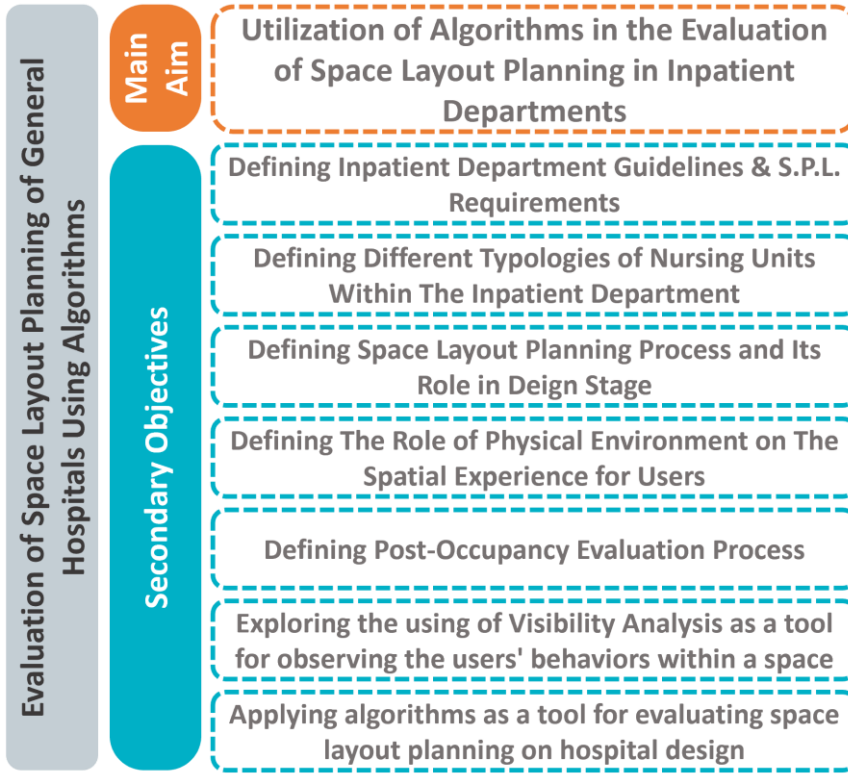

Figure 0- 1: Research Main Aim & Secondary Objectives
By: Researcher

v. Research Hypothesis

“The space layout planning of the inpatient department configuration directly affects the performance of the medical staff, the satisfaction of the patients and their families, and the delivery of services within the space configuration of the department”

So, the research studies the integration of visibility analysis based on algorithms (Isovist Theory) as a post-occupancy evaluation process methodology for the inpatient department in general hospitals. Considering it in the development of existing configurations or as a reference in the new planning process for the inpatient department space layout configuration.

vi. Research Methodology

The research follows exploratory research methodology, investigating using algorithms as a new tool in the post-occupancy evaluation of space layout planning in general hospitals. The research is built on stages, including the following:

First, Theoretical Study: Defining the literature review related to hospital facilities and exploring the design guidelines of inpatient departments. Also reviewing the effect of the physical role on the healing process, using visibility analysis to explore the effect of spatial configurations on the user's behaviors, and the role of using P.O.E. on the development of the building life cycle.

Second, Analytical Study: Analyzing process of space layout planning and the factors and criteria that should be followed and taken into consideration during this stage. Conducting Aspects used in applying algorithms in the post-occupancy evaluation process of inpatient department.

Third, Experimental Study: Applying algorithms for evaluating the space layout planning of the inpatient department based on the aspects of space layout planning.

Finally, Conclusions and Discussion: Conduct an analysis of the research findings and provide recommendations for future research.

vii. Research Structure

The following figure summarizes the research structure, as shown in figure (0-2):

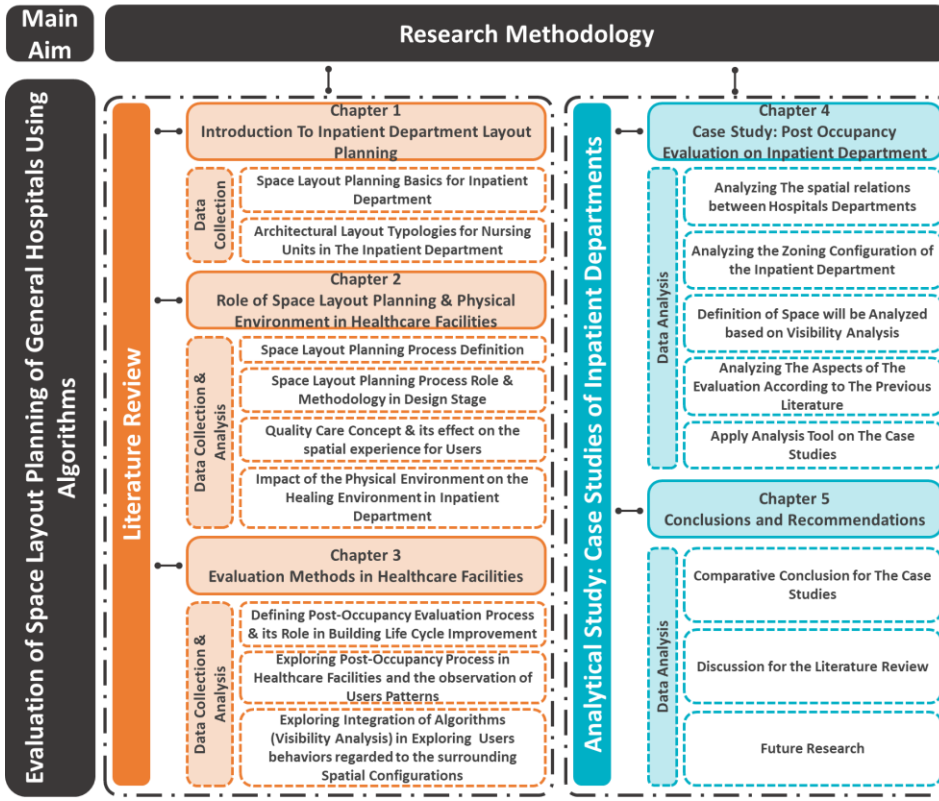

Figure 0- 2: Research Methodology
By: Researcher

i. Research Scope

This research aims to evaluate the impact of spatial configuration on user behavior in the inpatient department of a general hospital for the following reasons:

a. The inpatient department is one of the departments where the space layout planning directly affects the users, as patients and medical staff spend a long time in hospitals and could be extended for weeks.
b. Inpatient department indoor physical department affects directly patients recovery rate.
c. Hospitals are a type of facility that necessitates regular enhancement in order to allow the delivery of high-quality services through continual evaluation.

The evaluation of space layout planning using algorithms will be performed on the inpatient department spatial configurations based on the following:

a. Space layout planning has different criteria that should be considered in the creation of floor plans, including views, accessibility, efficiency of circulation, and the geometric composition of the floor layout.
b. Test the validity of using algorithms in the post-occupancy evaluation process for inpatient departments of general hospitals instead of conventional methods including surveys, on-site observations, and interviews with users that were done by the researchers.
c. Using the visibility analysis concept, algorithms based on Isovist theory have been used in evaluating the space layout planning of the inpatient department with different layout configurations.

Finally, upon presenting study data, analyzing outcomes, and conducting tests on the research hypothesis, the research will present a comprehensive understanding of the manner in which human behavior is influenced by spatial configurations within inpatient departments of general hospitals. By expediting the duration of the post-occupancy evaluation process, a higher level of efficiency can be attained in the process.

Chapter 1

Introduction To Inpatient Department Layout Planning

- Introduction
- Overview of General Hospital Planning
- Design Guidelines for General Hospitals Planning
- Design Guidelines for Nursing Unit
- Nursing Units Architectural Layout Typologies
- Conclusion

1.1. Introduction

Hospital facilities are typically designed by architects with a focus on long-term considerations of operation process in hospitals, drawing on their expertise, design principles, and adherence to legal requirements. Nevertheless, the arrangement of facilities and resources also plays a significant role in determining the operational effectiveness of healthcare services.

This chapter aims to provide a comprehensive understanding of hospitals and other health facilities. It will elucidate the classification of health services and the levels of healthcare available to patients. These classifications and levels are indicative of the diverse range of health buildings that offer medical care to patients, either directly or indirectly. Additionally, the chapter will define the structures associated with these healthcare facilities. The topic of health encompasses various challenges related to the core functional elements of each department, including therapeutic spaces, diagnosis, and the identification of medical, nursing, and supportive service spaces. Particularly within the context of an inpatient department, the present study focuses on examining various design typologies and their characteristics in relation to the architectural layout configurations of the inpatient department.

1.2. Overview of General Hospital Planning

A hospital is more than just an architectural envelope that occupies clinical functions and facilities. Architects have historically faced significant challenges when tasked with the design of hospitals. Architects are faced with a multitude of design criteria when engaging in the design process of a complex artefact. The main users of hospitals are patients, and the evolution of hospital design and planning has mainly been influenced by architects, nursing staff, and physicians with the objective of enhancing staff efficiency.

A crucial aspect in investigating the factors that influence patients' recovery rate and the competence of medical staff lies in comprehending the planning and design guidelines. By enhancing the spatial experience and physical environment for both patients and hospital staff, these guidelines play a significant role.

1.2.1. Hospital Facility Definition

A hospital is a facility that offers healthcare services to individuals and patients, with the scope and range of services being contingent upon the size and services of the hospital. Multiple institutions have provided varying definitions of the hospital, as outlined below:

- **The American Hospital Association (AHA):**

The American Hospital Association (AHA) has established a contemporary definition of a hospital as an institution that houses medical equipment and possesses permanent medical facilities for the purpose of delivering essential diagnostic and therapeutic services to patients (مخيمر، عبد العزيز, ٢٠١٤ &الطعامنة، محمد).

- **The World Health Organization:**

The World Health Organization (WHO) has presented a more functional definition of a hospital. According to this perspective, a hospital is considered an integral component of both social and medical organizations. Its primary purpose is to deliver comprehensive healthcare services to the population, encompassing both curative and preventive measures. Furthermore, the hospital's outpatient services extend to the family within their domestic setting. Additionally, hospitals serve as training centers for healthcare professionals and facilitate essential social research activities. (مخيمر، عبد العزيز, ٢٠١٤ &الطعامنة، محمد).

1.2.2. General Hospital Facility Definition

In order to establish a more precise research framework, a review of the Egyptian design guidelines has been undertaken to determine a comprehensive definition of a general hospital. This investigation primarily centers on the building features and scale of the hospital.

- **Egyptian Design Standards for Hospitals and Health Facilities:**

General Hospital should be in a separate building, the number of beds should not be less than 15 bed. (*Egyptian Design Standards for Hospitals and Health Facilities - Part 1*, 2022)

1.2.3. Healthcare Facilities Classification

Hospitals and healthcare facilities are categorized based on various criteria and classifications. The primary criteria include ownership and administrative affiliation, treatment levels, and specialization or services offered to patients. Furthermore, the classification can also be based on the size and capacity of the beds. The research will elucidate several of these classifications as shown in figure (1-1):

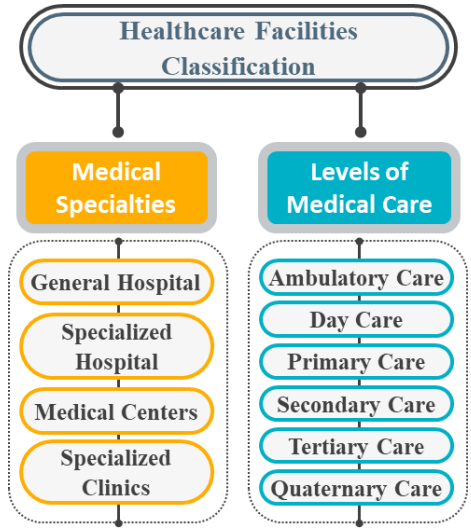

Figure 1- 1: Healthcare Facilities Classification
Source: By Researcher, from (Hopayian, 2022), (World Health Organization. Patient Safety, 2009), (World Health Organization. Patient Safety, 2009)

1.2.3.1. Medical Specialties

Hospitals are categorized based on medical specializations and the services they offer, divided into (*Egyptian Design Standards for Hospitals and Health Facilities - Part 1*, 2022):

a. General Hospital

These hospitals are characterized by their extensive size and include a multitude of specialized treatment departments, diagnostic facilities, and diverse supportive services aimed at delivering comprehensive healthcare to patients. The basic components of a general hospital that must be available shown in figure (1-2):

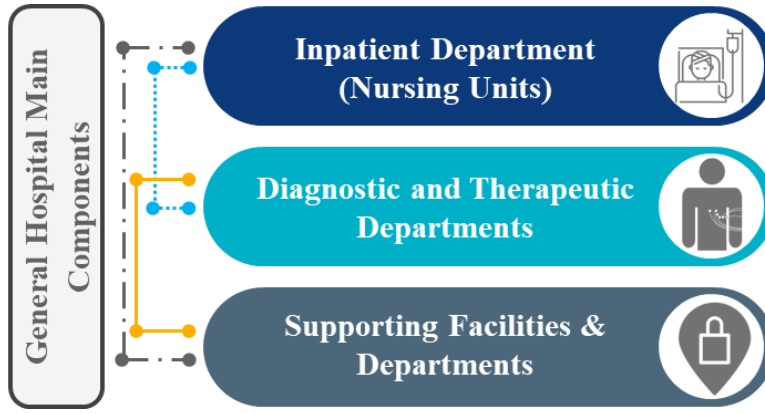

Figure 1- 2: General Hospital Main Zones
Source: By Researcher, from *(*Egyptian Design Standards for Hospitals and Health Facilities - Part 1*, 2022)*

b. Specialized Hospital

- Specialized hospitals are required to incorporate all fundamental components found in general hospitals, with the exception of departments that are unrelated to the main specialization of the hospital.
- Specialized hospitals may encompass one or multiple departments of medical specialization.
- It is imperative that specialized hospitals be located in distinct building, with a minimum bed capacity of 15 beds.

c. Medical Centers

- The specialized medical center should have its main specialization along with its corresponding complementary specializations.
- The maximum allowable number of beds should not exceed twenty-five beds.
- It may include operating rooms, provided that the operating rooms do not exceed two rooms, except for specialized centers for one day.
- The medical center can be part of a building if it has an entrance that is completely separated from the uses of the common building.

d. Specialized Clinics

- The organization recruits several doctors with diverse specialties, who are brought together under a unified management structure and shared support services.
- It is allowed to include a small operating room.
- The number of beds must not exceed five for a one-day stay.

1.2.3.2. Levels of Medical Care

Hospitals are categorized based on level of medical care they offer, divided into:

a. Ambulatory Care

The term "Ambulatory Care" refers to the various forms of medical care offered to individuals who are not hospitalized and do not require overnight stays. These services are provided to patients during the time frame of their treatment. The provision of ambulatory care within healthcare institutions that also offer inpatient services is commonly referred to as "outpatient care". Ambulatory care services are rendered across a variety of settings, which includes physicians' offices, standalone ambulatory surgical facilities, and cardiac catheterization centers (World Health Organization. Patient Safety, 2009).

b. Day Care

The provision of medical and paramedical services to patients who undergo formal admission for the purpose of diagnosis, treatment, or other forms of healthcare, with a specific goal of discharging the patient on the same day (World Health Organization. Patient Safety, 2009).

c. Primary care

Primary care refers to the provision of medical services by healthcare professionals who serve as the first point of contact for individuals seeking healthcare. The sequence of healthcare provider encounters for patients may vary based on geographical location and the configuration of the healthcare system. In certain regions, patients may initially consult with a chemist or nurse prior to their consultation with a physician. Patients may be referred for secondary or tertiary care based on the specific characteristics of their medical condition. The term "primary care" is commonly employed to denote the medical services rendered to the local community. The provision of this service can be found in diverse settings, including walk-in clinics or urgent care facilities that provide immediate appointments (Hopayian, 2022).

d. Secondary Care

Acute care refers to a form of secondary healthcare that is necessary for a short period of time to address a critical yet temporary illness, injury, or medical condition. The provision of this care is often offered in the emergency department of a hospital. Furthermore, secondary care encompasses the provision of trained birth attendants, acute care, and medical imaging services. Hospitals serve as facilities where certain primary care services are rendered. In certain instances, patients may be required to initiate communication with a primary care physician in order to obtain a referral for secondary care, contingent upon the framework and regulations of the national healthcare system (Hopayian, 2022).

e. Tertiary Care

A tertiary care facility, such as a tertiary referral hospital, is equipped with an experienced staff and extensive resources for conducting advanced medical research and delivering specialized consultative health care. This level of care is typically provided to inpatients who have been referred by primary or secondary health professionals. Tertiary care services encompass a range of complex medical and surgical procedures, such as cancer management, neurosurgery, heart surgery, therapy for serious burns, and palliative care (Hopayian, 2022).

f. Quaternary Care

The term "quaternary care" is sometimes employed to denote an advanced level of medical care that builds upon the concept of "tertiary care," which pertains to highly skilled and sought-after medical services. Quaternary care encompasses the utilization of experimental medical interventions as well as the application of select diagnostic or surgical procedures that are infrequently employed. In general, a limited number of regional or national health care facilities provide these services (Hopayian, 2022).

1.3. Design Guidelines for General Hospitals Planning

The planning and design of a hospital and other health facilities should adhere to appropriate architectural principles, fulfil specified functional requirements, and comply with relevant codes, as is customary in the field of professional practice. Design guidelines are crucial for meeting the proposed requirements.

1.3.1. Using Design Guidelines in Planning Process

Hospital planning and design must adhere to architectural principles, functional requirements, and codes, with design guidelines crucial for achieving these requirements as listed below.

1.3.1.1. Role of Using Design Guidelines in Planning Process

The design standards for healthcare facilities encompass a comprehensive set of guidelines that serve as a fundamental reference for the design and construction of these establishments. These standards outline the essential information necessary for the effective planning and execution of facility and healthcare service buildings.

This guide is intended for all stakeholders involved in the planning and execution of hospital projects, including both public and private healthcare institutions (*Egyptian Design Standards for Hospitals and Health Facilities - Part 1*, 2022).

1.3.1.2. Design Guidelines Field of Application

- The implementation of design standards with specified minimum parameters is an obligatory requirement for hospitals and healthcare facilities. These standards are applicable to the construction of new public and specialized hospital buildings, as well as all other medical facilities (*Egyptian Design Standards for Hospitals and Health Facilities - Part 1*, 2022).
- Horizontal and vertical extensions of horizontal facilities are also subject to their application (*Egyptian Design Standards for Hospitals and Health Facilities - Part 1*, 2022).

1.3.2. Introduction to Departments of General Hospitals

General hospital divided into three main zone, beside to other zones as Administrations, public space, and circulation routes (*Egyptian Design Standards for Hospitals and Health Facilities - Part 1*, 2022):

- **Inpatient Zone:** Includes the departments of nursing units and intensive care units.
- **Diagnostic and therapeutic Departments:** Includes different Diagnostic Departments.
- **Supporting Facilities:** Includes medical services such as pharmacy, morgue, and Central sterilization. Also, non-medical services as kitchen, storages, …. Etc.

The following figure (1-3) show the main Departments of general hospital as following:

Figure 1- 3: Main Departments of General Hospital
Source: By Researcher, from *(*Egyptian Design Standards for Hospitals and Health Facilities - Part 1*, 2022)*

The research will focus on studying the inpatient department as a sample case study from different general hospital departments for exploring applying algorithms in the post-occupancy evaluation process of general hospital departments, so the research will review in detail the guidelines for the inpatient department in general hospitals.

1.3.2.1. Inpatient Department

The provision of patient care and healthcare services for inpatients in the hospital's inpatient department relies heavily on the nursing units. These units are mainly charged with creating an optimal environment for patient care and ensuring the availability of necessary resources and facilities for them (*Egyptian Design Standards for Hospitals and Health Facilities - Part 1*, 2022).

The nursing unit is specifically designated for the accommodation of patients who require diagnosis, treatment, or postoperative care. In certain healthcare facilities, there exist specialized units designated for accommodating patients with specific conditions, such as infectious diseases, as well as units tailored to provide specialized nursing care, such as the cardiac nursing unit or the paediatric unit. These units coexist alongside the general nursing unit, which serves as the fundamental unit within a general hospital. User categories for nursing units include (*Egyptian Design Standards for Hospitals and Health Facilities - Part 1*, 2022):

- Patients.
- Medical Staff including doctors, and nursing staff, also non-medical staff: Laborers.
- Visitors and patients` family.

The following figure shows the configuration of different nursing stations in the inpatient department, as shown in figure (1-4):

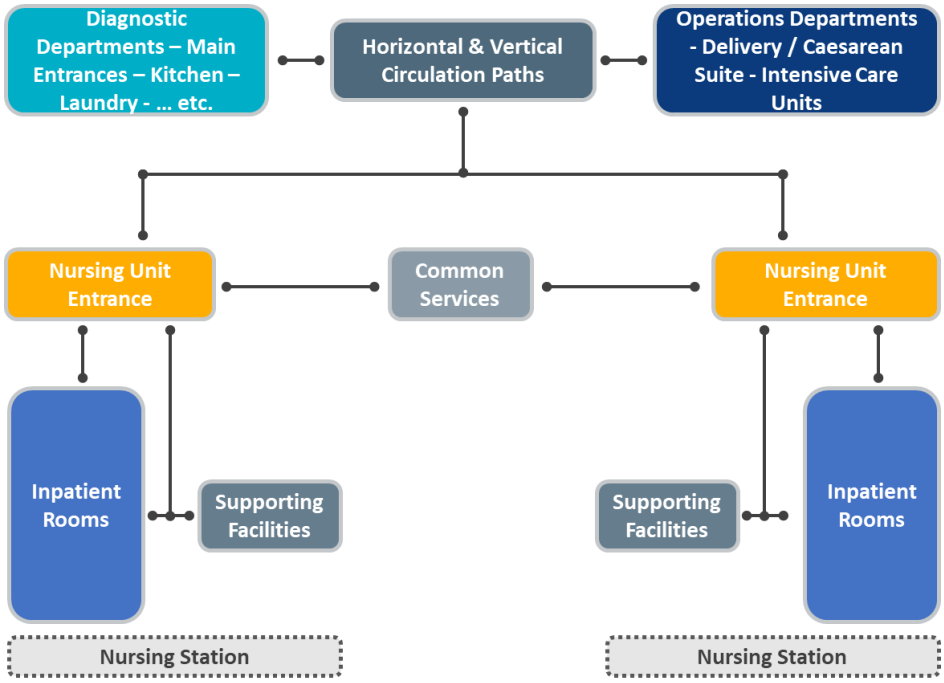

Figure 1- 4: Inpatient Department Configuration
Source: By Researcher, from*(*Egyptian Design Standards for Hospitals and Health Facilities - Part 1*, 2022)*

1.3.2.2. Diagnostic and Therapeutic Departments

Encompasses all departments that offer broad medical services to patients, responding to either those admitted for hospital stay or individuals who require outpatient care. (*Egyptian Design Standards for Hospitals and Health Facilities - Part 1*, 2022)

1.3.2.3. Supporting Facilities

It includes all services that help in the efficiency of the operation process, including medical services and non-medical services. (*Egyptian Design Standards for Hospitals and Health Facilities - Part 1*, 2022)

1.4. Design Guidelines for Nursing Unit

Nursing units encompass various restrictions that necessitate careful consideration during the planning process. These restrictions include:

1.4.1. Location and General Consideration

Efficient interconnectivity is crucial among nursing units, operations departments, Obstetrics, intensive care, therapeutic services, diagnostic services, and the entrance in order to facilitate easy mobility. Also, the nursing unit should be designed as an independent unit with restricted access to other units. The access to the nursing unit should be that are separate from any other unit within the hospital, thereby ensuring separate access (*Egyptian Design Standards for Hospitals and Health Facilities - Part 1*, 2022).

1.4.2. Nursing Unit Regulations

The maximum capacity for the number of nursing units is 30 beds, and it is possible for multiple nursing units to work alongside one another on some supporting services, if that they are located on the same floor as shown in figure (1-5), (*Egyptian Design Standards for Hospitals and Health Facilities - Part 1*, 2022).

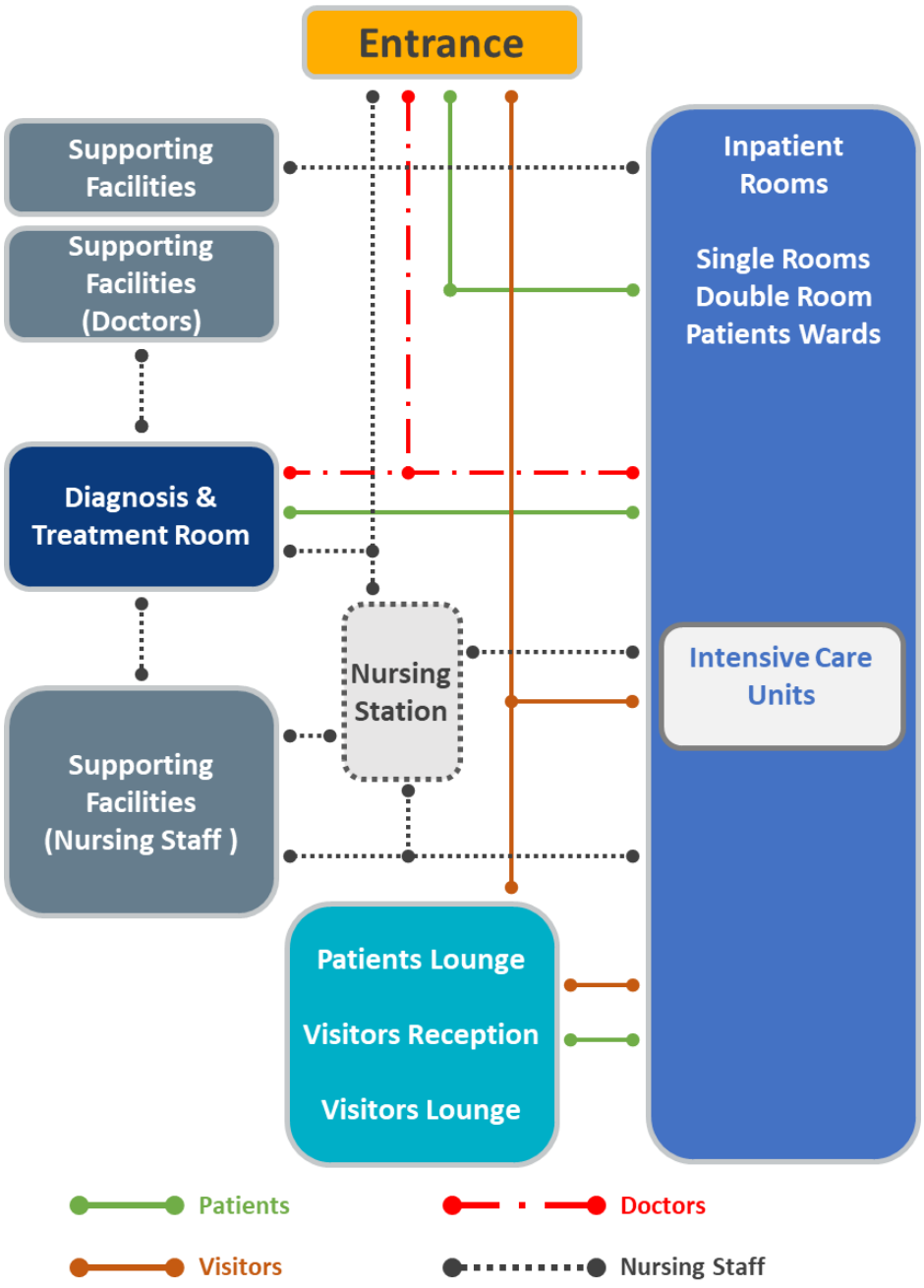

Figure 1- 5: Nursing Station Zones Regulation

Source: By Researcher, from *(*Egyptian Design Standards for Hospitals and Health Facilities - Part 1*, 2022)*

1.4.2.1. Inpatient Rooms

Inpatient Rooms divided into two main types (*Egyptian Design Standards for Hospitals and Health Facilities - Part 1*, 2022):

a. Single Rooms

- The size of the single room should not be less than 10 square meters, without taking into account the space designated for the entry hall and bathroom.
- The single room's width shouldn't be less than 3 meters.
- The bed must have minimum nominal dimensions of 1 x 2.20 meters.
- The sides and end of the bed must have at least 1 meter of clear space with no permanent obstructions.

b. The Wards

- The maximum number of beds per ward should not exceed four beds.
- The individual's share in the wards cannot be less than 8 square meters.
- The ward's width shouldn't be less than 3.30 meters.
- The minimum distance between beds should not be less than 1.20 meters, and the minimum distance between beds and wall should not be less than 1.00 meters.
- Mobile curtains should be used between the beds to give each patient privacy without restricting their mobility to and from the entrance to the room and the entrance to the toilet.

1.4.2.2. Nursing Stations

In addition to administrative tasks, the nurses' stations also perform therapeutically related functions that have an impact on the delivery of care to patients. And serves as the link between patients and medical facility staff members, following considerations should be taken in nursing stations (*Egyptian Design Standards for Hospitals and Health Facilities - Part 1*, 2022):

- The location of the nursing station must facilitate access to all of the unit's functional activities.
- Patients and their families must have easy access to the nursing station.
- The nursing station must be equipped with a counter, communication system, computer, and resuscitation Trolley area.
- The nursing station must provide a hand-washing basin.
- It is necessary to provide space for the department's secretary and medical records storage.

1.4.2.3. Service Areas for Patients and Visitors

Each nursing unit should have a lounge for both patients and visitors including the following (*Egyptian Design Standards for Hospitals and Health Facilities - Part 1*, 2022):

- The nursing unit is required to have a lounge that can accommodate multiple nursing units on the same floor.
- The lounge must accommodate the number of beds, at a rate of 0.50 square meters per bed, with a minimum of 7 square meters.
- The lounge must include toilets for both genders.

1.5. Nursing Units Architectural Layout Typologies

The nursing station serves as the central hub for nursing care activities within a hospital or long-term care facility. The designated workspace is commonly assigned as the primary area for a particular unit. The nursing station typically encompasses unit reception, as well as areas assigned for records storage and charting work. The critical factors in nursing station design have been identified as walking distances, accessibility, visibility, and ease of supervision (Zborowsky et al., 2010).

1.5.1. Nursing Units Different Architectural Layout Configurations

The nursing units are classified into seven main types based on their spatial layout. Additionally, the floor plan shape of nursing units has changed in response to advancements in technology and medicine. The most commonly seen floor plan shapes can be categorized as follows (James & Tatton-Brown, 1986), as cited in [(Ileri, 2022) (Ibrahim et al., 2022)]: **Open (Nightingale) floor plan, Single corridor floor plan, Duplex (Nuffield) floor plan, Double corridor (racetrack) floor plan, Courtyard floor plan, Cruciform (cluster) floor plan, Radial floor plan, and Triangular floor plan**. Their floor plans can be either simple, complex or other shapes. as shown in figure (1-6).

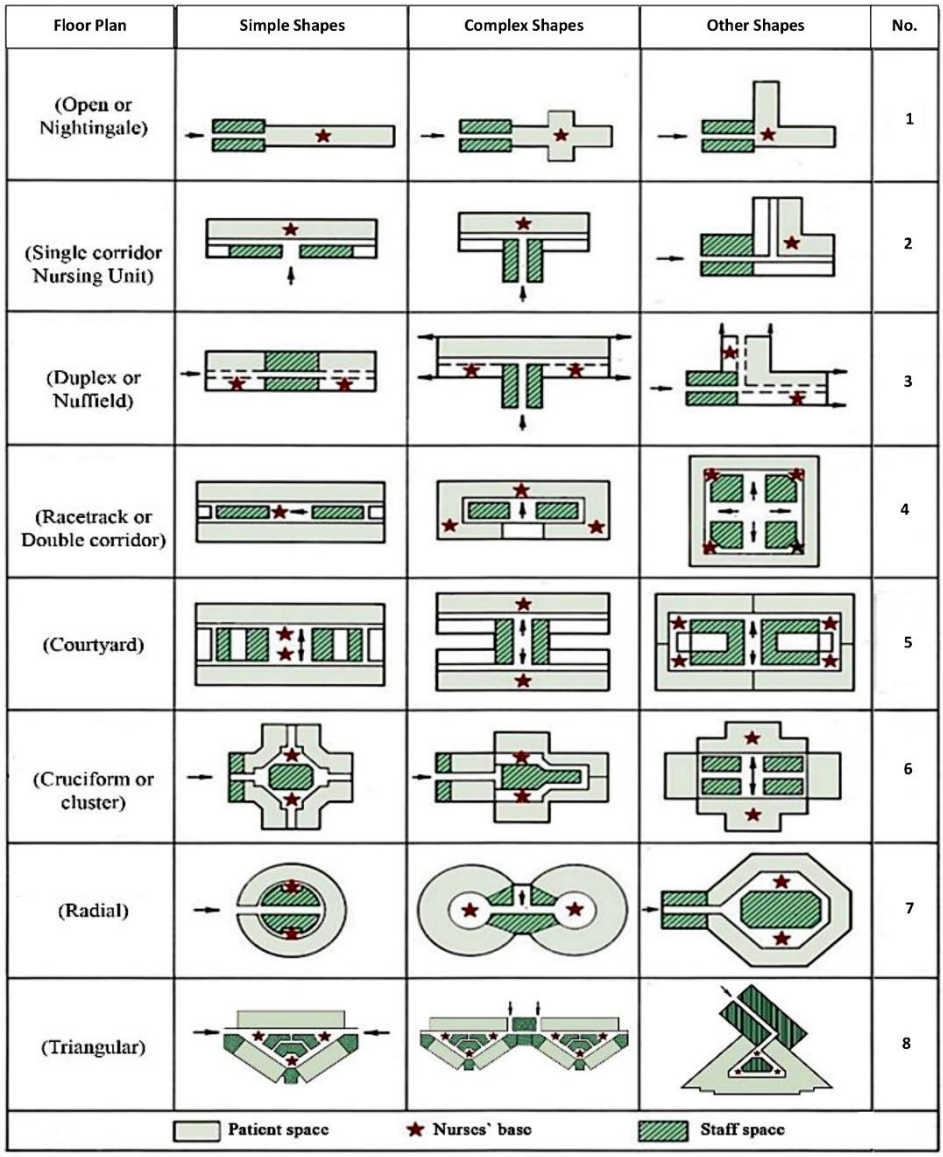

Figure 1- 6: Typical nursing unit floor plan shapes

Source: (James & Tatton-Brown, 1986), (Ibrahim et al., 2022)

In all Typical nursing unit floor plan shapes, Corridors are essential areas where nurses mainly spend time, facilitating their communication, engagement, and continuous learning, as well as providing access between different locations. Multiple attractors are placed along corridors to create widespread circulation. The most appealing areas identified include nurse stations, nurse rooms, and medication preparation rooms (Ileri, 2022)

The nurse stations stated previously are a crucial factor that influenced the direction and intensity of the circulation loads in the corridor. Furthermore, the observation that movement is generated near nurse stations highlights the significance of the stations' placement on corridors and in connection to other highly populated places. The nurse stations, usually situated at the center of the units, functioned as central meeting points where healthcare staff spent the majority of their shifts (Ileri, 2022).

Accordingly, As space integration increases, it becomes more public and accessible (Kim & Lee, 2010), Public and accessible spaces can enhance communication among their users. studies suggest that radial unit types give increased visibility due to their ability to provide many viewing angles from a single location, followed by nursing units of a double corridor design (Zook et al. 2019, as cited in Ileri, 2022; Zimring & Yi, 2010)

1.5.2. Historical Background of Nursing Units Typologies

Nursing Units Typologies passes mainly through three phases as the following:

The emergence of nursing work areas can be traced back to the late nineteenth and early twentieth century, primarily within the Nightingale wards, which were established in a conventional manner. During this period, nursing units characterized by open wards, wherein a nursing station was positioned centrally within the ward, emerged as the prevailing typology. In each open ward, a nursing station was positioned at the central location, enabling nurses to have visual oversight of all their patients. However, the primary workspace for nurses was situated at the bedside of each patient, as shown in figure (1-7), (Hamm, 2011).

Figure 1- 7: Nightingale Wards
Source: *(*Johns Hopkins Magazine*, n.d.)*

During the mid-twentieth century, there was a shift in the organization of nursing units, whereby semi-private patient rooms were arranged on both sides of a central corridor. The unit work areas were distinguished by a substantial, fortress-like workspace situated at the core of the unit, accompanied by a range of auxiliary areas surrounding the central nurse workstation. The implementation of enclosed semi-private rooms resulted in a decrease in visual access to patients and led to a diversion of nurses from direct patient care, as shown in figure (1-8), (Hamm, 2011).

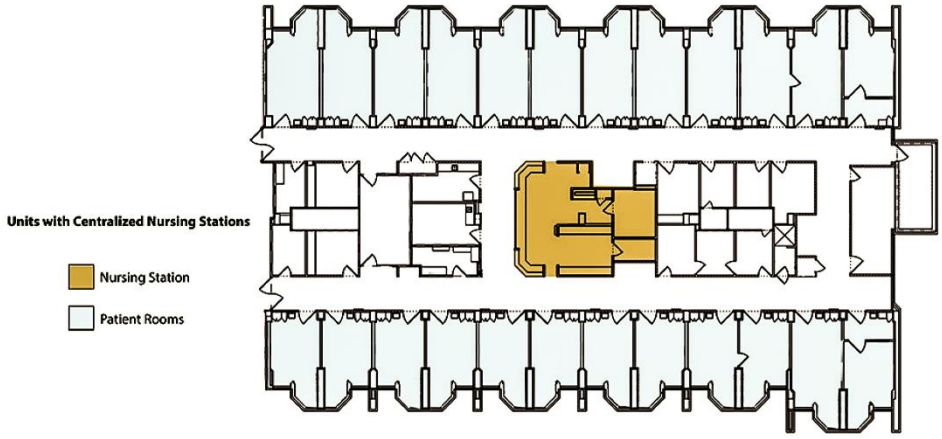

Figure 1- 8: Centralized Nursing Station
Source: (Bayramzadeh et al., 2014)

In recent times, particularly during the late twentieth and early twenty-first centuries, there has been a notable transition towards decentralized nursing work environments. The units are designed such that private patient rooms are situated along the outer edges of the building, while the work areas are distributed throughout the central core. Although the current model of nursing practice generally places nurses in closer proximity to their patients compared to the single central stations prevalent in the mid-twentieth century, nurses are still required to exert significant effort in order to ensure a consistent standard of care throughout the nursing unit, as shown in figure (1-9), (Hamm, 2011).

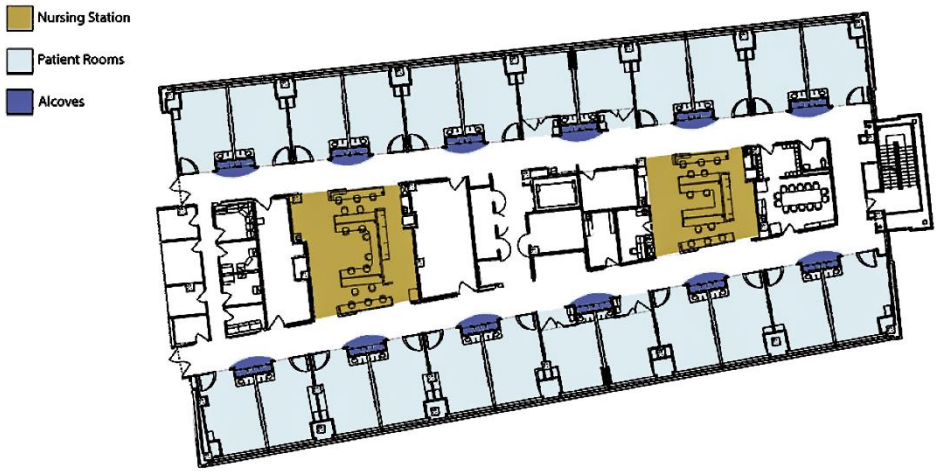

Figure 1- 9: Decentralized Nursing Station
Source: (Bayramzadeh et al., 2014)

1.5.3. The Impact of Nursing Unit Architectural Layout on Users

The growth of information technology has facilitated the transition of nurses from conventional centralized paper-charting stations to more compact, decentralized workstations and charting substations situated in closer proximity to, or within, patient rooms. Historically, nursing units were constructed with a singular centralized nursing station. The progress in information technology has facilitated the transition of nurses from conventional centralized paper-charting stations to more compact, decentralized workstations and charting substations that are situated in closer proximity to or within patient rooms. In conjunction with the implementation of required private rooms in the construction of new hospitals, these modifications result in the creation of extended patient care units, consequently leading to increased distances that nurses must traverse (Zborowsky et al., 2010).

1.5.3.1. Centralized Nursing Stations

According to conventional practices, nursing stations are typically positioned in a centralized area within the given unit. This type of design concentrates the work in a particular spot for nurses and other staff, as shown in figure (1-10), (Bayramzadeh et al., 2014).

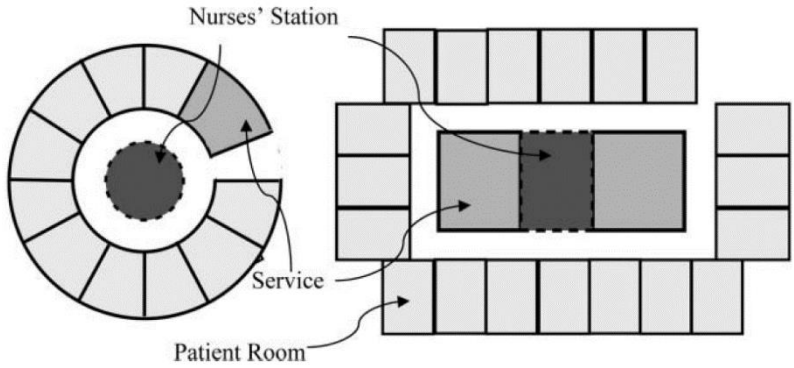

Figure 1- 10: Centralized Nursing Stations
Source: (Seo et al., 2011)

Centralized nursing stations offer a designated area for staff members to carry out their duties, thereby facilitating effective communication among healthcare providers, particularly nurses. The configuration of this nursing station not only enhances the efficiency of carers' interpersonal communication but also fosters a collaborative environment for interdisciplinary engagement among healthcare personnel from diverse areas (Zborowsky et al., 2010). Further, the implementation of centralized nursing stations within a hospital unit serves to establish distinct boundaries, facilitating the distinction between public and private spaces (Wakefield, 2002). This might be beneficial in protecting the privacy and confidentiality of the patient-related information that is constantly being exchanged or documented in a nursing station (Bayramzadeh et al., 2014) (Zborowsky et al., 2010).

1.5.3.2. Decentralized Nursing Stations

On the other hand, decentralized nursing stations aim to distribute the workload within a unit by implementing multiple nursing stations. This approach promotes a balanced work environment that enhances accessibility for both patients and staff members (Bayramzadeh et al., 2014), and this distribution varies in different configurations as shown in figure (1-11).

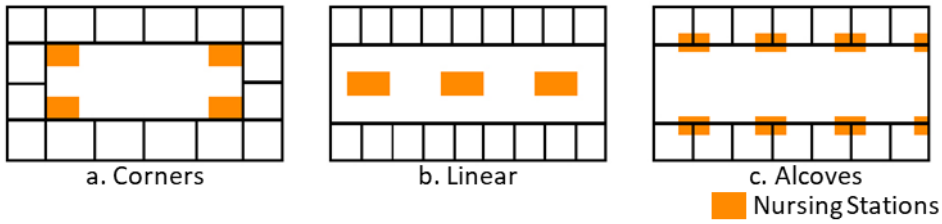

Figure 1- 11: Decentralized Nursing Station
By: Researcher, Source: (Chiang, 2010)

An increasing number of nursing unit designs are integrating decentralized nurses' stations located outside patient rooms. This strategic placement allows staff members to be distributed throughout the unit, in closer proximity to the point of care. Consequently, this arrangement reduces the need for staff members to traverse long distances, thereby minimizing unnecessary walking and maximizing the duration of time dedicated to patient care. This effect is particularly pronounced when supply spaces are also decentralized and positioned in close proximity to the nursing stations (Hendrich et al., 2004)(Bayramzadeh et al., 2014). Despite the fact that it improves the level of engagement between nurses and patients (Ulrich et al., 2004).

Nurses have reported experiencing heightened feelings of isolation from their colleagues and a diminished sense of team cohesion when comparing their experiences to those working in centralized nursing stations (Tyson et al., 2002), as shown in figure (1-12).

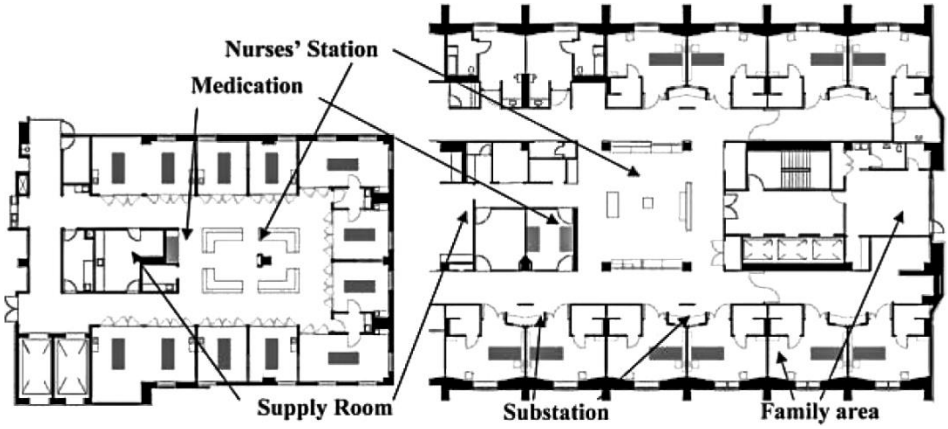

Figure 1- 12: Comparison between Centralized & Decentralized Nursing Stations
Source: (Seo et al., 2011)

1.6. Conclusion

This chapter explained the definition of healthcare facilities and their classification, especially for the inpatient departments of general hospitals, with the aim of defining the design guidelines to be considered while applying the P.O.E. process using algorithms, as the following and as shown in figure (1-13):

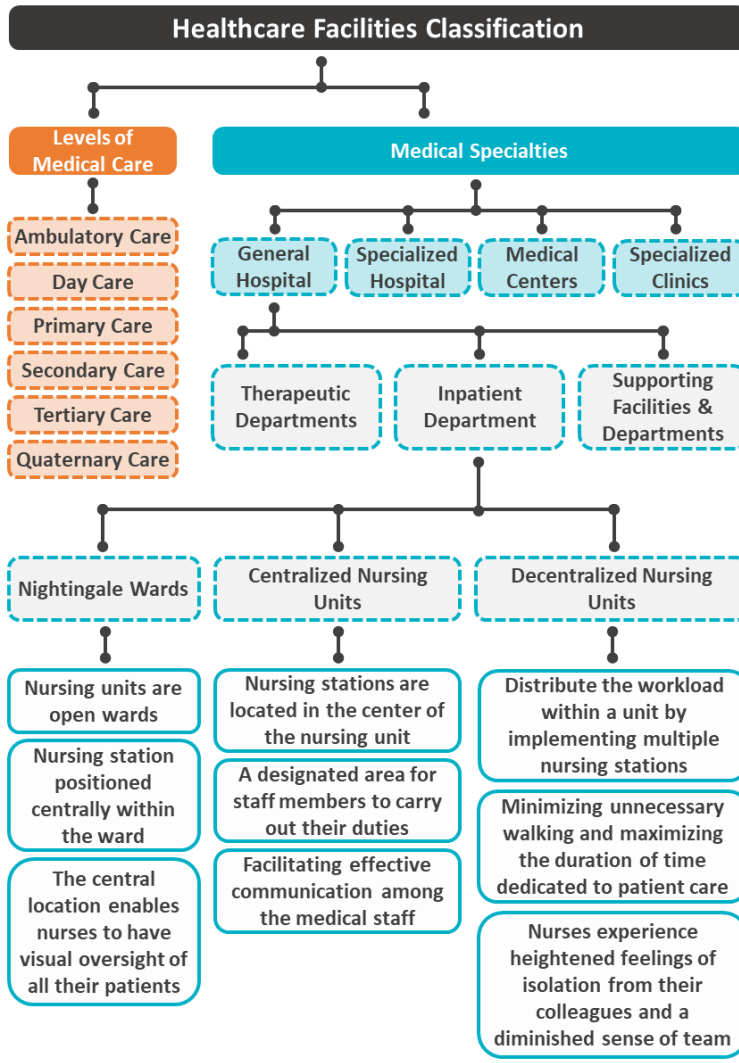

Figure 1- 13: Healthcare Facilities Classification
Source: By Researcher

Chapter 2

Principles of Space Layout Planning & Space Quality in the Evaluation of Hospital Facilities

- Introduction
- Overview of Space Layout Planning
- Spatial Qualities in Hospital Facilities
- Healing Environment in Hospital Facilities
- Conclusion

2.1. Introduction

This chapter reviews the flow of the space layout planning process, starting with the definition of the process and its role in the design stage process, and how it formulates guidelines for the designers and architects by defining the geometrical and topological constraints of the space layout planning process while taking into consideration the human activities done in these spaces. The chapter discusses the methodology of the space layout planning process, breaking down the process into defined steps with the procedures that should be followed in each step, followed by the criteria that should be found in the creation of the floor plans and architectural layout configurations.

The construction and design of hospital facilities should consider developments in technology, adequately meet the needs of patients, their families, and medical staff, operate efficiently, incorporate suitable indoor air quality, heating, ventilation, and lighting features, and be equipped with appropriate measurements, spatial configurations, positioning, and orientation (Güner, 2018). Accordingly, the chapter discusses the concepts of spatial qualities in hospital facilities and the factors that should be applied to achieve these qualities. And how the existence of indoor environment factors helps in achieving the healing environment for the patients in the inpatient department.

2.2. Overview of Space Layout Planning

The layout problem (LP) is finding the best arrangement for many non-overlapping indivisible departments in a specific facility. Layout problems have several applications that can involve one or multiple objectives in determining the most efficient plan. The main goal of these issues is to reduce the overall cost of inter-departmental movements inside a facility. This expense may include the straight-line distance between departments, adjacency preferences, or other expenditures related to the facility's functions such as transportation or material handling. Furthermore, the issues discussed may pertain to single or multiple floor facilities with either equal or uneven space areas (Dorrah & Marzouk, 2021).

Also, The creation of floor-plan layouts has significant importance in the field of architecture, and it presents an interesting challenge due to its complex nature, without a definitive universal strategy for its resolution. (Lobos & Donath, 2010), creating the floor plans starts with the planning for the spaces required in each individual building. The process of space planning is naturally complicated. Hence, a sequence of planning tasks is offered as the principal method for developing space planning skills, beginning with small spaces, and progressing towards larger spaces with increasingly involved program requirements. Furthermore, the utilization of planning rules of thumb, suggestions for employing suitable sketching approaches, as well as recommended literature and reference sources (Karlen, 2009).

2.2.1. Space Layout Planning Definition

The initiation of the space planning process occurs when an individual or a collective makes the decision to allocate a building or a section of a building for a unique and functional purpose. This encompasses a wide range of scenarios, ranging from simple homes or workspaces to extensive and complicated business and institutional facilities. The process of space planning is not a straightforward task that only encompasses one category of information. Instead, it is a multifaceted integration of numerous procedures that encompass various categories of information pertaining to the arrangement and structure of structures. The range of processes involved in achieving adequate use of space is extensive, encompassing program analysis, utilization of building code principles, implementation of environmental control techniques, and the creation of desired spatial qualities. However, it is important to acknowledge that the task of achieving satisfactory use of space is highly intricate and surpasses the abilities of most building users. Consequently, the involvement of a space planning specialist (Karlen, 2009).

2.2.2. Role of Space Layout Planning in Design Stage

In architecture, the layout problems are applied to assign activities to building spaces, known as the space layout problem (SLP). This assignment process considers factors such as natural daylight, building orientation, circulation between spaces, and relational proximity requirements (Dorrah & Marzouk, 2021) (Lobos & Donath, 2010).

Also, It is the stage at which the process of developing an architectural floor plan involves assigning relationships to a function and subsequently determining the geometry and scale of this function. The document referred to as the Space Program serves as a manifestation of the requirements associated with a particular project. which are derived from human activities, into an architectural programmatic language (Lobos & Donath, 2010).

This language consists of verbal and numerical expressions that can be subsequently utilized by the architect to determine the dimensions, spatial configurations, and interconnections among various rooms (Lobos & Donath, 2010).

When architects are approached to start a space layout planning process, they have to face many constraints related to achieving the objective requirements for each individual building. In the standard method, the process typically commences with the identification of specification constraints. Subsequently, preliminary sketches are generated to depict spatial planning concepts or topologically viable solutions, devoid of precise geometrical dimensions. The current phase of development is the sketch stage. Geometrical dimensioning is primarily influenced by objective criteria, such as the need for optimal spatial proportion and the minimization of surface area (Medjdoub & Yannou, 2000):

- **Dimensional constraints:** One potential limitation is the presence of limits on the surface, such as limitations on length, width, or spatial orientation.

- **Topological constraints:** Several spatial relationships can be seen, including adjacency, adjacency to the perimeter of the building, non-adjacency, and proximity.

2.2.3. Space Layout Planning Methodology

Within the professional environment, there exists a widely acknowledged procedure or series of steps that transpires when a planner embarks on a project until the stage at which project analysis concludes, and the tangible planning process commences. Despite the potential for variances in technique and vocabulary employed by planners, the fundamental process of formulating a design program may be distilled into the following elements, which are succinctly outlined here (Karlen, 2009):

Table 1: Space Layout Planning Methodology, (Karlen, 2009)

Step	Procedures
Interview	a. Organizational Overview at the Executive Level. b. Managerial level, often known as the departmental function. c. The operational level pertains to the specific details of processes and equipment.
Observe (Existing Or Similar Facilities)	a. The practice of guided observation. b. The method of silent observation c. An assessment of the current stock of furniture and equipment that is intended for reuse.
Establish Architectural Parameters	a. Obtain comprehensive foundational plan information, encompassing both mechanical and electrical services. b. Gather and analyze contextual information encompassing architectural, historical, and social aspects. c. The investigation pertains to the examination of code limitations.
Organize Collected Data (The First-Phase Program)	a. Organize data in a sequential pattern that is highly advantageous for the purpose of planning. b. The proven quantitative elements, such as square footage and equipment sizes, will be summarized. c. provide initial views on the conceptual planning approach.

Research The Unknowns	a. Please collect comprehensive data regarding the process and equipment. b. Collect case study data pertaining to comparable facilities. c. Incorporate empirically derived data into the initial part of the program.
Analyze The Data	a. To explore the various planning affinities, including working interrelationships, public/private zoning, and unique acoustic demands. b. Identify scheduling preferences that optimize the utilization of available space. c. Identification of planning or architectural relationships, specifically pertaining to site, structural, mechanical, and electrical conditions.
Interpret And Diagram The Data (The Complete Program)	a. In planning terminology, functional difficulties may be defined as issues or challenges that arise in the effective functioning or operation of a system, process, or organization. b. Outline a fundamental conceptual framework, focusing on the objectives related to human and social aspects, as well as those pertaining to image and aesthetics. c. Create connection or adjacency diagrams to facilitate visualization for both the client and the designer.
Summarize The Data (The Finished Document)	a. Finalize project concepts. b. Provide an overview and analysis of fundamental budgetary concerns. c. Create a comprehensive package intended for client feedback and as a designer's manual for the purpose of space planning.

2.2.4. Creation of Floor Plan & Architectural layout Configurations

The process of developing an architectural floor plan involves assigning relationships to a function and subsequently determining the geometry and scale of this function. When a client makes the decision to acquire a new residential or commercial property, it is usual for them to present the architect with the site details and articulate their specific requirements for the project. The document referred to as the Space Program serves as a manifestation of the requirements associated with the project. It functions as a transcription or translation of the client's needs, pertaining to human activities, into an architectural programmatic language. This language comprises words and numerical values that can be subsequently interpreted by the architect to determine the appropriate spatial arrangements, dimensions, and interconnections among various (Lobos & Donath, 2010).

When starting the refinement and organization of the Space Program, the architect is required to meet certain requirements. The relative importance of several criteria may vary depending on individual cases. Based on our practical expertise and extensive review of relevant literature sources such as Neufert and Time Saver, we have identified a set of often observed criteria that may be categorized into rational criteria, which can be quantitatively assessed, and generic design requirements, which cannot be objectively quantified (Lobos & Donath, 2010).

2.2.4.1. Rational Design Criteria

Rational criteria for architectural floor-plan layout divided into the following (Lobos & Donath, 2010):

- **Solar:**

  In order to strategically position and orient the rooms with respect to solar exposure for maximum efficiency. Objective: In order to ensure optimal natural lighting for a maximum number of long-term occupancy rooms.

- **Views:**

In order to strategically position and orientate rooms in respect to the views, it is imperative to identify the optimal locations. Objective: In order to optimize the visual experience of the natural scenery or the surrounding environment for guests staying for an extended period of time.

- **Accessibility:**

The term referred to the measurement of the distance separating the main street (or access road) and the entry point of the building. Objective: In order to decrease the distance required to enter the building.

- **Related Functions:**

Certain functions within the Space Program exhibit a higher degree of interrelatedness compared to others. Objective: In order to determine the degree of association between rooms, namely whether they are strongly, moderately, or little connected, as well as to identify the room that should be isolated from the others, an investigation is required.

- **Minimum distance:**

The aim of this study is to determine the optimal distance between rooms in order to maximize the efficiency of circulation spaces.

- **Efficiency (Circulation/Usable Ratio - Circulation):**

The outcome of evaluating the circulation surface in relation to the useable surface. Objective: In order to maximize the available surface area for use while minimizing the surface area allocated for circulation purposes.

- **Efficiency (Volume/Usable):**

The outcome of making a comparison between the volume of each space and its corresponding useful volume. Objective: In order to maximize the useable capacity while minimizing the amount of useless space. Additional factors, such as solar exposure and ventilation, may exert an impact on this particular variable.

- **Size:**

The dimensions of the room (width x length).

2.2.4.2. General Design Criteria

General design criteria for architectural floor-plan layout divided into the following (Ching, 1979; Lobos & Donath, 2010):

- **Geometric Composition:**

The rooms should be situated inside a broader geometric structure, such as a square, circular, arc, or rectangle, and their dimensions and arrangement should adhere to aesthetic considerations.

- **The Divine Proportion/Golden Ratio:**

The distribution of the wall adheres to the perimeter of a rectangular shape, whereby the lengths of both sides of the rectangle exhibit a constant numerical ratio of 1.6180339887. Consequently, it is feasible to quantify this distribution.

- **3D Shape to Fill:**

Define Possible arrangements of spatial distributions are classified as follows: Linear, Central, Yard, U Shape, L Shape, Organic Shape, and Religious Shapes.

- **Sustainable Criteria:**

The optimal allocation of space should adhere to sustainable principles, including minimizing perimeter wall surface area, reducing energy usage, solar gain on surfaces, quantifying materials efficiently, and minimizing room lighting loads, ... etc.

- **Others:**

The utilization of cost-effective, structural, as well as construction techniques.

2.3. Spatial Qualities in Hospital Facilities

Hospitals are institutions designed to provide medical care and support to individuals who are experiencing illness, physical disabilities, and mental health challenges. It is imperative for hospitals to ensure that their services are accessible and inclusive, meeting the needs of persons of all age groups, genders, and diverse cultural backgrounds. Hospitals serve as environments in which individuals encounter a wide variety of emotional experiences, including fear, trauma, frustration, and happiness (Alhonsuo & Colley, 2019), reflecting on Patient's emotional experience during his accommodation which can be improved by enhancing the spatial experience of the indoor environments. Accordingly, The process of space layout planning should involve a review of various concepts, including entrance impact, room shape, spatial order, symbolic qualities, and the interior space and time experience of the users. These factors should be taken into consideration while making planning decisions (Lobos & Donath, 2010).

In the following, the space quality is explained. Within the research limitations concerning the inpatient department, the research investigates aspects of the spatial qualities integrated with the quality of care components introduced to the patients in hospital facilities.

2.3.1. Space Quality Concept

The goal of "quality" is a fundamental objective in the construction and production of every building and architectural output. The correlation between quality and users in the context of architectural quality programs involves enhancing the extent to which design meets the requirements and expectations of individuals (Nelson (2006), as cited in, Samah et al., 2013). By prioritizing the involvement of users in the building design process and employing the concept of performance, which is a more tangible and measurable phrase, one may effectively evaluate the quality of a building's design and its resulting output. The concept of building performance evaluation (BPE) was proposed as a quantifiable design criterion that evaluates the extent to which a constructed building satisfies the requirements and performance objectives of its occupants (W. Preiser & Vischer, 2005).

2.3.2. Components of Space Quality

Performance analysis in (BPE) is classified into three primary components such as, (Samah et al., 2013):

- **The technicality component:** Incorporates criteria pertaining to the domains of health, safety, and security.
- **The functionality component:** Pertains to the effectiveness of a work process or work performance as well as the functionality inherent to itself.
- **The behavioral component:** examines performance in terms of psychological, social, cultural, and aesthetic aspects.

Each of those components mentioned above have its own space quality parameters in order to fulfill this component criteria (Samah et al., 2013), as shown in figure (2-1). prior to research scope the functionality component will be explained in detail.

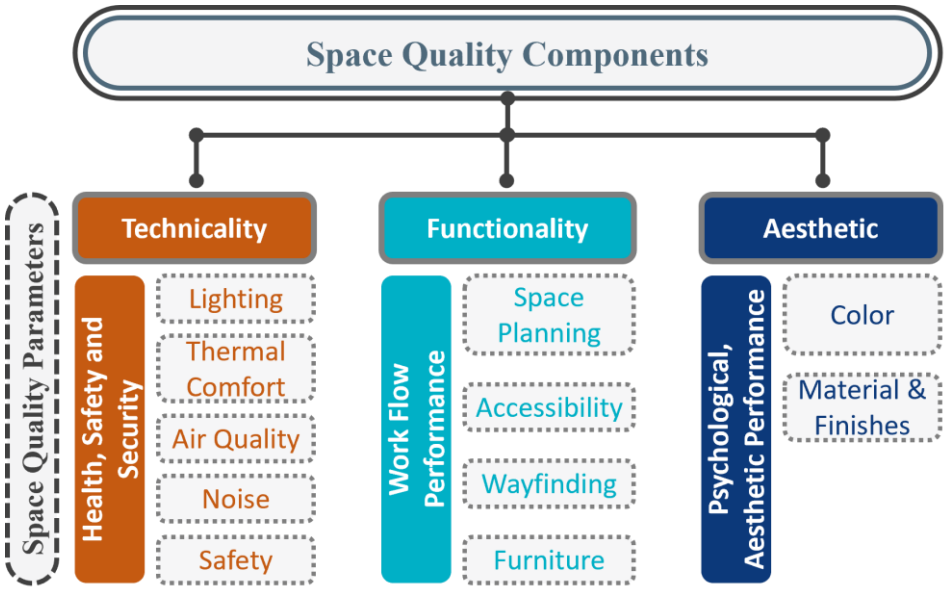

Figure 2- 1: Space Quality Parameters Related To Space Quality Component
By: Researcher, Source: (Samah et al., 2013)

2.3.3. Parameters of Space Quality Components:

The functionality quality component is consisting of the following parameters:

2.3.3.1. Space Planning

Spatial layout planning is directly linked to three key physical attributes: appearance distinction, visual access, and layout complexity (Montello, 2007, as cited in, Samah et al., 2013). In addition, people have the cognitive and behavioral ability to accurately determine their spatial position within a particular context, enabling them to navigate properly (Tawfik et al., 2007).

2.3.3.2. Accessibility

Visual accessibility refers to the extent to which various locations and characteristics within a given environment are visible to the human eye (Montello, 2007, as cited in, Samah et al., 2013). Accessibility is a crucial factor that is closely linked to the sequential flow of operations within a building, particularly in relation to the movement of patients and visitors. This encompasses their journey from the moment they arrive at the facility until the conclusion of their visit. It is essential to ensure adequate illumination in circulation areas, hallways, stairways, and entrance areas to promote secure and comfortable movement (Oberascher L, 2002, as cited in, Samah et al., 2013).

2.3.3.3. Wayfinding

The wayfinding design encompasses various elements related to the built environment, such as spatial organization, the articulation of distinctive design elements, the arrangement of circulation systems, and the delivery of environmental information (Hunter, 2010). Effective signposting, which is characterized by simplicity, clarity, and consistency, together with the provision of written and spoken information, has been identified as a crucial element in facilitating navigation and wayfinding (Netherland of board, 2008, as cited in, Samah et al., 2013). According to (Carpman et al., 1985), effective wayfinding systems should extend beyond the utilization of signage and color codes as means of distinguishing distinct sections inside a hospital.

2.3.3.4. Furniture

The furniture is developed with a focus on functionality. The inclusion of armrests in a chair is beneficial as they provide assistance when transitioning into and out of the seated position (Charles, 2011). Furniture surface should be easily cleanable, lack of surface joints and seams, and has nonporous and smooth characteristics (EBD checklist, as cited in, Samah et al., 2013).

2.4. Healing Environment in Hospital Facilities

The concept of healing architecture operates under the notion that the physical characteristics and spatial aspects of a built environment can influence the well-being of individuals who inhabit the space, as well as the activities and behaviors that take place inside it. Spatial factors can encompass various aspects that influence the efficiency of certain practices, such as the distances staff members need to traverse inside a hospital department. In recent years, there has been a growing interest among healthcare providers in the field of healing architecture. This interest stems from the acknowledgment that the design and spatial characteristics of hospital environments have a significant influence on the healing process and can lead to improved outcomes. Consequently, healthcare providers have recognized that investing in healing architecture can enhance healthcare efficiency and result in cost reductions (Kathrine Frandsen et al., 2012).

2.4.1. Definition of Healing Environment

The origins of the term **"healing"** can be traced back to the Anglo-Saxon word **"haelen"**[1] which conveys the concept of make whole or the recovery and restoration. This term can be conceptualized as the integration and coherence of mental, physical, and spiritual elements. The concept of healing should not be conflated with curing, as the curing pertains to the resolution of problems elimination of diseases, and reduction of symptoms. People have the potential to experience healing, irrespective of whether they achieve a complete cure. For instance, those afflicted with a long-term illness can acquire the ability to achieve a state of calmness in spite of their medical condition. On the other hand, it is possible for individuals to experience a cure without achieving complete healing. Healing environments are intentionally created to promote a sense of balance among the mental, physical, and spiritual aspects of people (Sadek et al., 2013; Zborowsky & Kreitzer, 2008).

[1] The Old English language, known as Anglo-Saxon, was the spoken and written language in England prior to the year 1100.

A healing environment may be described as an environment wherein the interaction between patients and healthcare professionals generates desirable health results within the context of the physical surroundings (Huisman et al., 2012).

2.4.2. Factors of spatial qualities in Healing Environment

The indoor environment has the potential to affect health outcomes through having influence on the behaviors, actions, and relationships of patients, their families, and medical staff. The expression "First, do no harm," which has been attributed to Hippocrates and has long served as a guiding principle for health practitioners, appears to be less frequently adhered to in contemporary times. The presence of unhealthy buildings has been found to be associated with a heightened risk of various illnesses among tenants. Sick building syndrome (SBS) is a phenomenon characterized by a variety of symptoms experienced by individuals within a particular building, for which a definitive cause cannot be readily identified. The impact of indoor environmental quality (IEQ) extends beyond the physical well-being of individuals occupying a building, encompassing their psychological health as well (Sadek et al., 2013).

Multiple investigations have demonstrated that a variety of factors have significant influences on occupant happiness inside indoor spaces. It is imperative to acknowledge that these elements should be seen as integral components, as the characteristics of one factor exert a significant impact on those of another. It is important to note that every decision pertaining to Indoor Environment Quality (IEQ) should be seen as having the ability to yield both good and negative outcomes across many elements within the healing environment for the patient (Sadek et al., 2013), as shown in figure (2-2).

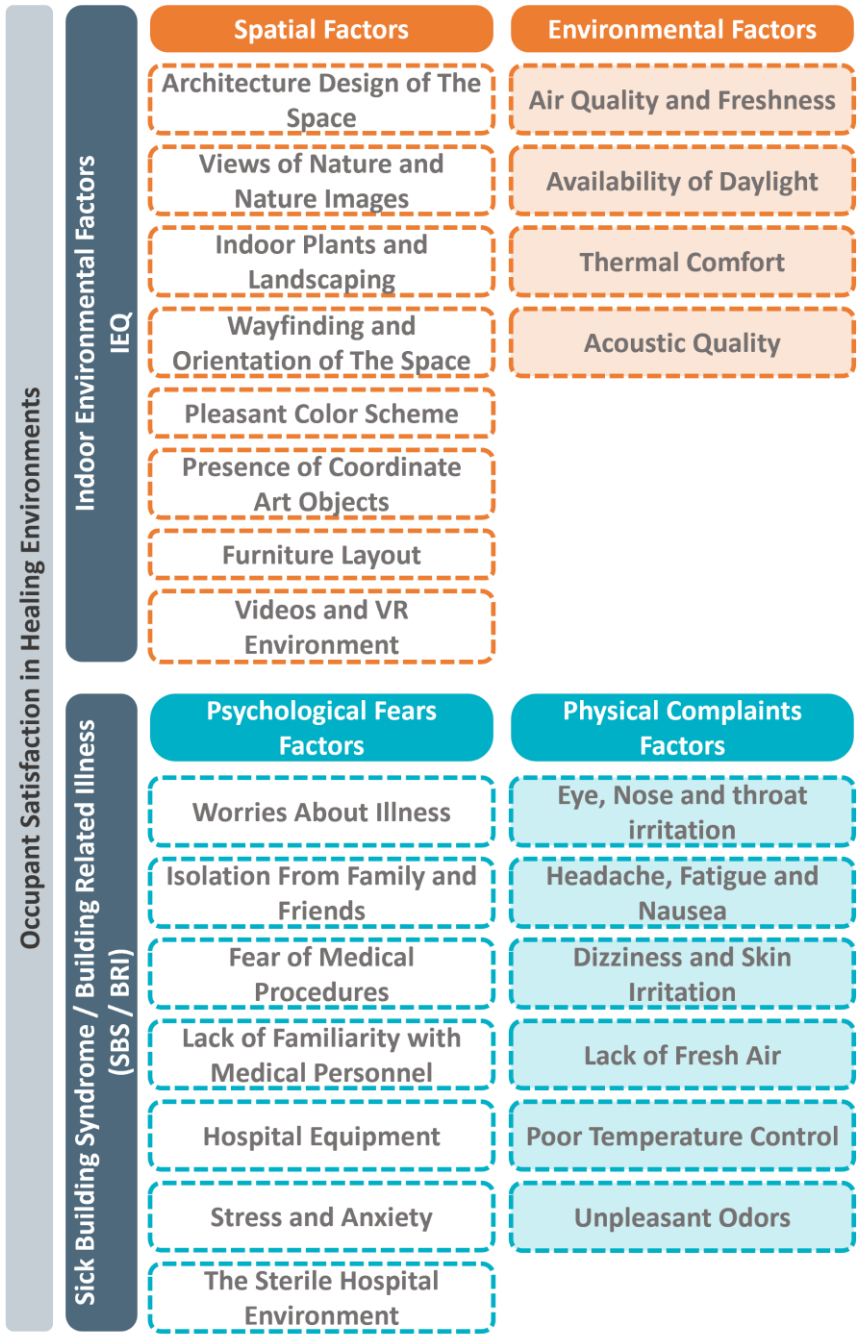

Figure 2- 2: Factors Affecting Occupant Satisfaction in Healing Environment
By: Researcher, Source: (Sadek et al., 2013)

The spatial indoor environmental factors related to spatial configurations will be discussed in the following:

2.4.2.1. Architecture Design of The Space:

The architectural design of a space has a significant impact on the perception of its users, as well as the hiring and staying power of staff members, and the general productivity and efficiency of the space (Mourshed & Zhao, 2012). Furthermore, it exerts an impact on the behaviors, actions, and interactions of patients, families, and staff members (Schweitzer et al., 2004).

The presence of adequate space in patient rooms and waiting spaces facilitates increased opportunities for social interaction. Additionally, the implementation of decentralized nursing stations creates favorable conditions for interactions between patients and staff members (Schweitzer et al., 2004). The architecture of healthcare facilities can impact the relationship patterns among staff members, including physicians and nurses. For instance, the presence of gardens and lounges in these facilities can promote good interactions, which in consequence may contribute to increased satisfaction with work among the staff. The architectural design of a space can contributes to the reduction of patient falls. For example, the widening of bathroom doors allows for the inclusion of a staff member who can assist in the mobility of the patient (Sadek et al., 2013).

2.4.2.2. Views of Nature and Nature Images

The presence of nature imagery has a significant influence on the level of satisfaction experienced by patients within healing environments. an experiment was conducted to examine the impact of specific nature images on individuals experiencing pain. The findings revealed that participants who did not view any images reported higher levels of pain in the affective pain ratings compared to those who were exposed to image categories associated with refuge, hazard, and mixed prospect and refuge. The image category characterized by a combination of prospect and refuge elements provided a notably reduced perception of sensory pain feeling. However, the hazard image, despite its considerable efficiency in diverting participants' attention from pain, prompted the highest scores for mood disturbance among all the groups (Sadek et al., 2013; Vincent et al., 2010), as shown in figure (2-3) (2-4).

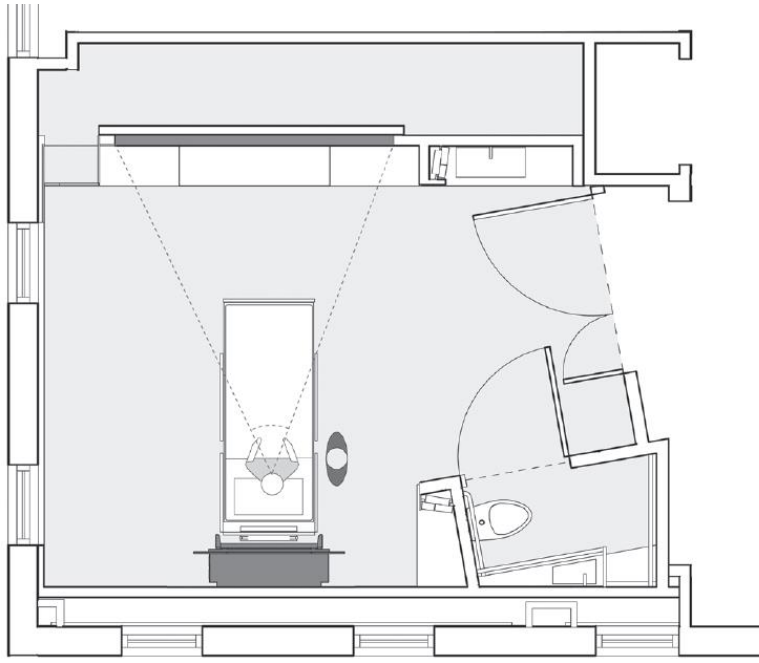

Figure 2- 3: Floor Plan of Simulated Hospital Room
Source: (Vincent et al., 2010)

Figure 2- 4: Participant Viewing Image
Source: (Vincent et al., 2010)

"Prospect" in the landscape presents real or symbolic access to a view in landscape images, including clear skies, low ground-cover vegetation, and ideal viewing vantages (from a high vantage point, for example) that allow viewers to survey their surroundings (Appleton, 1996, p. 191, as cited in,Vincent et al., 2010), as shown in the following figure (2-5).

Figure 2- 5: Meaning of "Prospect" in The Landscape
Source: *(*View of The Plateausoni Kougen in Japan*, n.d.)*

The term “Refuge” in the context of the natural environment refers to actual or metaphorical situations of obscuring or sheltering (Appleton, 1996, p. 191, as cited in,Vincent et al., 2010), as shown in the following figure (2-6).

Figure 2- 6: Meaning of “Refuge” in The Landscape
Source: *(*Hollow Tree Trunk Stock Photo*, n.d.)*

The term “Hazard” in the landscape presents incidents or conditions that pose actual or symbolic threats to life and well-being (Appleton, 1996, p. 191, as cited in,Vincent et al., 2010), as shown in the following figure (2-7).

Figure 2- 7: Meaning of “Hazard” in The Landscape
Source: *(*Australian Bush Fires Loan Firefighter*, n.d.)*

2.4.2.3. Indoor Plants and Landscaping:

The act of observing plants has been recognized as a beneficial form of pleasant distraction, capable of eliciting positive emotions, diminishing distressing thoughts, and facilitating recovery from stress. Researches that have conducted evaluations on the influence of plants on human well-being have proposed that interactions with nature and plant environments are correlated with favorable outcomes for human physical, psychological, emotional, and cognitive health. Moreover, the act of observing plants has been found to be associated with a decrease in discomfort, a reduced reliance on analgesic medication, and a swifter recuperation process following surgical procedures. The use of live plants within the interior spaces of hospitals has the potential to enhance both the health and comfort of these environments. Prior studies have demonstrated that the presence of indoor plants can mitigate sick building syndrome by effectively eliminating pollutants, enhancing relative humidity to a level conducive to human comfort, and ameliorating indoor air quality by reducing the concentration of mold spores and airborne microbes. the process of plant selection ought to be guided by several key factors, the availability of sunshine, temperature and humidity requirements, ease of care, as well as aesthetic considerations including a diverse range of colors, sizes, patterns, and shapes (Schweitzer et al., 2004).

2.4.2.4. Wayfinding and Orientation of the Space:

Wayfinding problems in hospitals are costly and stressful and have particular impacts on outpatients and visitors, who are often unfamiliar with the hospital and are otherwise stressed and disoriented. Informational handouts, information desks, you-are here maps, directories and signages along the way are critical wayfinding aids. Previous studies found that people who used signs found their destination faster than those who only used maps (Ulrich et al., 2004).

2.4.2.5. Pleasant color scheme

Color is certainly a perceptual attribute that holds significant importance in the context of designing the visual aesthetics of a space. There exist various methods for incorporating color into an environment, encompassing the coloration of architectural surfaces such as walls, floors, and ceilings, as well as the coloration of furniture elements, fabrics, linens, and the utilization of colored lighting (R. Del Nord, 2006, as cited in, Sadek et al., 2013).

Moreover, it has been observed that colors have the ability to impact the sense of time. Specifically, in spaces where repetitive tasks are carried out, the utilization of a chromatic scheme consisting of cool hues creates the illusion of time passing at an accelerated rate. Conversely, the patient's skin color serves as a significant chromatic indicator. Hence, it is imperative to provide optimal visual clarity for the purpose of diagnostics. The colors yellow, green, and purple have the potential to alter or modify the appearance of skin tone. Hence, it is imperative to stay away from utilizing these hues in settings where it is crucial for the personnel to have optimal visibility of the patient's skin, such as the nursing station and the patient's room. The utilization of the color blue should be minimized in cardiology wards due to its potential impact on the process of diagnosis (R. Del Nord, 2006, as cited in, Sadek et al., 2013).

2.4.2.6. Presence of coordinated art objects

While there may be variations in the specific duration of waiting periods experienced by patients and their families in hospitals and clinics, it is widely acknowledged that these intervals are commonly seen as lengthy, uneventful, and anxiety-inducing. Nevertheless, the negative consequences of waiting can be alleviated more efficiently through enhancing the appeal of the waiting environment rather than by reducing the actual duration of the wait (Pati et al., 2011).

2.4.2.7. Furniture Layout:

The presence of furniture and equipment in residential environments of patients typically serves to enhance their comfort and functionality. However, in hospital environments, those same elements may pose a potential hazard due to the patients' lack of familiarity with them. Hence, it is essential to address the issue of furniture arrangement, as it has been identified as the key contributing factor to patient falls inside hospital environments (H. Tzeng and C. Yin, 2009, as cited in, Sadek et al., 2013).

The impact of furniture layouts on communication within waiting areas, rooms, and lounges in healthcare environments has been found to be significant (Schweitzer et al., 2004).

In order to enhance patients' functionality, the design of furniture should prioritize achieving goals of ease in handling, flexibility, and modularity, alongside considerations for safety, hygiene, and non-toxicity (R. Del Nord, 2006, as cited in, Sadek et al., 2013).

2.4.2.8. Video and VR environments

Many research studies have investigated the impact of video and virtual reality (VR) techniques on the management of pain, pulse rate, and anxiety. These studies have provided significant information indicating a reduction in pain intensity, pain dissatisfaction and the duration of pain-related cognitive engagement. Virtual reality (VR) presentations ought to be tailored to individual patient attributes, including age, gender, and ethnicity (Malenbaum et al., 2008).

2.5. Conclusion

This chapter studies the process of space layout planning and the factors and criteria that should be followed and taken into consideration during this stage. Also, studying the factors of spatial qualities that should be found in hospital facilities to help in creating a good indoor environment for the users helps in achieving a healing environment for the patients in the inpatient department:

- Space layout planning process methodology passes through a series of steps, each step consists of certain procedures, as shown in figure (2-8).

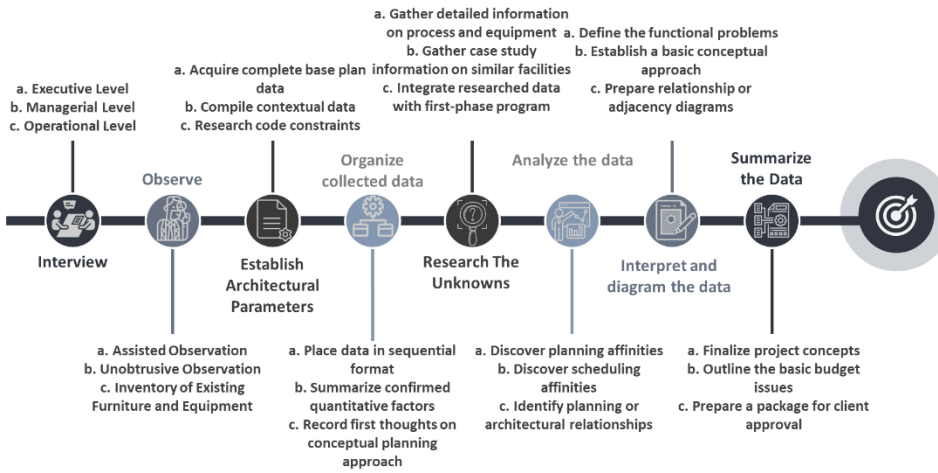

Figure 2- 8: Space Layout Planning Methodology
Source: By Researcher

- The creation of floor plans starting the refinement and organization of the Space Program, the architect is required to meet certain requirements. The relative importance of several criteria includes:
  - **i. Rational Design Criteria:** solar exposure efficiency, views, accessibility, related functions proximity, minimum distances, efficiency (Volume / Usability), size of spaces.
  - **ii. General Design Criteria:** geometric composition, the divine proportion/golden ratio, 3d shape to fill, sustainable criteria.

By overlapping the previous criteria mentioned in the chapter, as shown in figure (2-9). There are common factors that affect achieving good space quality for users by considering them during the space layout planning stage, which are: **Geometric Composition**, **Way Finding**, **Accessibility, Furniture Layout**, **Views of Nature**, **Walking Distances**, and **Efficiency of Circulation**.

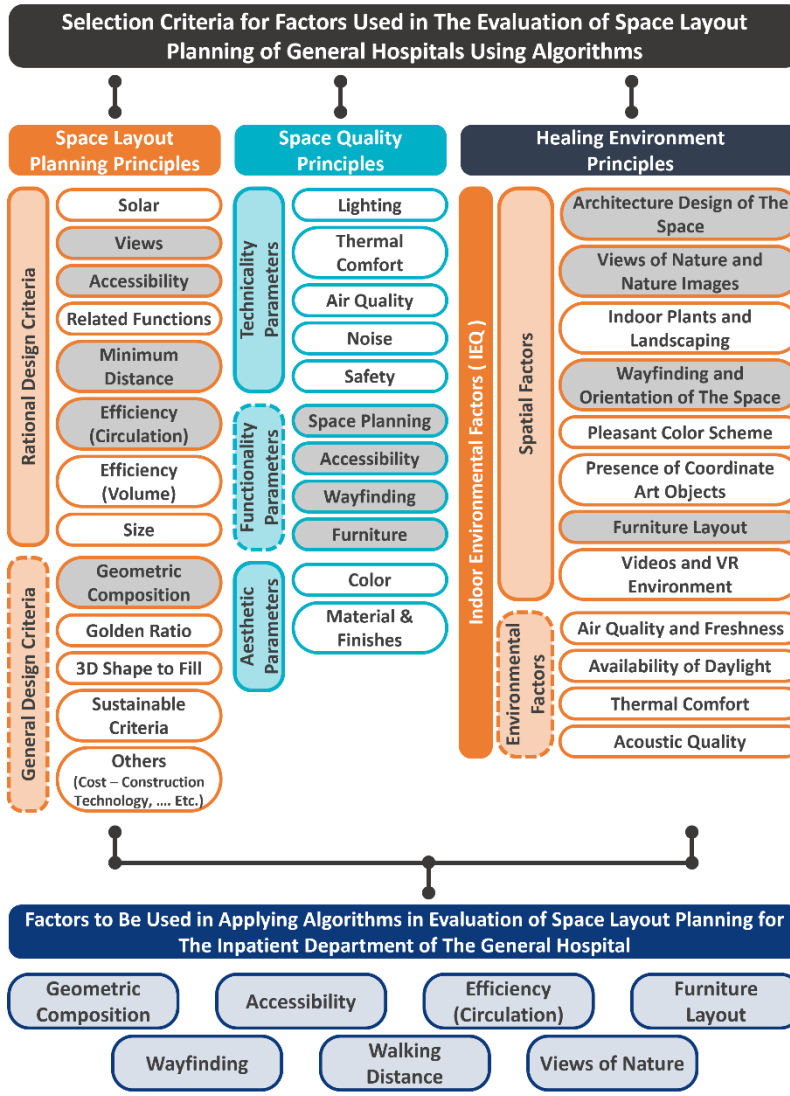

Figure 2- 9: Factors to Be Used in Applying Algorithms in The Evaluation Process
Source: By Researcher

Chapter 3

Integration of Algorithms in Evaluation Methods for Hospital Facilities

- Introduction
- Overview of Evaluation Process
- Introduction to Post Occupancy Evaluation
- Integration of Using Algorithms in Evaluation Process
- General Overview to Isovist Analysis Theory
- Conclusion

3.1. Introduction

Hospital facilities are considered complex facilities that need high performance and operation systems in both the medical and construction fields and continuous quality improvements through various evaluation methods. Many studies focus on the relation between the indoor environment and the healing process of patients.

This chapter reviews the building evaluation process, especially the post-occupancy evaluation process. In order to apply a post-occupancy evaluation to hospital facilities, an overview of the process must be provided by defining the process and its types. The level of detail can be determined through the post-occupancy evaluation process, and the limitations can be faced by experts and architects during the post-occupancy evaluation process.

Also, reviewing theories based on integrating the field of sight and visibility analysis in exploring the surrounding spatial configurations and environments around the users of the space And how developing tools using algorithms is being used in evaluating different layout configurations and exploring their effect on users behaviors, especially in the inpatient department in hospital facilities prior to the research scope.

3.2. Overview of Evaluation Process

The main goal of a building is to function as a shell for its intended purpose. With the advancement of technology, buildings now offer comprehensive services to their users. They are no longer just structures that provide protection, but rather safe environments that respond to the expectations of owners who have invested in modern construction technologies. These buildings aim to ensure functionality, comfort, and safety for users, without compromising their overall experience. To achieve this, a continuous cycle of improvements is necessary, which can be facilitated through an evaluation process for buildings. which can be achieved with a simple evaluation process, as shown in the following figure (3-1).

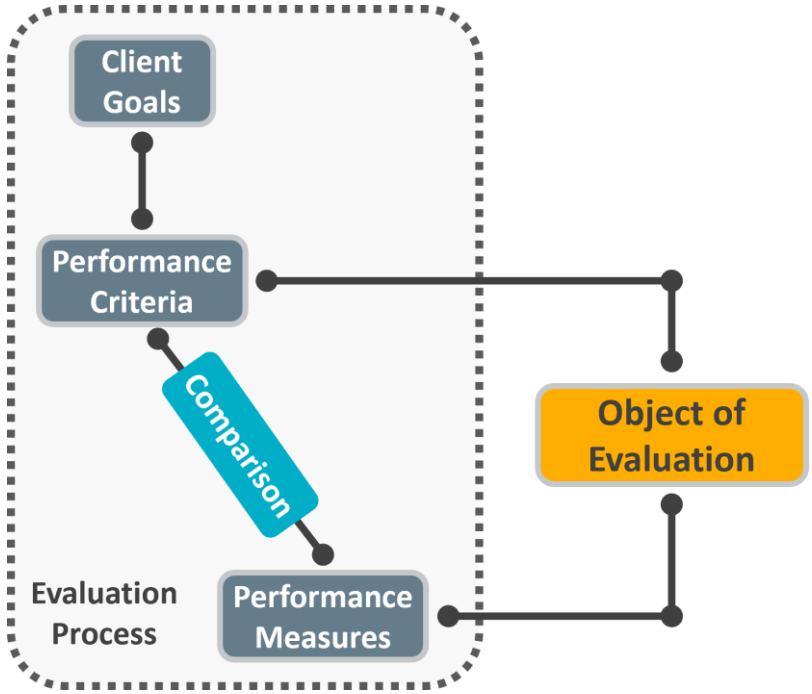

Figure 3-1: Basic Evaluation Process
By: Researcher, Source: *(W. F. E. Preiser & Vischer, 2005)*

There is a multitude of approaches and tools for assessing facilities based on specific areas of focus. This discussion provides suitable evaluation methods to be employed during different stages of facility construction. Typically, the focus lies on the performance, functionality, usability, or form of the building. Two examples of evaluation methods commonly used are post-occupation evaluation (POE) and usability appraisal. However, assessments of occupied buildings are rarely conducted. The inclusion of long and costly elements characterizes them as integral components of the final stage of a building project. Consequently, the documentation of completed construction projects is not systematically gathered, resulting in the repetition of errors (Fronczek-Munter & Aneta, 2017).

According to the evaluation process reasons must be set clearly before the start of the process due to its complexity nature, Evaluation Process Reasons can be grouped as the following (Cold, B. (2012), as cited in Fronczek-Munter & Aneta, 2017) :

- **Recognition:**
  In order to properly understand the significance and implications of spaces, get into the contextual background, personal experiences, and cognitive comprehension that contribute to the formulation and development of theoretical frameworks.

- **Control:**
  In order to get insights into the experiences, utilization, and acquisition of skills and information by individuals in a given context, it is imperative to observe and analyze their interactions with their surroundings, exercise control over their environment, and harness their abilities.

- **Professional information:**
  In order to acquire recommendations from experts, engage in discussions and spread information.

The evaluation process is dependent upon the particular goals of the application and the current level of progress achieved in the project, as the following (Fronczek-Munter & Aneta, 2017):

- **Existing building:**
  The investigations conducted in the facility encompass two main areas: testing the current existing conditions and applying knowledge for the purpose of making changes or achieving radical innovation.

- **New building:**
  The investigation aims to assess the fulfillment of requirements, gather insights from current facilities, and provide feedback for the briefing and innovation process in a new building. This approach is rooted in user involvement and co-learning, allowing for knowledge exchange and sharing of information.

- **Develop generic knowledge:**
  This investigation aims to provide a comprehensive documentation of best practice instances in a given type of building or geographical location, with a focus on the role of inspiration in stimulating innovation. The analysis will encompass several cases that illustrate excellent practices and serve as sources of inspiration for innovative approaches.

The following figure (3-2) shows the application context of evaluation approach according to different goals:

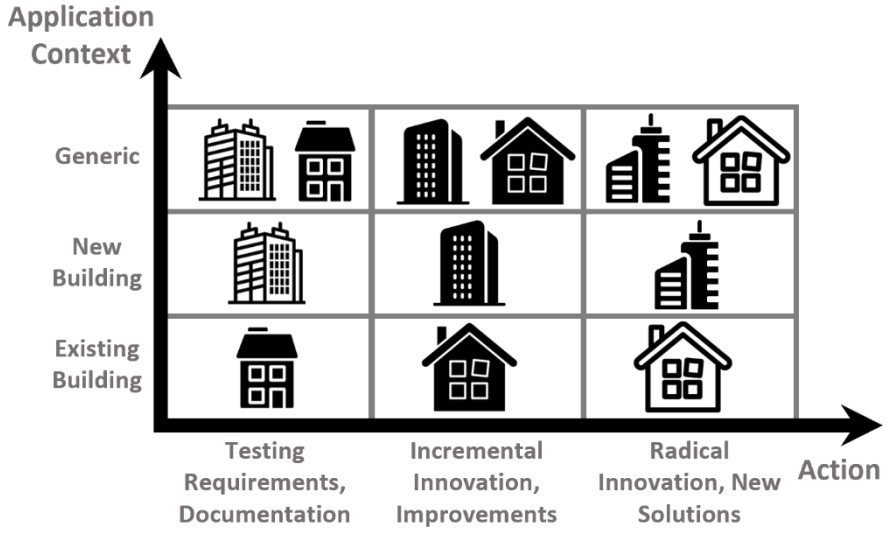

Figure 3-2: Levels of Actions in Evaluation Process
By: Researcher, Source: *(Fronczek-Munter & Aneta, 2017)*

3.3. Introduction to Post Occupancy Evaluation

Post-occupancy evaluation (P.O.E.) refers to the systematic evaluation of a building's performance subsequent to its occupation. The basis of this concept is that conducting systematic evaluations of human responses to buildings and other designed places is a valid objective of architectural research, with the intention of understanding users' requirements. The initial endeavors in the field of POE were primarily directed towards addressing the housing requirements of marginalized populations with the aim of enhancing the overall environmental conditions in government-funded housing. Subsequently, the previously mentioned procedure was extended to encompass more governmental establishments, including military residential areas, medical institutions, correctional facilities, and judicial edifices. P.O.E. was initially adopted for the purpose of powering office buildings and other commercial real estate during the mid-1980s. Since then, it has remained a prevalent technology for various types of buildings up until the present day (Federal Facilities Council, 2001).

The application of Post-Occupancy evaluation (POE) has expanded to encompass a broader spectrum of building types and has adapted to changing expectations for buildings. Consequently, POE now encompasses all activities aimed at understanding the performance of a constructed building, including the assessment of its compliance with expectations and the satisfaction of its occupants with the created environment. While the primary objective of Post-Occupancy evaluations (POEs) remains the assessment of user comfort and satisfaction, organizations are currently exploring methods for using the collected data for enhanced decision-making regarding space and building investments throughout the various stages of a facility's life cycle, including programming, design, construction, and operation. In order to accomplish this, it is imperative for businesses to create specific design criteria, databases, or alternative methodologies for effectively consolidating insights derived from Post-Occupancy evaluations (POEs). Furthermore, these valuable lessons must be disseminated across the whole organizational hierarchy, encompassing senior executives, midlevel managers, project managers, consultants, and clients alike (Federal Facilities Council, 2001).

3.3.1. Post Occupancy Evaluation Definition

Post-occupancy evaluation (POE) primarily involves the collection of data regarding users and buildings through the utilization of questionnaires, interviews, site (Mahmood & Tayib, 2021; Nawawi & Khalil, 2008)ib, 2021; Nawawi & Khalil, 2008). There are a number of definitions for the post-occupancy evaluation process, but the following are the most common definitions that are mostly repetitive in the literature studied.

According to (W. F. E. Preiser et al., 1988) "Post-occupancy evaluation refers to the systematic and detailed evaluation of structures subsequent to their construction and occupancy over a certain period of time. Post-Occupancy Evaluations (P.O.Es) center their attention on the occupants of buildings and their requirements, offering valuable insights into the implications of previous design choices and the subsequent performance of the facility. This information serves as the basis for the development of improved buildings in future projects". (Vischer, 2001) defines P.O.E process as "All operations pertaining to the examination of a building's performance post-construction, encompassing the evaluation of its compliance to estimated requirements and its overall efficiency".

(W. F. E. Preiser, 1995, 1997) Presenting another viewpoint, specifically the perspective of the facility manager, the concept of Post-Occupancy Evaluation (POE) can be characterized as "a diagnostic instrument and framework that empowers facility managers to methodically recognize and evaluate important aspects of building performance".

post-occupancy evaluation (P.O.E) can be conducted by many professionals in the building business, or as is frequently observed, by the client or owner of the property. In the context of this study, the term (P.O.E) was operationally defined as the systematic evaluation of health service buildings or facilities. It was believed that this evaluation would take place at some point after the buildings or facilities have been occupied, typically after a specified period of usage ranging from 12 months to 2 years (Carthey, 2006).

3.3.2. Levels of Detail in Post Occupancy Evaluation

The term post occupancy evaluation refers to the fact that the building is already in use at the point of evaluation. Depending on the objectives of the client organization and the time frame involved, the level of detail of the process is defined as the following (Fronczek-Munter & Aneta, 2017; W. F. E. Preiser, 1995):

- **Indicative P.O.E.:**

  Quick, walk-through evaluations including structured interviews with key staff, group meetings with end-users, and examinations are conducted. The end result includes a brief analysis of the beneficial and negative aspects of building performance, achieved through a limited use of resources.

- **Investigative P.O.E.:**

  The comprehensive evaluation methods employed in this investigation include in-depth evaluations, interviews and survey questionnaires, photographic/video recordings, physical measurements, benchmarking with relevant literature, and comparison with the latest technology. The outcome entails an extensive evaluation of the facility.

- **Diagnostic P.O.E.:**

  Focused, longitudinal, and cross-sectional evaluations are conducted to comprehensively examine many performance elements such as stair safety, orientation and wayfinding, artificial versus full spectrum lighting, privacy, and overcrowding. These studies employ a research approach that considers multiple variables. The outcome entails gaining knowledge derived from contemporary and innovative case studies.

A (P.O.E.) process model was developed which outlines in three phases and nine steps the process a typical post-occupancy evaluation goes through, as shown in figure (3-3) (W. F. E. Preiser, 1995).

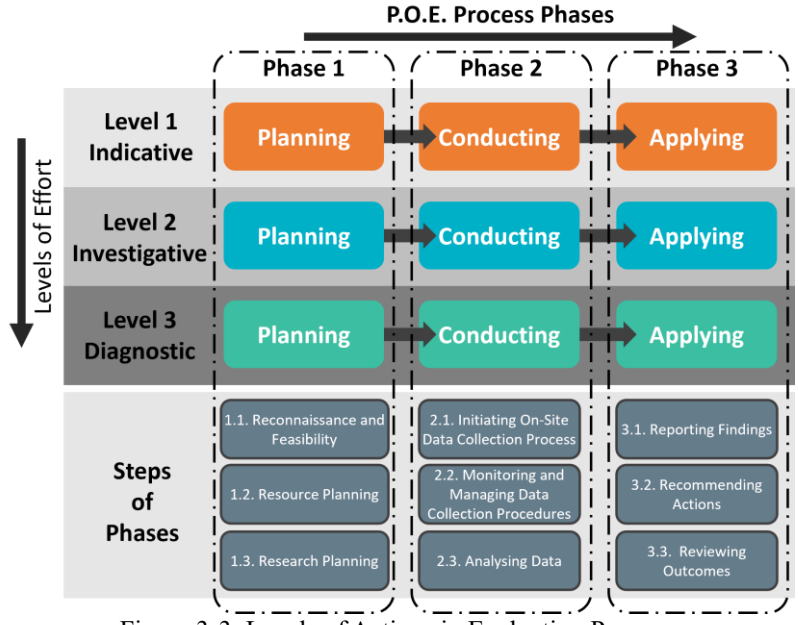

Figure 3-3: Levels of Actions in Evaluation Process
By: Researcher, Source: (W. F. E. Preiser, 1995)

The dominant form of post occupancy evaluation (POE) is the indicative type, typically conducted immediately following the collection of on-site data, with a relatively short duration. Generally, an executive summary provides a compilation of priority concerns and suggested plans of action. Typically, the findings become accessible within a few days subsequent to the visit to the site. The duration of investigative post occupancy evaluation (POE) can vary significantly, ranging from one week to several months. This variation is dependent upon the complexity of the investigation and the level of staff engagement from the client organization responsible for the evaluation of their building(s). Diagnostic post occupancy evaluation (POE) shows resemblance to conventional in-depth research conducted within a highly concentrated domain of study. The process can span several months or even years, requiring the utilization of advanced methodologies for data collection and analysis (W. F. E. Preiser, 1995).

3.3.3. Goals of The Post Occupancy Evaluation Process

A (P.O.E.) can fulfill multiple purposes, dependent upon the goals and objectives of the client organization. Post occupancy evaluation (P.O.E.) may provide the information needed for the following (W. F. E. Preiser, 2001):

- **Measuring the functionality and appropriateness of design:**

In order to ensure compliance with the performance requirements outlined in the functional program. When employing the Principles of (P.O.E.) for evaluating design, it is essential that the evaluation have its basis according to the performance requirements given in the functional program statement mentioned earlier in the design process.

- **Fine-tuning of a facility:**

Some facilities, such as office buildings, integrate the principle of "adaptability" to accommodate the regular need for modifications. In this scenario, regular and repetitive evaluations play a significant role in a continuous process of modifying the facility to align with developing organizational requirements.

- **Adjust programs for repetitive facilities:**

Certain organizations construct facilities that are fundamentally identical on a repetitive basis. The concept of POE encompasses the identification of evolutionary enhancements in programming and design criteria, as well as the evaluation of the validity of fundamental assumptions that support a repeating design approach.

- **Research the effects of buildings on their occupants:**

Enhancing comprehension of building-occupant interactions can prove advantageous for professionals such as architects, designers, environment-behavior researchers, and facility managers. The utilization of more reliable scientific methodologies is necessary beyond the typical skills of design practitioners. The research on POE in this particular case entails comprehensive and precise methodologies, as well as advanced degrees of

data analysis such as factor analysis and studies, in order to enhance the applicability of the findings.

- **Test the application of new concepts:**

The process of innovation necessarily involves the assumption of risk. Established and proven concepts and ideas have the potential to result in effective practices, while the introduction of innovative concepts is essential for driving development. The utilization of (P.O.E.s) can facilitate an examination of the effectiveness of an innovative idea upon its practical implementation.

- **Justify actions and expenditures:**

Organizations are increasingly seeking greater levels of accountability, and the (P.O.E) plays a crucial role in generating the necessary information to achieve this purpose.

Also, post-occupancy evaluation process goals can be defined according to the time frame of the process. P.O.E.s have uses and benefits over the short, medium, and long term, as the following (W. F. E. Preiser, 1995; W. F. E. Preiser et al., 1988), as shown in figure (3-4):

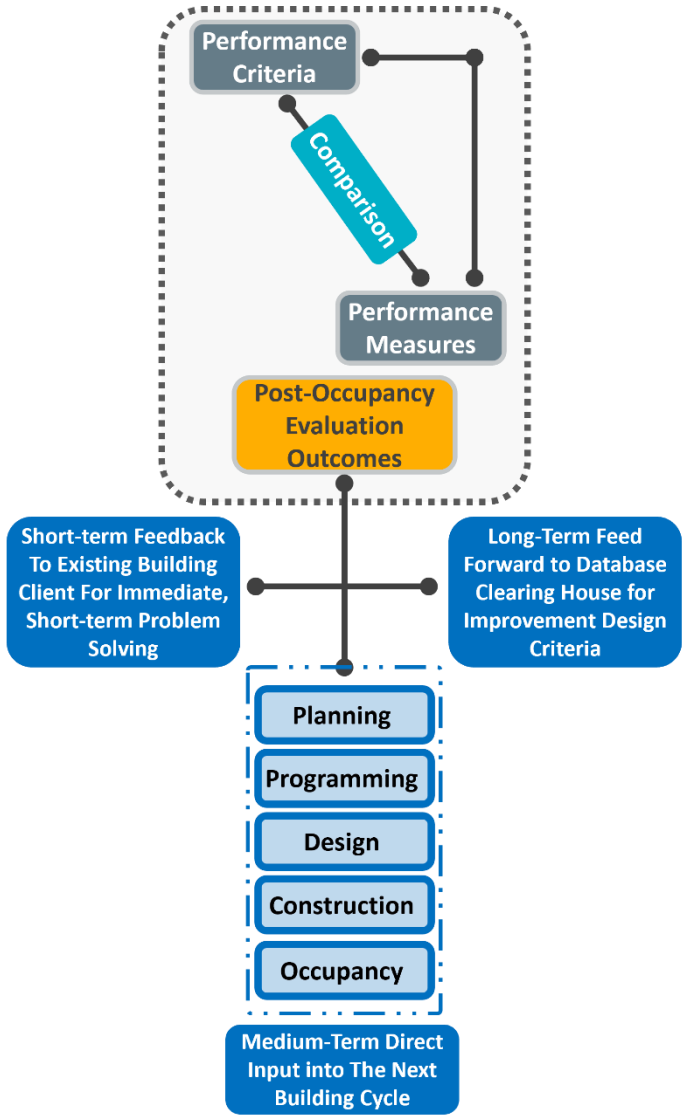

Figure 3-4: Goals of P.O.E. According to Time Frame
By: Researcher, Source: (W. F. E. Preiser, 1995)

a. SHORT-TERM BENEFITS:

- The identification and management of issues related to facilities.
- The implementation of proactive facility management practices that are concerned with the values of building users.
- Enhanced usage of space and enhanced input on the performance of buildings.
- The active participation of building users in the evaluation process has been found to enhance their attitude towards the building.
- Comprehending the performance implications associated with changes needed by financial constraints.
- The ability to make informed decisions and have an in-depth understanding of the consequences of design.

b. MEDIUM-TERM BENEFITS

- The inherent capacity of a facility to adapt to organizational changes and expansion over a period of time, encompassing the reuse of facilities for alternative uses.
- There are notable financial advantages associated with cost reductions in both the construction phase and the whole lifespan of a building.
- The concept of accountability for building performance is a matter of concern for both design professionals and owners.

c. LONG-TERM BENEFITS

- Enhancements in building performance over a longer time frame.
- Enhanced assessment of building performance through measurements.

3.3.4. Limitations of Post Occupancy Evaluation Process

Although there is a wide range of applications for the post-occupancy evaluation process, there are some limitations that prevent it from being an essential practice for buildings and why more evaluations are not carried out .

(Vischer, 2001) identify the obstacles that prevent the broader adoption and engagement with (P.O.E.). The author highlights several obstacles that limit the general acceptance and implementation of POE, including cost, time constraints, and skill requirements.

Also, The NSW Treasury Post Implementation Review notes that “there are a number of reasons The effectiveness of post-implementation reviews is often not studied enough, as cited in (Carthey, 2006):

- Upon the completion of each phase of a project, the assembled team splits quickly and moves to the future project.
- Extended project durations. Certain asset-based projects may exhibit significant time intervals ranging from the evaluation of feasibility to the actual occupation phase, spanning a duration of around 3 to 5 years.
- The extended duration of turnover results in alterations to several aspects that contributed to the initial asset solution. The factors encompass service delivery requirements, political considerations, budgetary constraints, economic conditions, industry norms, and other relevant elements.
- In instances where projects demonstrate deficiencies, there appears to be a general unwillingness to subject participants to perceived forms of critique.
- In a society that is becoming more litigious, the act of expressing critiques can potentially be interpreted as constituting libel.
- Funding for the implementation of effective and sustained (P.O.E.s) initiatives is often rare.
- (P.O.E) is frequently regarded as lacking effectiveness. Studies that are excessively complex and extensive are often seen as being inefficient in terms of time management.

- The asset management sector lacks a culture of critical analysis and assessment.
- The development of a "collective" reference system lacks an effective mechanism. For instance, one can draw a comparison between the legal and medical professions, particularly in relation to their comprehensive case histories.

3.4. Integration of Using Algorithms in Evaluation Process

The term “algorithm” is derived from the Latin word “Algoritmior Algorismus” which translates to "the calculation method". Algorithms are often regarded as a favored methodology for obtaining information or producing solutions to problems through the execution of a finite set of steps by a computer program. Therefore, the use of a computer program often entails the execution of an algorithm, with the resulting outputs being mainly dependent upon the data that has been provided (Morsi, 2014).

3.4.1. Definition of Algorithms

Algorithms play a crucial role in the design process since they are employed to address, organize, or investigate challenges characterized by organized complexity. In their basic manifestation, computational algorithms utilize numerical approaches to deal with these difficulties. The algorithm has emerged as a means to replicate and analyze the cognitive processes of humans, with the aim of simulating and studying the behaviors of both humans and machines through discrete operations. (Morsi, 2014; Terzidis, 2006)

- **Theoretically:**
  The solving of a problem can be achieved when the problem is formulated in a logical manner.
- **Traditionally:**
  An algorithm refers to a systematic approach that provides logical or mathematical solutions to a given problem. The feasibility of implementing these ideas significantly increased when computer-based implementation became a viable option.
- **Practically:**
  An algorithm refers to a prescribed sequence of instructions presented in a certain format that outlines the necessary steps for resolving a given problem using a computer. Algorithms play a crucial role in enabling computers to comprehend and execute these instructions effectively.

3.4.2. Characteristics of Algorithms

"An algorithm is a well-ordered collection of unambiguous and effectively computable operations that when executed produces a result and halts in a finite amount of time" (Schneider & Gersting, 1995). According to this concept, the five significant attributes of algorithms can be identified as follows,(Morsi, 2014; Schneider & Gersting, 1995):

- **Algorithms are well-ordered:**

The accurate ordering of instructions is of greatest importance, particularly in computer processes, to achieve the desired outcome.

- **Algorithms have unambiguous operations:**

Every action within an algorithm must possess a level of clarity that reduces the necessity for simplification. When an algorithm is expressed using computational primitives, it becomes unambiguous and can be executed by a computer.

- **Algorithms have effectively computable operations:**

Every operation within an algorithm must be feasible; it should be an action that can be executed.

- **Algorithms produce a result:**

The most basic definition of an algorithm states that it is a collection of instructions designed to address and resolve a given problem. The probability of the end result being true is contingent upon the production of a result by the algorithm. The verification of algorithms as correct or incorrect is contingent upon their ability to generate results.

- **Algorithms halt in a finite amount of time:**

Algorithms are required to consist of a limited set of operations and must be capable of terminating within a finite duration.

3.4.3. Visibility analysis Using Algorithms

This study examines the correlation between spatial features of layout and individuals' preferences and behaviors inside various environments. The inquiry necessitates the utilization of a technique that can effectively capture the influence of the spatial structure of a layout on individuals' preferences and behavior within architectural environments (Rajab Alalouch, 2009). (Peponis & Wineman, 2002) has been argued that the exploration of the fundamental role of spatial layout has its foundations in research on environment and behavior. Hence, employing a syntactic methodology to examine spatial environments may provide beneficial in comprehending the logic behind individuals' preferences and dislikes towards spatial qualities, based on quantifiable spatial characteristics of a given floor plan (Rajab Alalouch, 2009).

In the subsequent section, an overview of the dominant theories based on visibility concepts will be discussed.

3.4.3.1. Space Syntax Analysis

Space Syntax refers to a collection of theories and methodologies that were formulated by Bill Hillier and his colleagues at the Bartlett School of Architecture in University College London (UCL). This innovative approach aims to represent, quantify, and interpret spatial environments within communities and buildings by examining their social relationships. The field of space syntax examines spaces as social product that are influenced by and embedded within a social framework (Hiller & Hanson, 1984).

The theory and its analytical techniques have been widely applied in the fields of architecture, urban design, planning and interior design. The use of these techniques has been extended to involve a variety of other fields such as archaeology, information technology, geography and anthropology. In addition to the initial focus of space syntax, which was mainly on the pattern of predestination movements, the use of these techniques has been extended to include modelling of urban traffic, predicting air pollution levels, estimating the potential of retail development and many other aspects (Ratti, 2004). The examination of visual relationships between locations provides a means to explore the social functioning of a specific spatial setting. (Rajab Alalouch, 2009). The argument states that a network of places that are easily accessible and easily visible tend to be more conducive to social interaction, while locations that have boundaries are comparatively less welcoming (Hiller & Hanson, 1984).

Furthermore, space syntax provides a diverse range of computer applications that facilitate the analysis of architectural plan drawings. The value of a space is contingent upon how it interacts with other spaces. Consequently, any modification to the spatial system, such as altering the number of spaces or adjusting the connection pattern (e.g., adding or removing doors, blocking off corridors), will inevitably impact the value attributed to that particular place (Haq & Luo, 2012).

3.4.3.2. Isovist Analysis

The recognition of the significance of the concept in architecture appears to have been established by (Benedikt, 1979), who defines the Isovist as "the set of all points visible from a vantage point in space with respect to an environment". This cognitive approach enables him to apply geometric metrics in order to quantify both the size and shape of the Isovist. Consequently, the Isovist emerges as a valuable tool for explaining the perception and interaction of individuals with spatial environments, thereby facilitating the explanation of various spatial behaviors (Rajab Alalouch, 2009).

The concept of isovists maintains interest due to its logical nature in understanding spatial environments. Isovists offer a descriptive perspective of space from an individual's point of view, encompassing their perception, interaction, and movement within it. Therefore, isovists hold significant relevance in the field of architectural analysis. (Benedikt, 1979) starts the analysis by taking into consideration the observable volume from a specific vantage point, and subsequently simplifies this depiction by capturing a horizontal cross-section of the (isovist polyhedron). The resulting isovists consist of single polygons that do not contain any holes (Turner et al., 2001), as shown in figure (3-5).

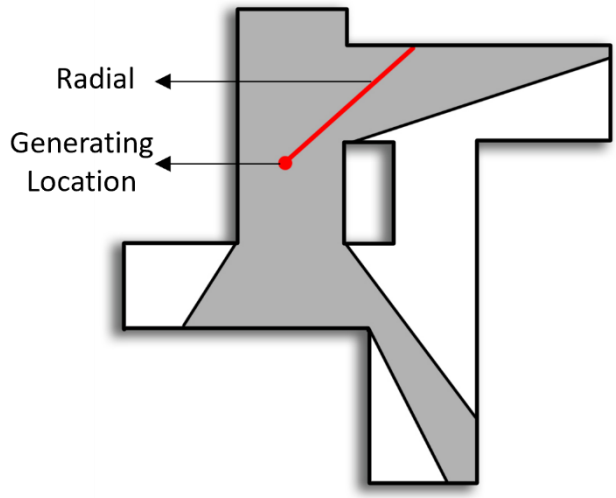

Figure 3-5: Goals of P.O.E. According to Time Frame
By: Researcher, Source: (Turner et al., 2001)

3.4.3.3. Visibility Graph Analysis (VGA)

The (Visibility Graph Analysis) emerged as a result of the integration of two theoretical frameworks: isovists and space syntax. However, it is commonly categorized under the broader framework of space syntax. The technique employed in this study is based on graphs, wherein each isovist inside the given configuration is shown as a node. Consequently, the resulting graph is composed of a grid of points. The connection between these nodes is established through edges in the event that they possess the ability to see each other simultaneously. (Rajab Alalouch, 2009). The process of overlapping resulted in the creation of the integrating isovist, which was initially introduced by (Penn & Turner, 1999). The development of the concept of integrating isovist has subsequently led to the formulation of visibility graph analysis (VGA) by (Turner, 2001).

Within the context of VGA, a matrix of individual points is superimposed onto the underlying graphical structure. Subsequently, each individual point is closely linked to every other point within its perceptual range. The VGA is employed for the purposes of both connection and visual integration (Chau et al., 2018; Geng et al., 2020).

Many computer-based applications have been developed to facilitate the generation of visibility graphs and enable their subsequent analysis. The University College London, specifically the Bartlett School of Graduate Studies, is recognized as a leading institution in this area. It was at this institution that the concept of VGA was first introduced, inside the framework of space syntax. During the 3rd International Space Syntax Symposium held in Atlanta (Rajab Alalouch, 2009). (Turner, 2001) The initial software to conduct visibility graph analysis, known as Depthmap, was introduced by (Hiller & Hanson, 1984) The initial software to conduct visibility graph analysis, known as Depthmap, was introduced. The development of Depthmap has progressed rapidly, resulting in the production of many newer versions. The improvements encompassed various additional aspects of spatial arrangement, such as integration and control. In addition to VGA, the Depthmap has the capability to do axial maps, segment analysis, metric analysis, and agent-based analysis (Rajab Alalouch, 2009).

3.5. General Overview to Isovist analysis Theory

An isovist is a method used for spatial analysis, commonly applied in the field of architecture. The utilization of this concept has been observed in the fields of architecture, geography, and mathematics. The term "Isovist" was initially introduced under this title by (Turner et al., 2001) who employed this technique as a means of analyzing the landscape. (Benedikt, 1979) attempted to bring together the interests of psychologists and architects in the field of spatial design by developing a tool that facilitates the integration of psychological principles relating to space from an architectural perspective (Rajab Alalouch, 2009).

Building his assumption on (Gibson, 1966) conceptualization of the visual environment refers to the understanding of it as the collection of light rays that are received by the eye from the surrounding environment, as shown in figure (3-6). The perception of the visual environment is contingent upon the position of the observer, who experiences alterations in the visual information received when moving within a given space. This is due to the fact that the light rays received by the observer are subject to change based on their spatial location. Accordingly, Benedikt provides a definition of the visual environment as "the field light-borne information" in which the observer is engaged. Based on the above definition, one can observe a significant correlation between spatial elements, light, and visibility can be noticed. The Isovist is conceptualized as a method for examining the interplay in question (Rajab Alalouch, 2009).

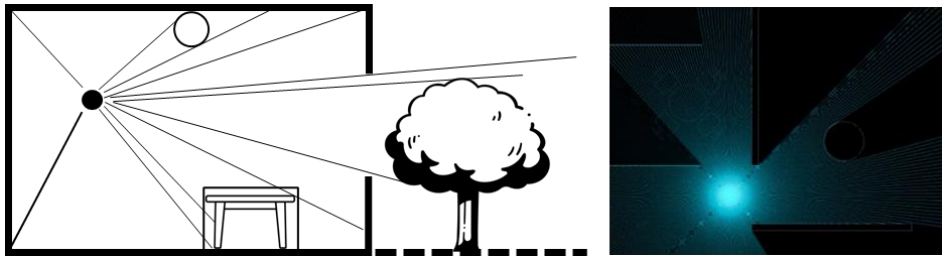

Figure 3-6: Goals of P.O.E. According to Time Frame
Source: *(Gibson, 2015; as cited in, Johanes & Atmodiwirjo, 2015)*

3.5.1. Isovist Field

Benedikt's observation pertains to the distinctiveness of individual isovists within a certain context, both in terms of their shape and size. Furthermore, the isovist undergoes alterations in response to the movement of the generating point. Therefore, he assumes that in order to measure the spatial environment and comprehend individuals' perception, movement, and utilization of it, it is essential to take into account the interaction between the Isovist and the configuration. Consequently, he formulates the concept of the "isovist field" for each of his measurements.

The concept of the Isovist field pertains to the analysis of alterations occurring in a specific attribute (e.g., area, diameter, etc.) of an isovist as a result of the displacement of its generating point within the configuration. This analysis is visually represented by the charting of contour lines, which effectively illustrate the spatial variations in this property (Turner et al., 2001).

An isovist refers to the entire set of points that are perceptible from a specific viewpoint within a spatial context, relative to the surrounding environment. The configuration and dimensions of an isovist exhibit variability in relation to its location. Various numerical measurements are suggested to quantify significant size and form characteristics. These measures, in their entirety, generate a collection of scalar Isovist fields. The concept of isovist sets and isovist fields provides an alternate means of describing environments. The methodology appears to be applicable to behavioral and perceptual investigations in the field of architecture, particularly in relation to topics such as view control, privacy, defensibility, as well as the assessment of dynamic complexity and spaciousness judgments. Isovist analysis and the concept of isovist fields provide valuable insights into the interpretation of prevailing architectural concepts related to space (Benedikt, 1979).

3.5.2. Isovist Geometric Measures

Based on the boundary of the Isovist and the distribution of the radial length to generate quantitative metrics that assess the size and shape of the Isovist (Rajab Alalouch, 2009).

The boundary of an isovist can be categorized into three distinct types. These three types of isovist boundaries were subsequently utilized to quantify the size of the isovist (Benedikt, 1979), as shown in figure (3-7):

- Real surfaces, refer to physical surfaces that have the ability to enclose the field of sight.
- Occluding radial surfaces refers to the process of obstructing or blocking the surfaces of the radials that form the area of occlusion.
- The region-boundary surfaces, These surfaces are the outcome of the intersection between the field of sight and the boundaries of the surrounding environment.

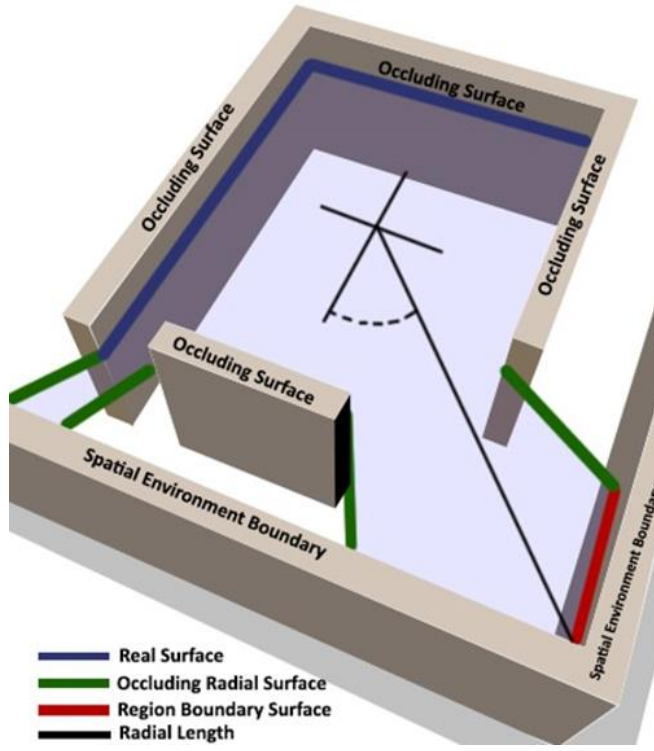

Figure 3-7: Isovist Boundaries Surface types
By: Researcher, Source: (Rajab Alalouch, 2009)

Consequently, Benedikt formulated a number of geometric measurements in order to quantitatively evaluate Isovist. These metrics encompass area, perimeter, occlusivity, variance, skewness, and circularity. The dimensions of the isovist are quantified by the area and perimeter, while the occlusivity, variance, skewness, and circularity metrics assess its shape (Benedikt, 1979; Rajab Alalouch, 2009), as shown in figure (3-8).

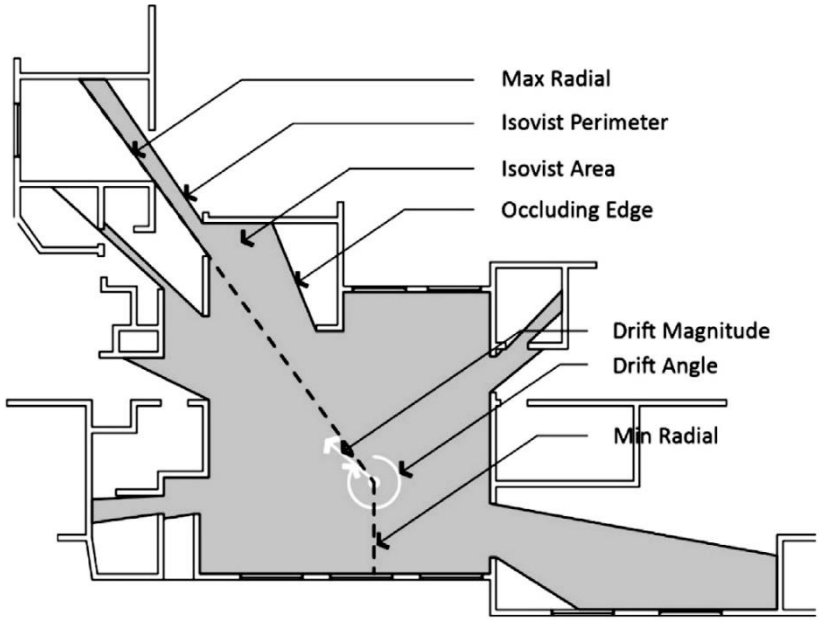

Figure 3-8: Isovist Geometric Measurements
Source: (Lee et al., 2017)

These six measures presented by (Benedikt, 1979) quantify numerically the size and shape of an isovist in an attempt to describe spatial configuration and explain some behavior in space such as privacy, visual control and way finding.

- **The area of the isovist:**

The isovist polygon's area is measured in square meters. In essence, it quantifies the extent of visible space from the originating location, and inversely, the extent to which the originating point is visible.

- **The Perimeter of The Isovist:**

The measurement method quantifies the extent of (real surface) from the point of origin. In the context of this measure, it is important to note that the occluding radial surfaces and area boundary surfaces are not considered as valid bounds for the isovist.

- **The Occlusivity of The Isovist:**

The measurement method quantifies the length of the occluding radial boundary of the isovist. In another way, it might be defined as the cumulative measurement of the length of all obstructing radial lines. When the occlusivity value is zero it signifies the absence of occluding areas, resulting in an isovist equivalent to the configuration. Conversely, an increment in the occlusivity value implies a greater level of uncertainty regarding the configuration.

- **The circularity of the isovist:**

The measurement of proximity between the isovist and a circle. In alternative terms, it represents a quantification of the central position of the producing point in relation to its isovist.

There are two measures which depend on the distribution of the radial of length of an isovist, the variance and the skewness.

- **The variance:**

The variance of the radical measures the diffusion of the perimeter of the isovist polygon.

- **The skewness of The Isovist:**

The measurement quantifies the degree of asymmetry exhibited by the perimeter of the isovist polygon. When the skewness is positive, there is a shortage of long radials and a large number of short radials. Conversely, when the skewness is negative, the opposite pattern is observed. The interiors of caves exhibit a positive skewness, while areas in close proximity to columns, trees, or outside corners display a negative skewness (*Isovists.Org*, n.d.).

3.5.3. Isovist Analysis Application in Healthcare Facilities

The objective is to provide a tool for isovist visualization, which allows an isovist to visually assess the level of visibility and visual access to the surrounding environment from a specific location, as shown in figure (3-9). The generation of isovists from multiple locations can be employed to demonstrate the concepts of visibility and intervisibility within a specific spatial configuration (Johanes & Atmodiwirjo, 2015), as shown in figure (3-10).

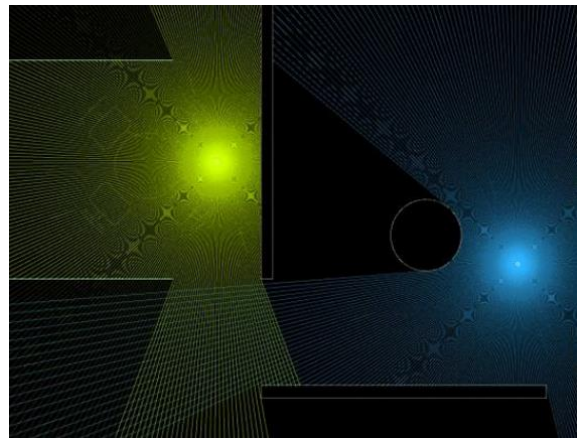

Figure 3-9: Visual Access From Point To Surrounding Environment
Source: *(Johanes & Atmodiwirjo, 2015)*

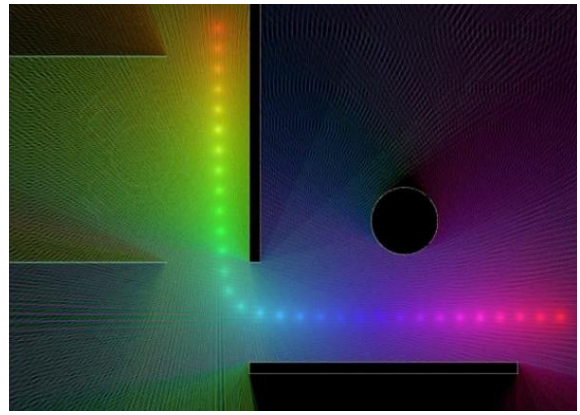

Figure 3-10: Isovists From Multiple Locations & Intervisibility Within a Spatial Configuration
Source: *(Johanes & Atmodiwirjo, 2015)*

In order to represent the movement inside a given environment, the isovists might be arranged as a sequential series that corresponds to a specific path. The researchers employ their methodology to evaluate the level of visibility within an inpatient ward. This evaluation encompasses the visibility observed from the nursing station, the visibility experienced while nurses traverse the corridor, and the visibility of the ward entry area. These factors collectively provide insight into the overall visibility of the ward (Johanes & Atmodiwirjo, 2015), as shown in figures (3-11) (3-12).

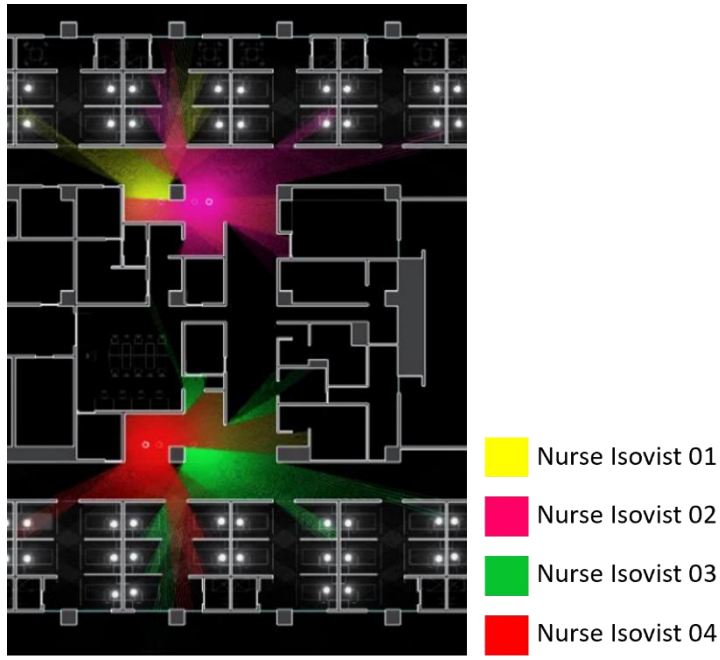

Figure 3-11: Isovist From Nursing Station
Source: *(Johanes & Atmodiwirjo, 2015)*

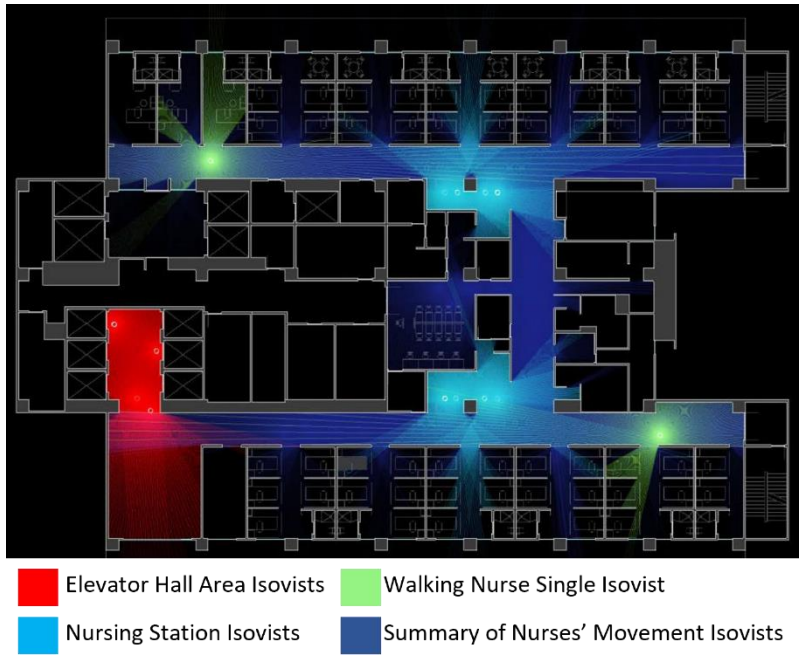

Figure 3-12: General visibility of the inpatient ward
Source: (Johanes & Atmodiwirjo, 2015)

Through the utilization of this approach, the evaluation of the perceptibility of numerous areas within the healthcare facility can be seamlessly accomplished by incorporating distances into the analysis. This is particularly advantageous when examining the visibility of inpatient wards and the isovists originating from nurse stations, as well as the pathways traversed by nurses during their circulation. This aids in identifying areas that may possess diminished visibility for nurses, thereby indicating the need for potential spatial reorganization, specifically in relation to the positioning of nursing stations. Additionally, the strategic placement of monitoring technology, such as closed-circuit television (CCTV), can be considered to ensure comprehensive surveillance of all sections within the ward. The strategic positioning of a nursing station in relation to patient rooms, other nurse stations, and the ward entrance requires careful review, as it has the potential to conflict with the imperative need for patient control, visitor surveillance, and staff communication (Johanes & Atmodiwirjo, 2015).

3.6. Conclusion

This chapter provides an overview of the building evaluation process, with a particular focus on the post-occupancy evaluation phase. Furthermore, this study aims to examine theories that incorporate the integration of sight and visibility analysis within the context of studying spatial configurations and settings surrounding individuals within a given space. Specifically, this research will focus on the application of algorithms in the inpatient department of hospital facilities:

- the post-occupancy evaluation process plays an important role in improving the design briefs and functional programs of new projects, which may present a non-preferred phase in the post-occupancy process as it takes a long time to apply after observing a lot of similar projects that are already occupied for enough time to detect problems and avoid repetition of mistakes in future projects.

- A (P.O.E.) can fulfill multiple purposes, dependent upon the goals and objectives of the client organization, as shown in figure (5-4). the goals could be defined as the following:
  i. Measuring the functionality and appropriateness of design.
  ii. Fine-tuning of a facility.
  iii. Adjust programs for repetitive facilities.
  iv. Research the effects of buildings on their occupants.
  v. Test the application of new concepts.
  vi. Justify actions and expenditures.

Also, the research examines the correlation between spatial features of layout and individuals' preferences and behaviors inside various environments based on visibility analysis using algorithms. Three approaches of analysis were discussed, including space syntax analysis, visibility graph analysis (VGA), and isovist analysis.

- Using **Isovist Theory**, understand the concept of analyzing the space from the observer's field of sight with different measurements to recognize the behavioral interaction between the users and the surrounding layout configuration.

- There are a number of geometric measurements in order to quantitatively evaluate Isovist. These metrics encompass **Area**, **Perimeter**, **Occlusivity**, **Variance**, **Skewness**, and **Circularity**. The dimensions of the isovist are quantified by the **Area** and **Perimeter**, while the **Occlusivity**, **Variance**, **Skewness**, and **Circularity** metrics assess its shape.

Chapter 4

Case Study: Application of Post-Occupancy Evaluation Using Algorithms on Inpatient Department Typologies

- Introduction
- Overview of General Hospitals Case Studies
- Case Studies Selection Criteria
- Evaluation Process of Space Layout Planning Using Algorithms
- Applying Algorithms in Evaluation of Space Layout Planning
- Conclusion

4.1. Introduction

This chapter presents a framework for a post-occupancy evaluation methodology based on three distinct case studies of inpatient departments, each with a different configuration of nursing stations. The evaluation is based on space quality factors that have been derived after a thorough review of relevant literature. The purpose of this framework is to emphasize the crucial role of space layout planning in hospital facilities. It achieves this by utilizing an analysis framework to examine existing hospitals and identify factors that should be avoided in future hospital design processes, particularly during the early design stage. Additionally, the framework aims to establish clear outcomes by identifying and addressing issues in existing case studies. The ultimate goal is to enhance the configuration of nursing stations, thereby improving the healing environment for patients. This improvement in the patient experience is expected to result in better service delivery and increased hospital turnover rates.

The framework additionally seeks to implement a visualized analysis evaluation for nursing stations, which can assist designers and consultants in the initial design phases by improving the spatial layout planning in hospitals. This approach aims to integrate the process of observing and studying multiple planned hospitals, thereby reducing the need for repetitive analysis and preventing the repetition of mistakes made in previous projects.

4.2. Case Studies Selection Criteria

With the goal of applying algorithms to the space layout planning of inpatient departments in general hospitals, case studies were selected based on the following:

- **Selection of General Hospitals as case studies :**

Inpatient departments in general hospitals were selected to work on as case studies based on their layout configuration, choosing three different floor layouts to find out different types of nursing units typologies and testing the validity of the algorithms used in different inpatient department layout configurations, as shown in the following:

1. **H1: Dar El-Fouad Hospital**, The inpatient department takes the form of a cluster with a centralized nursing station (double corridor), as shown in figure (4-1).

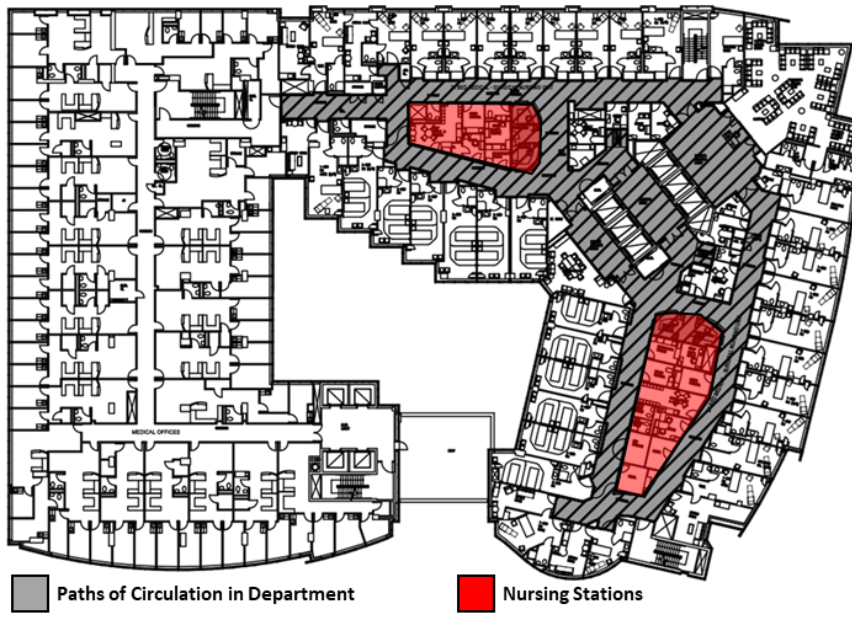

Figure 4- 1: Dar El-Fouad Hospital - Inpatient Department Layout Configuration
Source: By Researcher

2. **H2: As-Salam International Hospital**, The inpatient department takes a linear form with a decentralized nursing stations (double corridor), as shown in figure (4-2).

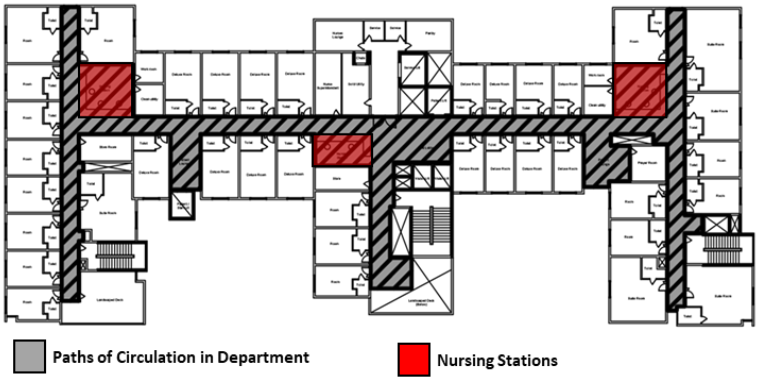

Figure 4- 2: As-Salam International Hospital - Inpatient Department Layout Configuration
Source: By Researcher

3. **H3: El-Sheikh Zayed Al Nahyan Hospital, The inpatient** department takes a shape of 2 linear vertical parts linked with another linear form that consists of supporting facilities and vertical circulation elements with a decentralized nursing stations (single corridor), as shown in figure (4-3).

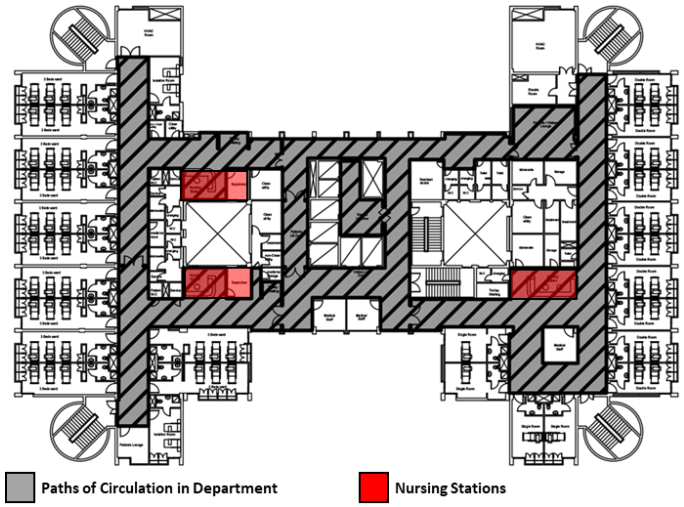

Figure 4- 3: El-Sheikh Zayed Al Nahyan Hospital - Inpatient Department Layout Configuration
Source: By Researcher

- **Goal of Using Post Occupancy Evaluation Process:**

The post-occupancy evaluation process was selected with the existing layout configuration of inpatient departments in general hospitals for the following goals (W. F. E. Preiser, 2001):

1. Measuring the functionality and appropriateness of existing layout configurations according to guidelines and aspects of evaluation mentioned in the research literature.
2. Research the effects of floor layouts on their occupants for the sake of creating a quick, in-depth analysis tool that can prove advantageous for professionals such as architects and designers to analyze previous projects in order to set outlines for new projects in the early design process.

According to the previous determined goals for the evaluation process, the level of detail of post occupancy evaluation process chosen to apply algorithms in the evaluation framework (Fronczek-Munter & Aneta, 2017; W. F. E. Preiser, 1995).

- **Diagnostic Level of Detail in The Post Occupancy Evaluation Process:**

The level of detail is characterized by Focused, longitudinal, and cross-sectional evaluations are conducted to comprehensively examine many performance elements such as **orientation and wayfinding, privacy, and overcrowding**. The outcome entails gaining knowledge derived from existing projects.

4.3. Overview of General Hospitals Case Studies

The evaluation process is applied on three different general hospitals that have different layout configurations in the inpatient department, a general overview will be explained briefly for the case studies.

4.3.1. Case Study 1: Dar El-Fouad Hospital

4.3.1.1. Hospital General Overview

Figure 4- 4: Dar Al Fouad Hospital & Clinics Tower, Nasr City
Source: By Researcher, from *(*Dar Al Fouad Hospital (New) - Orascom Construction*, n.d.)*

The Following Table briefly shows an overview for the Hospital (*Dar Al Fouad Hospital (New) - Orascom Construction*, n.d.):

Table 2: Dar El-Fouad Hospital General Overview

Case Study 1: Dar El-Fouad Hospital	
Hospital Name	Dar Al Fouad Hospital & Clinics Tower, Nasr City
Hospital Type	General Hospital
Location	Nasr City (the intersection of El Nasr Road and Youssef Abbas Street), Cairo, Egypt
Land Area	13,000 sqm.
Footprint Area	7,000 sqm.
Total Built Up Area	61,000 sqm.

Launch Date	2018
Brief	No. of Floors: 3 Basement Floors, Ground Floor, and 8 floors
	Starting from the 3rd floor, the building is divided into two towers: **Tower A** equipped with 158 beds and 5 operating rooms, And **Tower B** equipped with 220 medical clinics

4.3.1.2. Hospital Departments' Overview

- **Hospital Departments' Allocation**

The hospital includes many departments and services providing both inpatients with extended hospital stays and outpatients seeking short-term hospital services, typically within a day or less. The Figure (4-5) shown below offers an overview of different hospital departments:

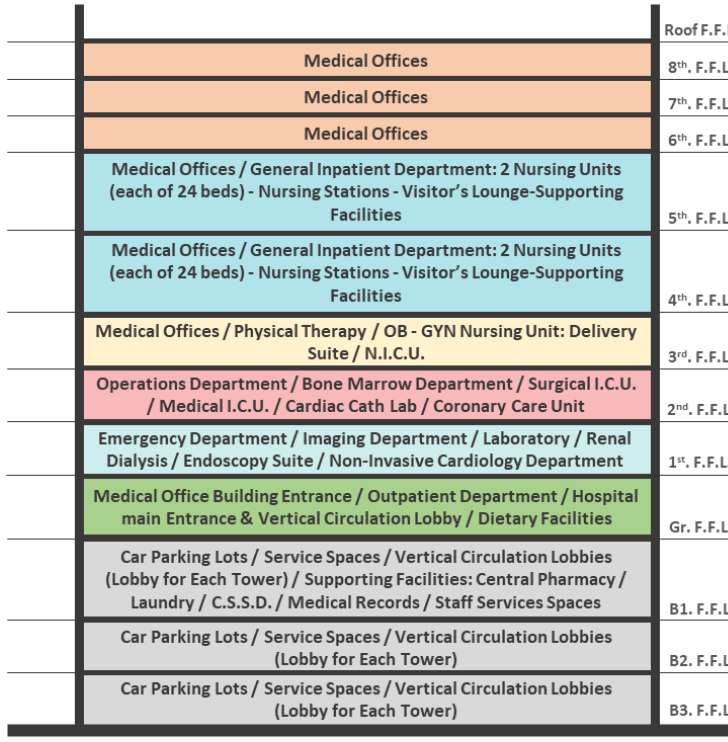

Figure 4- 5: Dar Al Fouad Hospital Departments' Allocation
Source: By Researcher

- **Hospital Departments' Zoning**

The following figures shows the layout configuration for the departments allocated in each floor:

a. Basement 3 Floor Plan

Figure 4- 6: Dar El-Fouad Hospital - Basement 3 Floor Plan
Source: By Researcher

b. Basement 2 Floor Plan

Figure 4- 7: Dar El-Fouad Hospital - Basement 2 Floor Plan
Source: By Researcher

c. Basement 1 Floor Plan

Figure 4- 8: Dar El-Fouad Hospital - Basement 1 Floor Plan
Source: By Researcher

d. Ground Floor Plan

Figure 4- 9: Dar El-Fouad Hospital - Ground Floor Plan
Source: By Researcher

e. First Floor Plan

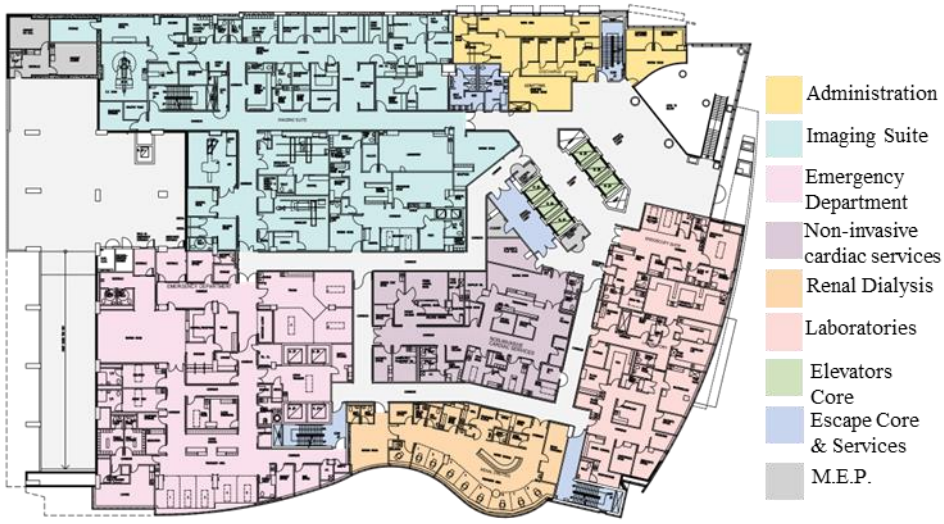

Figure 4- 10: Dar El-Fouad Hospital - First Floor Plan
Source: By Researcher

f. Second Floor Plan

Figure 4- 11: Dar El-Fouad Hospital - Second Floor Plan
Source: By Researcher

g. Third Floor Plan

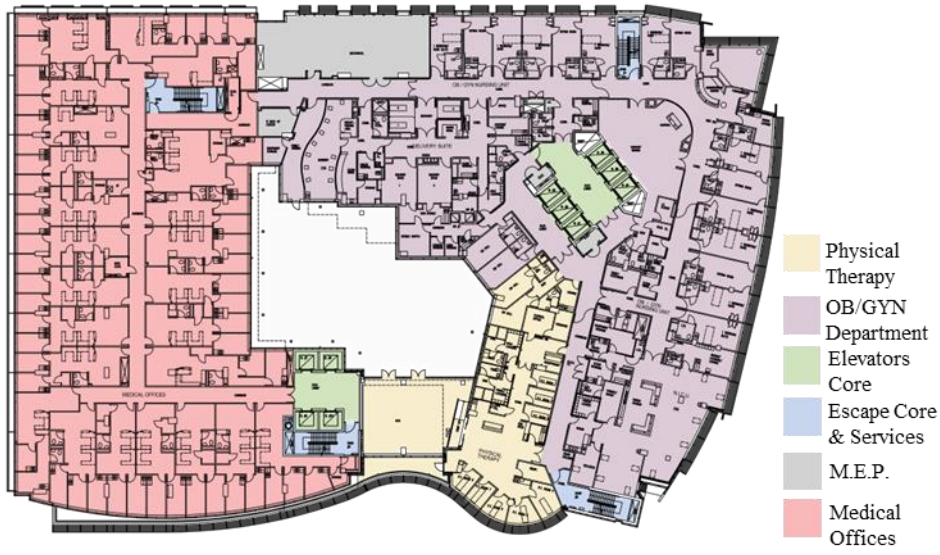

Figure 4- 12: Dar El-Fouad Hospital - Third Floor Plan
Source: By Researcher

h. Fourth & Fifth Floor Plan

Figure 4- 13: Dar El-Fouad Hospital - 4th & 5th Floor Plan
Source: By Researcher

i. Sixth & Seventh & Eighth Floor Plan

Figure 4- 14: Dar El-Fouad Hospital - 6th & 7th & 8th Floor Plan
Source: By Researcher

4.3.1.3. Inpatient Department Analysis

General Inpatient Departments existed in two Typical floors, which are the fourth and fifth floors. Each floor is divided into two individual parts, which are: Medical Offices and the Inpatient Department. Inpatient department in each floor consist of two centralized nursing units, the nursing stations allocated in the center of patients' rooms, along with Supporting Facilities like clean utility, a staff lounge and lockers, and Staff offices.

- **Inpatient Department Zoning**

Each nursing unit is responsible for 24 beds in different types of rooms, such as the following: 3 Suite rooms, 6 Double rooms, 7 Single rooms, and 2 Isolation rooms. as shown in figures (4-15) (4-16).

Figure 4- 15: Dar El-Fouad Hospital - Inpatient Department
Source: By Researcher

Figure 4- 16: Dar El-Fouad Hospital - Inpatient Department (Nursing Units)
Source: By Researcher

- **Inpatient Rooms Typologies**

a. Single-bed Patient Room

The room area is **29.20** m^2, Consists of patient's bed, 4 chairs for Patient Relatives, a lavatory, and a toilet for the patient.

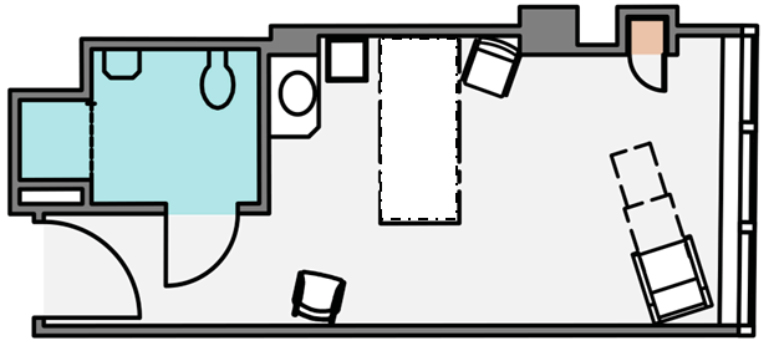

Figure 4- 17: Dar El-Fouad Hospital - Single-bed Patient Room
Source: By Researcher

b. Double-bed Patient Room

The room area is **30.25** m^2, Consists of 2 beds for patients, 2 chairs for Patient Relatives, a lavatory, and a toilet for the patients. The share of space area for each patient is **15.1** m^2.

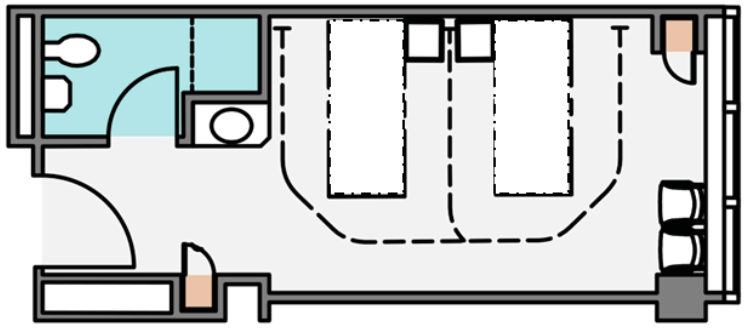

Figure 4- 18: Dar El-Fouad Hospital - Double-bed Patient Room
Source: By Researcher

c. Suite Patient Room

The room area is **48.00** m^2, Consists of Single bed patient room with 2 chairs for patient relatives, sitting room for patient family, a lavatory, and a toilet for the patient.

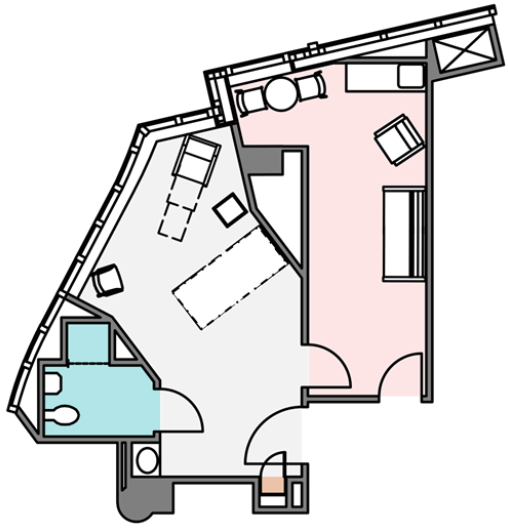

Figure 4- 19: Dar El-Fouad Hospital - Suite Patient Room
Source: By Researcher

- **Hospital On-Site Photos**

The following figures shows some photos for the inpatient Department in the hospital that is prior to research study scope:

a. Nursing Station

Figure 4- 20: Inpatient Department - Nursing Station
Source: By Researcher, from (*Dar Al Fouad Hospital (New) - Orascom Construction*, n.d.)

b. Visitors Lounge

Figure 4- 21: Inpatient Department - Visitors Lounge
Source: By Researcher, from *(*Dar Al Fouad Hospital - Google Maps*, n.d.)*

c. Patients' Rooms

Figure 4- 22: Inpatient Department - patients' Rooms
Source: By Researcher, from *(*Dar Al Fouad Hospital (New) - Orascom Construction*, n.d.)*

4.3.2. Case Study 2: AS-Salam International Hospital

4.3.2.1. Hospital General Overview

Figure 4- 23: AS-Salam International Hospital
Source: By Researcher, from *(*As-Salam International Hospital*, n.d.)*

The Following Table briefly shows an overview for the Hospital (*As-Salam International Hospital*, n.d.):

Table 3: AS-Salam International Hospital General Overview

Case Study 2: AS-Salam International Hospital	
Hospital Name	As-Salam International Hospital
Hospital Type	General Hospital
Location	Fifth Settlement, New Cairo City, Cairo, Egypt
Land Area	4,500 sqm.
Footprint Area	1,800 sqm.
Total Built Up Area	12,600 sqm.
Launch Date	2022
Brief	No. of Floors: 2 Basement Floors, Ground Floor, and 4 floors
	The hospital is equipped with 150 regular and critical care beds

4.3.2.2. Hospital Departments' Overview

- **Hospital Departments' Allocation**

The Hospital includes many departments and services providing both inpatients with extended hospital stays and outpatients seeking short-term hospital services, typically within a day or less. The Figure (4-24) shown below offers a concise overview of different hospital departments:

Figure 4- 24: AS-Salam International Hospital Departments' Allocation
Source: By Researcher

- **Hospital Departments' Zoning**

The following figures shows the layout configuration for the departments allocated in each floor:

a. Basement 2 Floor Plan

Figure 4- 25: AS-Salam International Hospital - Basement 2 Floor Plan
Source: By Researcher

b. Basement 2 Floor Plan

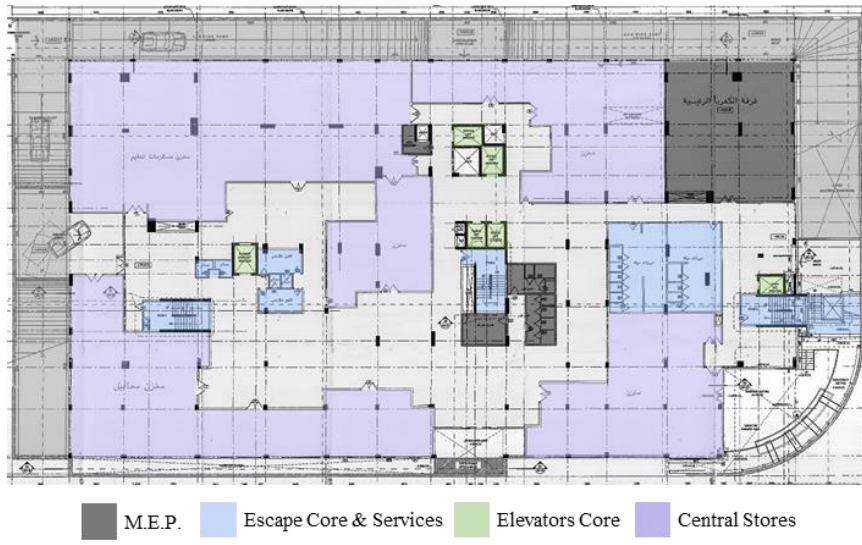

Figure 4- 26: AS-Salam International Hospital - Basement 1 Floor Plan
Source: By Researcher

c. Ground Floor Plan

Figure 4- 27: AS-Salam International Hospital - Ground Floor Plan
Source: By Researcher

d. First Floor Plan

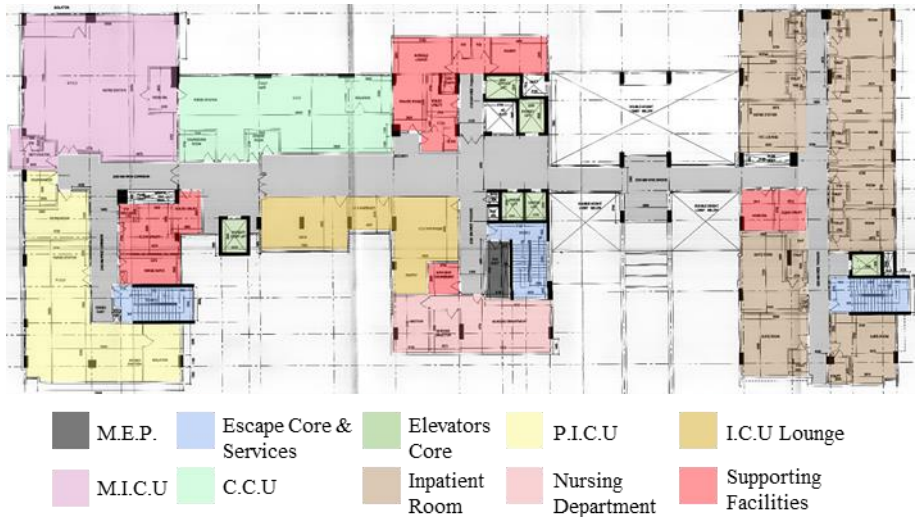

Figure 4- 28: AS-Salam International Hospital - First Floor Plan
Source: By Researcher

e. Second Floor Plan

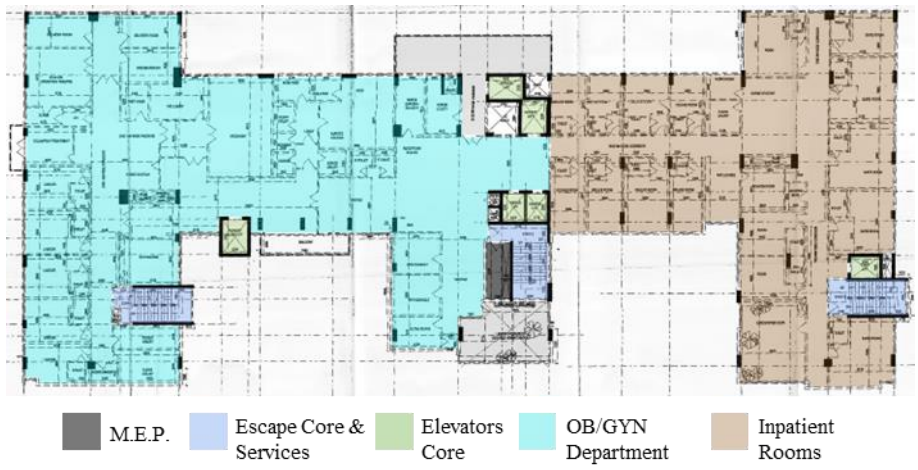

Figure 4- 29: AS-Salam International Hospital - Second Floor Plan
Source: By Researcher

f. Third Floor Plan

Figure 4- 30: AS-Salam International Hospital - Third Floor Plan
Source: By Researcher

g. Fourth Floor Plan

Figure 4- 31: AS-Salam International Hospital - Fourth Floor Plan
Source: By Researcher

4.3.2.3. Inpatient Department Analysis

- **Inpatient Department Zoning**

General Inpatient Departments existed in two different floors, which are the third and Fourth floors. The third floor will be the floor to be studied in the research.
The inpatient department comprises three decentralized nursing units. The nursing stations are strategically located along the main path of the department, and the supporting facilities are distributed throughout the floor plan in close proximity to the nursing stations. The three nursing units are divided into the following, as shown in figures (4-32) (4-33):

a. **Nursing Unit 1:** is allocated in the left vertical part of the plan, consists of a nursing station, 9 single patients' rooms, 1 suite patient room.
b. **Nursing Unit 2:** is allocated in the middle of the main horizontal path, consists of a nursing station, 3 single patients' rooms, and 16 deluxe single patients' rooms.
c. **Nursing Unit 3:** is allocated in the right vertical part of the plan, consists of a nursing station, 5 single patients' rooms, 4 suite patient rooms.

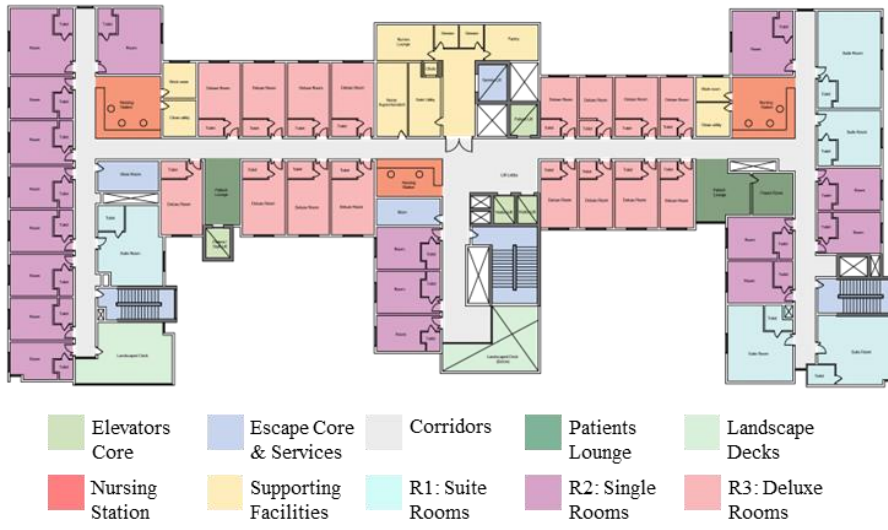

Figure 4- 32: AS-Salam International Hospital - Inpatient Department
Source: By Researcher

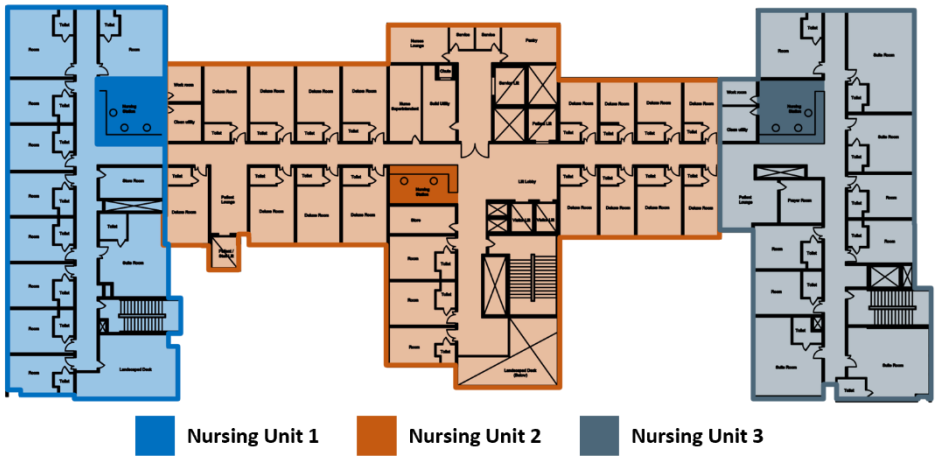

Figure 4- 33: AS-Salam International Hospital - Inpatient Department (Nursing Units)
Source: By Researcher

- **Hospital On-Site Photos**

The following figures shows some photos for the inpatient Department in the hospital that is prior to research study scope:

a. Patients' Rooms

Figure 4- 34: Inpatient Department - patients' Rooms
Source: By Researcher, from *(*Alameda - As-Salam*, n.d.)*

4.3.3. Case Study 3: El-Sheikh Zayed Al Nahyan Hospital

4.3.3.1. Hospital General Overview

Figure 4- 35: El-Sheikh Zayed Al Nahyan Hospital
Source: By Researcher, from (Sheikh Zayed AL Nahyan Hospital - Manshiet Nasser | The Arab Contractors, n.d.)

The Following Table briefly shows an overview for the Hospital (*As-Salam International Hospital*, n.d.):

Table 4: El Sheikh Zayed Al Nahyan Hospital General Overview

Case Study 3: El-Sheikh Zayed Al Nahyan Hospital	
Hospital Name	Sheikh Zayed AL Nahyan Hospital
Hospital Type	General Hospital
Location	Manshiet Nasser, Cairo, Egypt
Land Area	27,500 sqm.
Footprint Area	2,000 sqm.
Total Built Up Area	14,000 sqm.
Launch Date	2008

Brief	No. of Floors: Basement, Ground Floor, 5 Typical floors (2000m² for each one)
	The hospital is equipped with 150 beds
	In addition to the services building including pipes stores, ground tank, pumps chamber, electricity chamber, boilers building, medical gas building, fences, and the general site work

4.3.3.2. Hospital Departments' Overview

- **Hospital Departments' Allocation**

The Hospital includes many departments and services providing both inpatients with extended hospital stays and outpatients seeking short-term hospital services, typically within a day or less. The Figure (4-36) shown below offers an overview of different hospital departments:

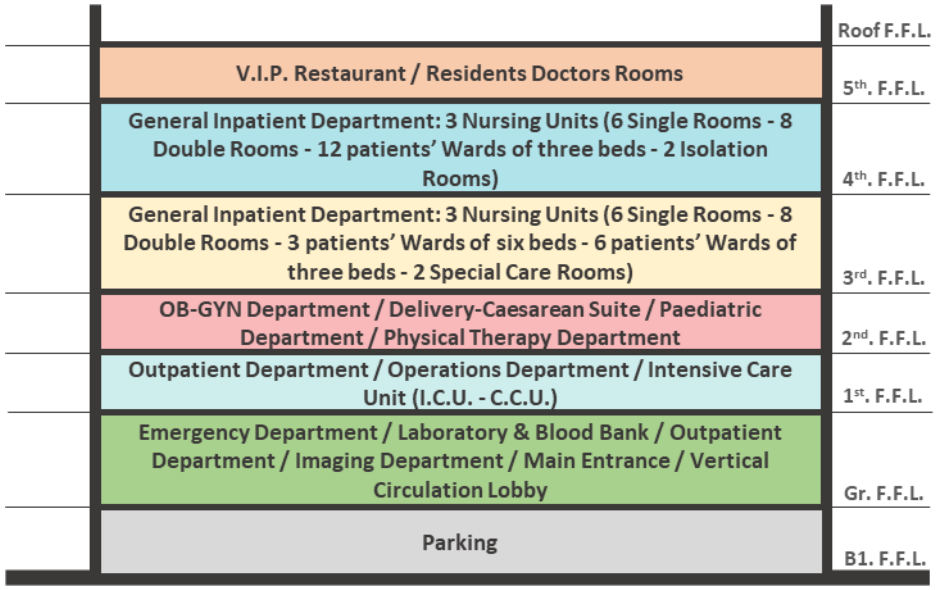

Figure 4- 36: El-Sheikh Zayed Al Nahyan Hospital Departments' Allocation
Source: By Researcher

- **Hospital Departments' Zoning**

The following figures shows the layout configuration for the departments allocated in each floor:

a. Ground Floor Plan

Figure 4- 37: El-Sheikh Zayed Al Nahyan Hospital - Ground Floor Plan
Source: By Researcher

b. First Floor Plan

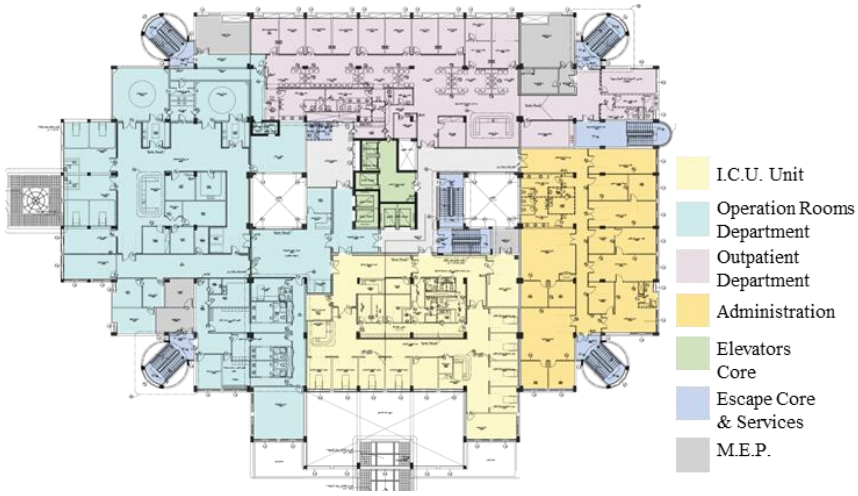

Figure 4- 38: El-Sheikh Zayed Al Nahyan Hospital - First Floor Plan
Source: By Researcher

c. Second Floor Plan

Figure 4- 39: El-Sheikh Zayed Al Nahyan Hospital - Second Floor Plan
Source: By Researcher

d. Third Floor Plan

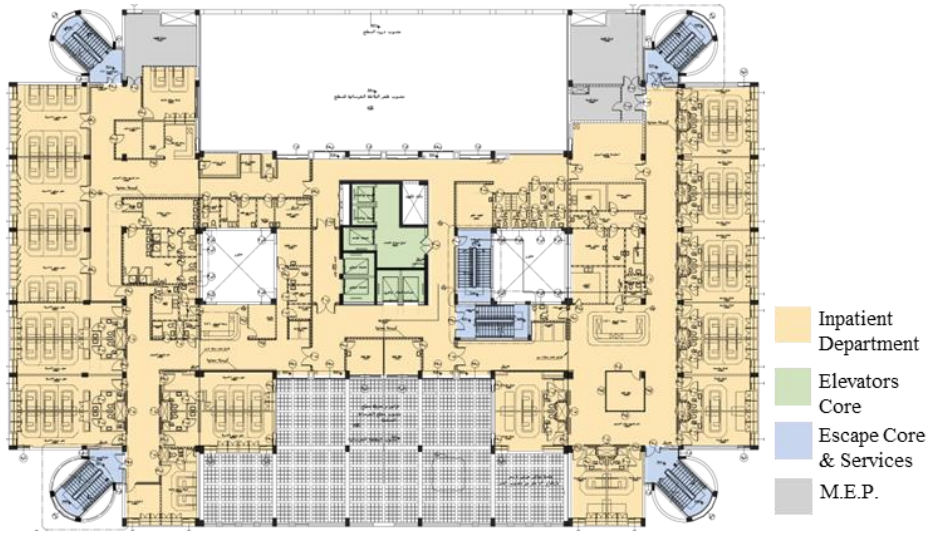

Figure 4- 40: El-Sheikh Zayed Al Nahyan Hospital - Third Floor Plan
Source: By Researcher

e. Fourth Floor Plan

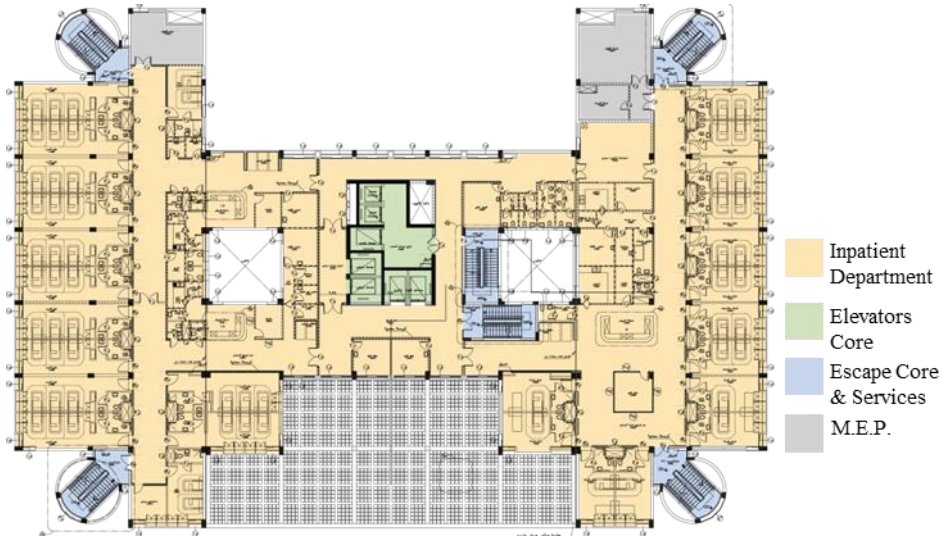

Figure 4- 41: El-Sheikh Zayed Al Nahyan Hospital - Fourth Floor Plan
Source: By Researcher

f. Fifth Floor Plan

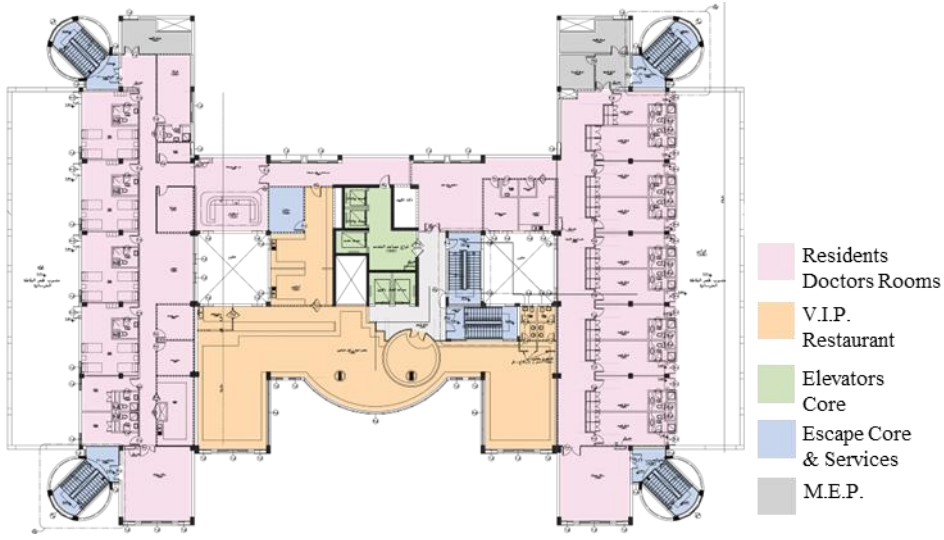

Figure 4- 42: El-Sheikh Zayed Al Nahyan Hospital - Fifth Floor Plan
Source: By Researcher

4.3.3.3. Inpatient Department Analysis

- **Inpatient Department Zoning**

General Inpatient Departments existed in two different floors, which are the third and Fourth floors. The fourth floor is the floor to be studied in the research. The inpatient department comprises three decentralized nursing units. The nursing stations are strategically located along the main path of the department, and the supporting facilities are distributed throughout the floor plan in close proximity to the nursing stations. The three nursing units are divided into the following, as shown in figure (4-43):

a. **Nursing Unit 1:** Consists of a nursing station, 6 patients' Wards of three beds - 1 Isolation Rooms**.**
b. **Nursing Unit 2:** Consists of a nursing station, 6 patients' Wards of three beds - 1 Isolation Rooms
c. **Nursing Unit 3:** Consists of a nursing station, 4 single patients' rooms, 10 double rooms.

Figure 4- 43: Dar El-Fouad Hospital - Inpatient Department Zoning
Source: By Researcher

Figure 4- 44: Dar El-Fouad Hospital - Inpatient Department Zoning (Nursing Units)
Source: By Researcher

- **Inpatient Rooms Typologies**

a. Single-bed Patient Room

The room area is **23.80** m^2, Consists of patient's bed, and a toilet for the patient.

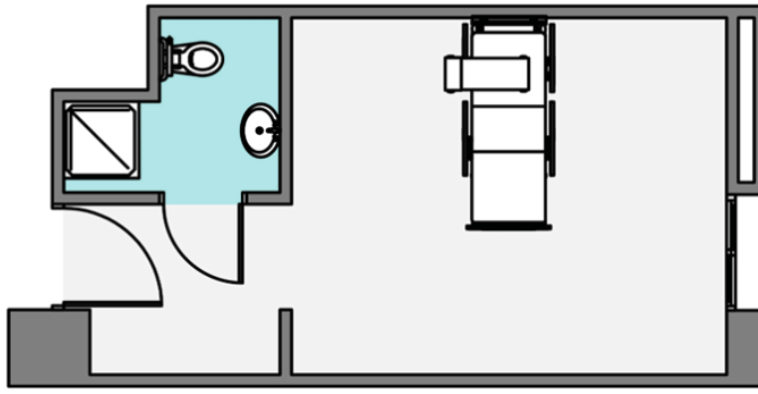

Figure 4- 45: Dar El-Fouad Hospital - Single-bed Patient Room
Source: By Researcher

b. Double-bed Patient Room

The room area is **22.90** m^2, Consists of 2 beds for patients, and a toilet for the patients. The share of space area for each patient is **11.45** m^2.

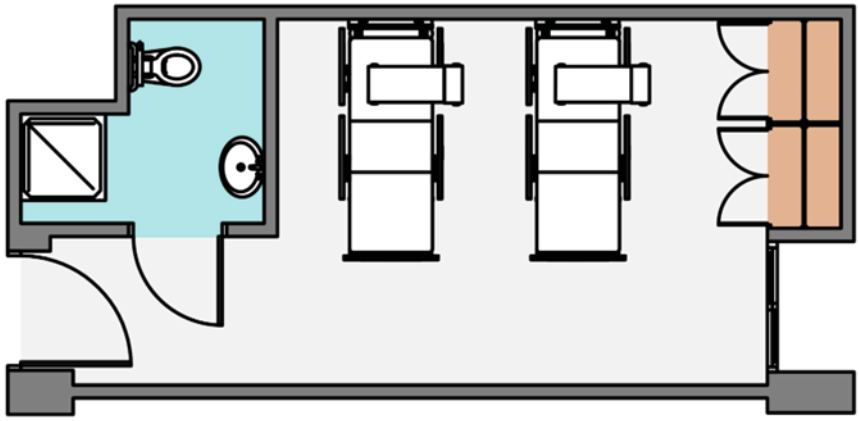

Figure 4- 46: Dar El-Fouad Hospital - Double-bed Patient Room
Source: By Researcher

c. Patients' Wards of Three Beds Room

The room area is **33.45** m^2, Consists of 2 beds for patients, and a toilet for the patients. The share of space area for each patient is **11.15** m^2.

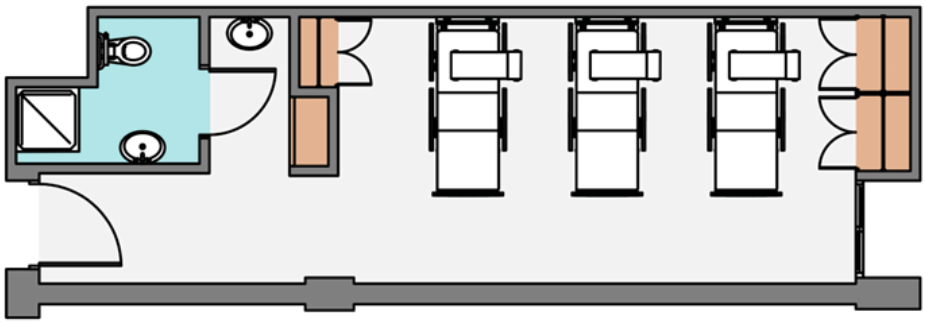

Figure 4- 47: Dar El-Fouad Hospital - Patients' Wards of Three Beds Room
Source: By Researcher

4.4. Evaluation Process of Space Layout Planning Using Algorithms

For evaluating the inpatient department of the case studies mentioned above, the evaluation workflow steps will be explained in order to formulate a framework that can be applied to any other case study or any other department in the general hospital. Each of the case studies will be evaluated on some parameters that can be grouped related to their concept principles. Also classified according to the scope of applying these concepts.

4.4.1. Definition of The Space in The Inpatient Department

In the start of the evaluation process for the inpatient department of the case studies, the space boundaries that will be analyzed must be defined based on the users and their paths in the inpatient department and the spaces that users interact directly in the floor layout.

The research focuses on the nursing units to evaluate using algorithms; the users concerned with the evaluation process are determined, and then evaluation aspects have been grouped according to the users as follows:

- **Patients:**

Spaces that are concerned with patients are the patients' rooms, which are being evaluated according to:

1. **Privacy**, measuring the visual depth to the rooms from the nursing units to the patient's bed.
2. **Safety,** measuring the visual access and medical surveillance from the nursing station to patients' rooms.
3. **View**, measuring the Visual access to the openings in the patient's room from the patient's bed.
4. **Furniture Layout**, measuring the placement of furniture in a patient's room achieving good visual connectivity between patients and their families and visitors.

- **Visitors & Patients Families:**

Spaces that are concerned with Visitors & Patients Families are the visitors Lobby, Visitors lounge, and the lobbies at which information desk are placed besides the nursing stations. Which are being evaluated according to:

1. **Wayfinding**, measuring the value of visual connectivity in the main lobbies and circulation paths and how their planning affects wayfinding for users.
2. **Accessibility**, measuring the visual access from the visitors' lobby to the information desk and nursing stations.

- **Nursing & Medical Staff**

Spaces that are concerned with nursing and medical staff are mainly the nursing station and its supporting facilities, as well as the observation of the patients' rooms and the whole department. Which are being evaluated according to:

1. **Controllability**, measuring the visual accessibility from the nursing unit to the patients' rooms entrances and the entrances to the nursing unit entrance.

Accordingly, spaces have been defined in the three case studies as an initial step for the evaluation process. Firstly, a cumulative path is defined that has been used by all of the target users mentioned above. Then, the zones will be evaluated according to the aspects and users that were used as input parameters in the evaluation process, as explained in the following:

a. H1: Dar El-Fouad Hospital

The defined path passes through the different entrances to the inpatient department, the visitors lobby, and the lounge, and the corridors pass through the patients' rooms and the nursing stations, as shown in figure (4 -48).

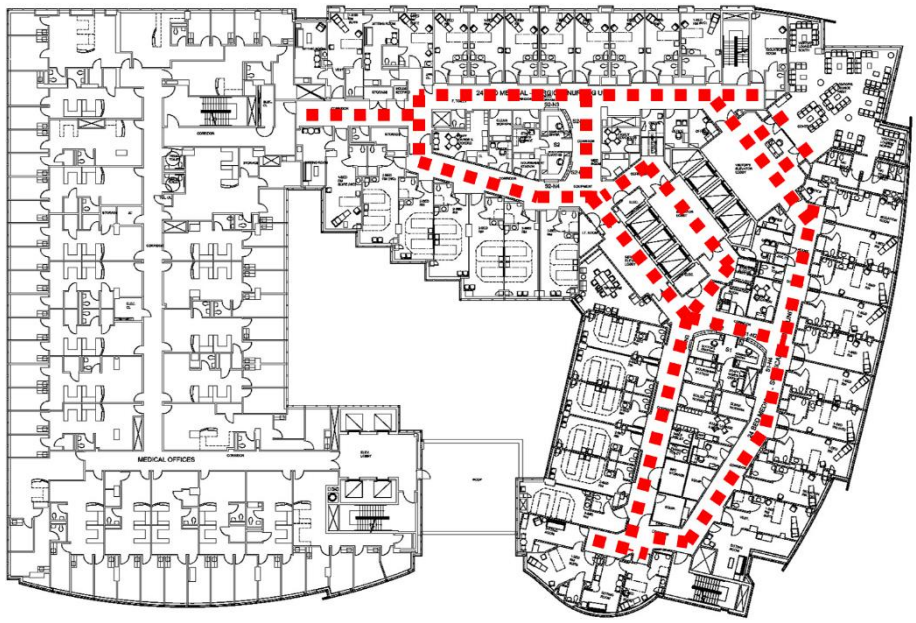

Figure 4- 48: Dar El-Fouad Hospital - Inpatient Department (Users Cumulative path)
Source: By Researcher

There are two zones to be evaluated which are the whole department floor plan and the corridors (circulation paths) connecting between departments spaces, as shown in figures (4-49) (4-50).

Figure 4- 49: Dar El-Fouad Hospital - Inpatient Department Zone 1
Source: By Researcher

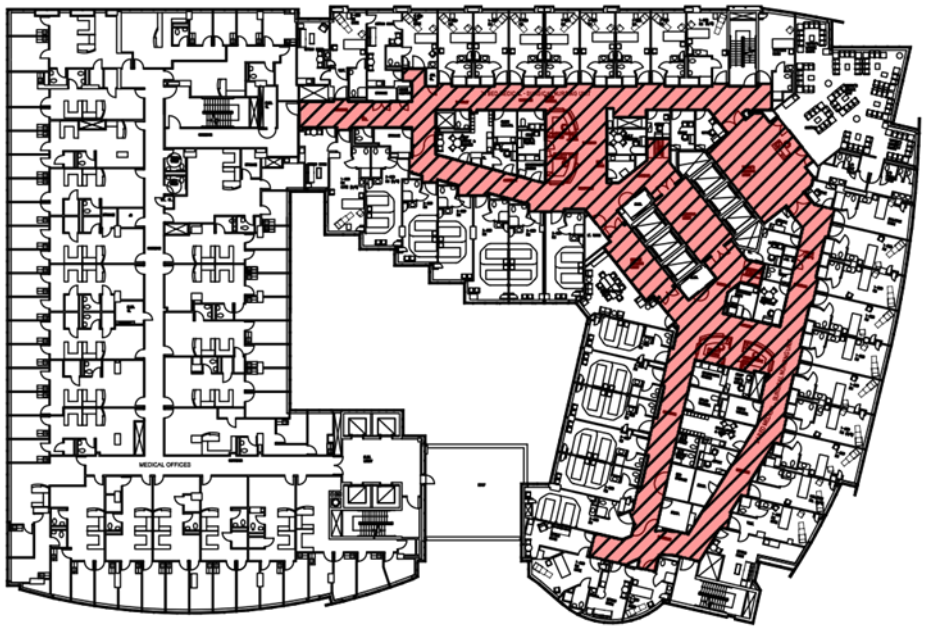

Figure 4- 50: Dar El-Fouad Hospital - Inpatient Department Zone 2
Source: By Researcher

b. H2: AS-Salam International Hospital

The defined path passes through the corridors, the patient rooms, the nursing stations, and the elevator lobby, as shown in figure (4-51).

Figure 4- 51: AS-Salam International Hospital - Inpatient Department (Users Cumulative path)
Source: By Researcher

There are two zones to be evaluated which are the whole department floor plan and the corridors (circulation paths) connecting between departments spaces, as shown in figures (4-52) (4-53).

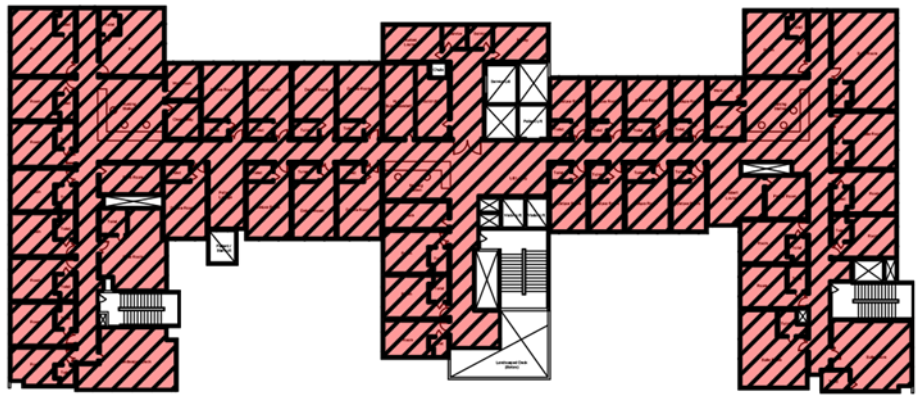

Figure 4- 52: AS-Salam International Hospital - Inpatient Department Zone 2
Source: By Researcher

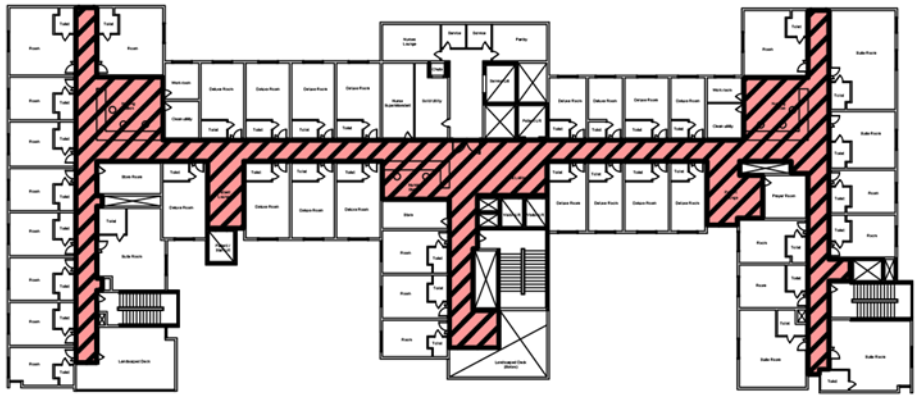

Figure 4- 53: AS-Salam International Hospital - Inpatient Department Zone 2
Source: By Researcher

c. H3: El Sheikh Zayed Al Nahyan Hospital

The defined path passes through the corridors, the patient rooms, the nursing stations, Patients Lounges, and the elevator lobby, as shown in figure (4-54).

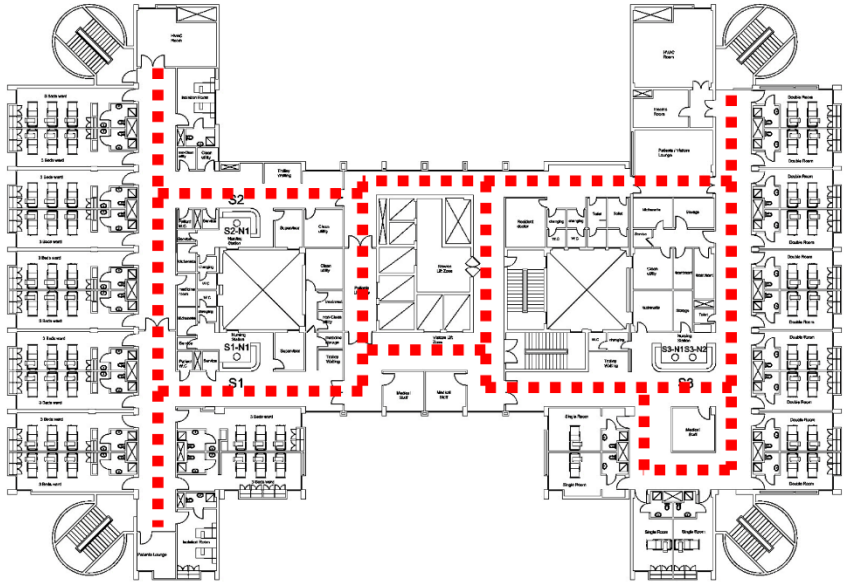

Figure 4- 54: El Sheikh Zayed Al Nahyan Hospital - Inpatient Department (Users Cumulative path)
Source: By Researcher

There are two zones to be evaluated which are the whole department floor plan and the corridors (circulation paths) connecting between departments spaces, as shown in figures (4-55) (4-56).

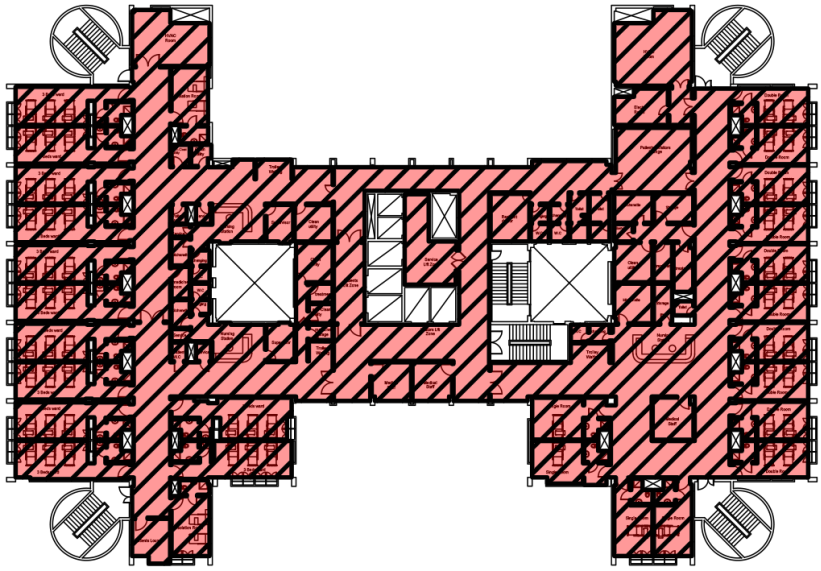

Figure 4- 55: El Sheikh Zayed Al Nahyan Hospital - Inpatient Department Zone w
Source: By Researcher

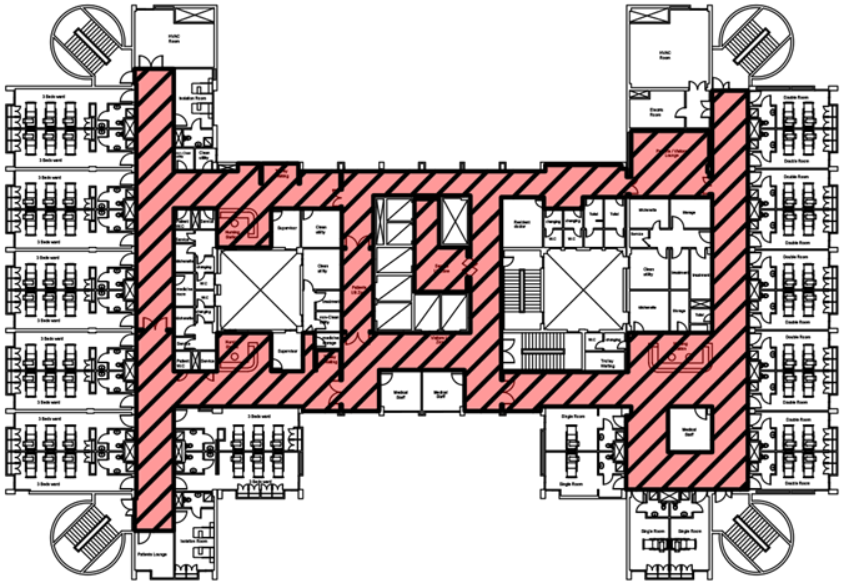

Figure 4- 56: El Sheikh Zayed Al Nahyan Hospital - Inpatient Department Zone 2
Source: By Researcher

4.4.2. Aspects of Input Parameters Used in Evaluation Process

The research focused on translating factors conducted from the previous literature review about space layout planning in hospital facilities and also evaluating factors that affect the quality of space for both patients and medical staff. The evaluation process in the research will be limited to the following factors:

i. Wayfinding

The concept of wayfinding is beyond create a good signage system and a use of color scheme referring to various zones in hospitals, the design of built components in a clear way focusing on the adjacency of spaces according to users' needs, especially for visitors and outpatients.

Accordingly, wayfinding is measured based on the visual connectivity in the floor layout, exploring the existence of vital points such as information desks and nursing stations in the most visually connected zones to help visitors with easy wayfinding.

ii. Accessibility

The accessibility will be measured according to exploring the accessibility to the information desks and nursing stations from visitors' lobby based on visibility analysis using 2D-Isovist theory.

iii. Controllability

Measuring the visual access with the concern of the layout of wards and visibility of nursing staff to the patients and visitors, as the following:

a. The placement of nursing stations in relation to rooms to ensure efficient monitoring of patients is based on visibility analysis using 2D-Isovist theory.
b. The placement of nursing stations in relation to visitors' lobby and nursing unit entrances to control the access of visitors to the inpatient department, based on visibility analysis using 2D-Isovist theory.

iv. Walkability Efficiency:

The Walkability Efficiency will be measured upon two concepts:

a. The measurement of walking distances in nursing units according to different users according to the following: the distance between nursing station and patients' rooms.
b. The measurement of the circulation surface in relation to the whole useable surface in the floor layout, Minimizing the area of circulation relative to the usable spaces in the floor layout.

v. Privacy

Measuring the visual access from the nurse station to the patients' rooms in the case of open doors for the rooms relative to patient bed exposure from the corridors to ensure the establishment of a secure physical environment that caters to the safety and well-being of patients, their relatives, and medical staff based on visibility analysis using 2D-Isovist theory.

vi. Views of Nature

The access to outdoor natural view has an impact on the satisfaction of patients in healing environments. Measuring the visual access to the outdoor environment through the openings exists in the patients' rooms relative to the patient bed, based on visibility analysis using 2D-Isovist theory.

vii. Furniture Layout

Furniture and equipment in the patients' residential environments often support their comfort and function. With the concern of the allocation of furniture in rooms affect the patient experience, Measuring the visual integration inside the room exploring how its affect the communication between the patients and the visitors or their families relative to the furniture layout, based on the visibility analysis using Isovist field theory.

According to the research scope, aspects of evaluation could be grouped according to their concern with evaluation, whether they are primary aspects related to space layout planning criteria or complementary aspects related to space quality components, or non-primary aspects related to creating a good healing environment for users, as shown in figure (4-57):

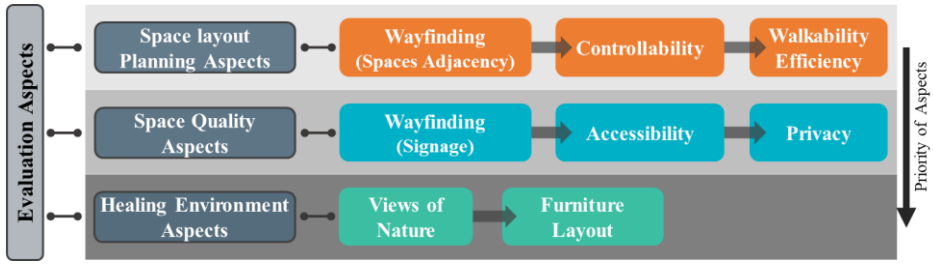

Figure 4- 57: Evaluation Aspects Priority
Source: By Researcher

4.4.3. Evaluation Process Workflow Map

For the utilization of algorithms in the evaluation of space layout planning in general hospitals. The selected aspects of evaluation and the defined spaces to be evaluated have been translated into terms of parameters to achieve values, making a comprehensive understanding of the evaluated layout configurations of the case studies as follows:

i. Wayfinding

Way finding analysis is running for measuring the adjacency of spaces within the floor plan by measuring the plan visual connectivity using isovist field analysis, where the highest values of the isovist field analysis are considered to be the more open spaces, while the least values mean the existence of adjacent spaces beside each other, as shown in figure (4-58).

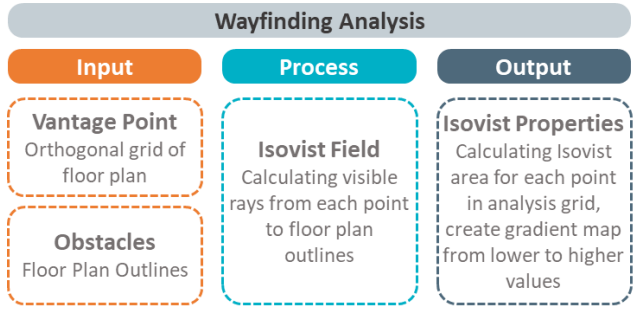

Figure 4- 58: Wayfinding Analysis Components
Source: By Researcher

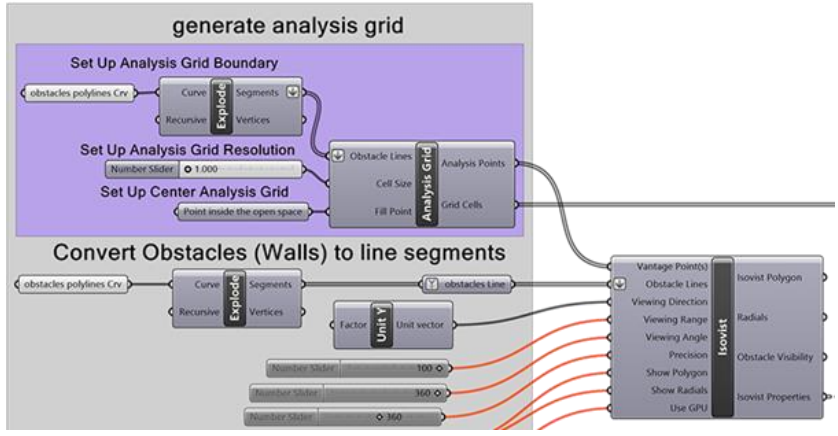

Figure 4- 59: Wayfinding Analysis Input Parameters
Source: By Researcher

ii. Accessibility

Accessibility analysis is running for measuring visual access from the inpatient department lobby to nursing unit entrances within the inpatient department by finding out the intersection of isovist rays from the observer point to the walls of nursing unit entrances, as shown in figure (4-60).

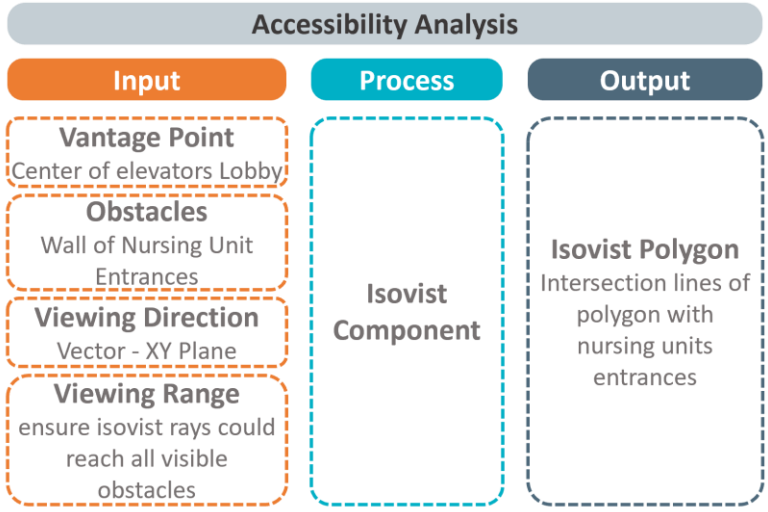

Figure 4- 60: Accessibility Analysis Components
Source: By Researcher

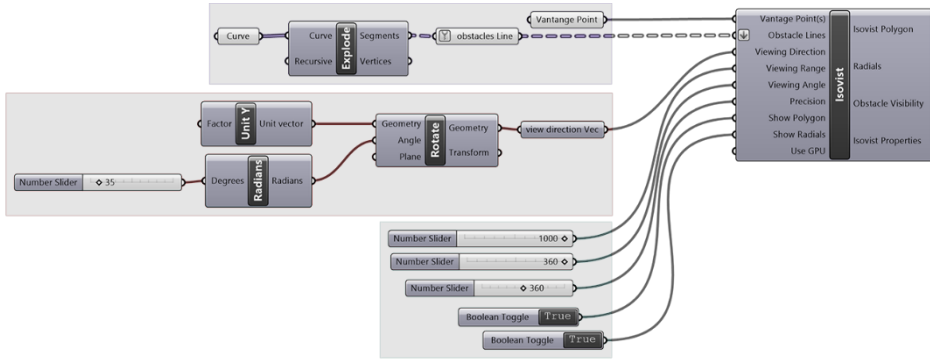

Figure 4- 61: Accessibility Analysis Input Parameters
Source: By Researcher

iii. Controllability

Accessibility analysis is running for measuring medical surveillance from nursing stations to patients rooms by finding out the intersection of isovist rays from a vantage point, which is considered the seats of nursing staff inside nursing stations with the patients rooms entrances, and the intersection of the same isovist rays with nursing unit entrances for the sake of control of medical staff to the nursing unit, as shown in figure (4-62).

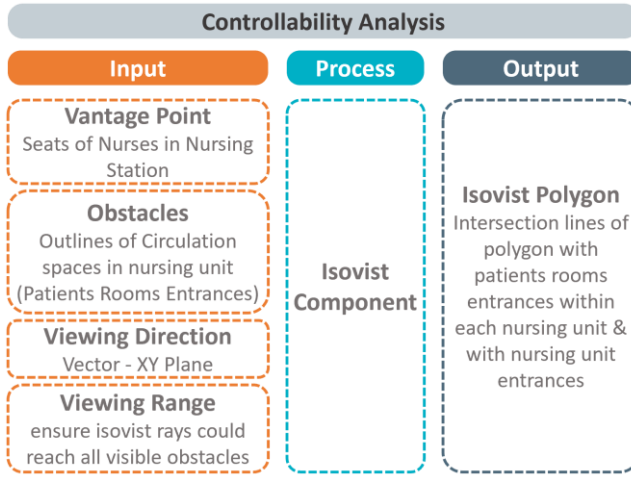

Figure 4- 62: Controllability Analysis Components
Source: By Researcher

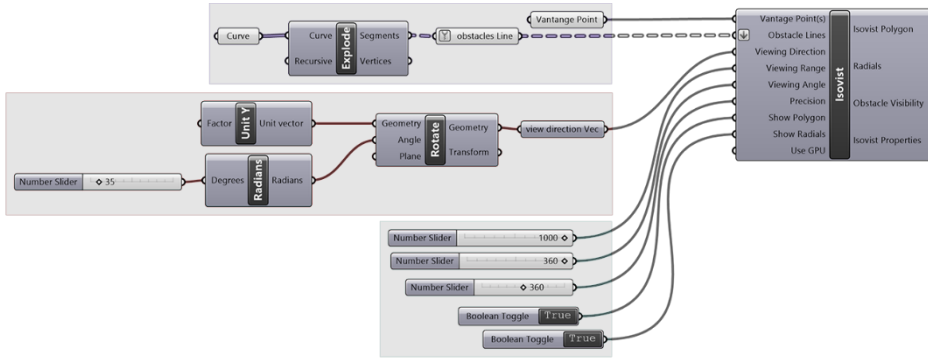

Figure 4- 63: Controllability Analysis Input Parameters
Source: By Researcher

iv. Walkability Efficiency:

Walkability efficiency has been measured by two different methods. The first method is walking distances from nursing stations to all patient rooms within the nursing unit. The other method is by calculating the circulation area ratio to the whole floor plan area, as shown in figure (4-64).

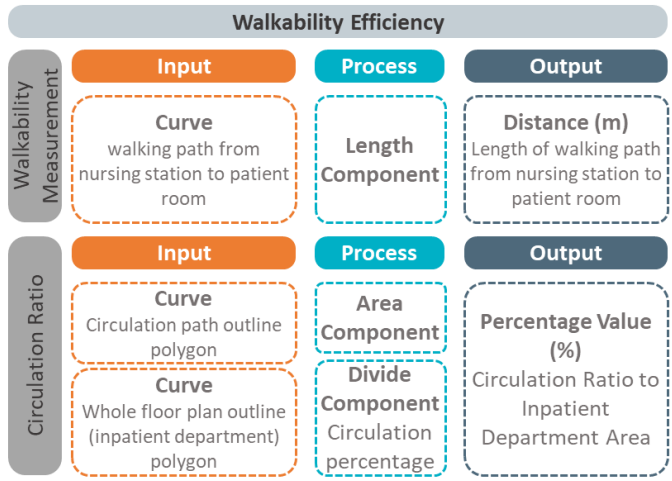

Figure 4- 64: Walkability Efficiency Analysis Components
Source: By Researcher

v. Privacy

Privacy analysis is run to measure the sense of privacy of patients in their rooms from nursing stations, which are commonly considered to be the most crowded point within the nursing unit, by finding out the intersection of isovist rays from the vantage point, which is considered a nursing station, to the patient's rooms in the case of open doors, as shown in figure (4-65).

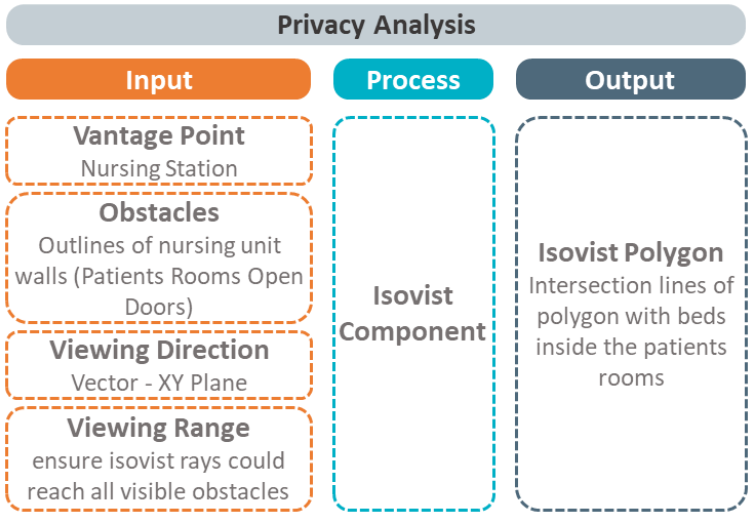

Figure 4- 65: Privacy Efficiency Analysis Components
Source: By Researcher

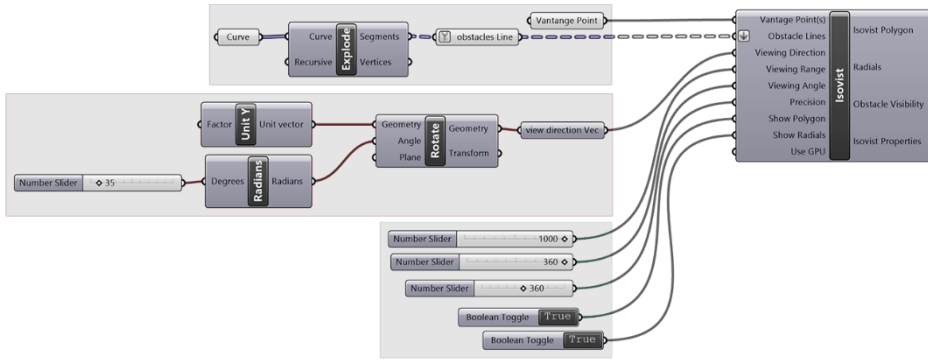

Figure 4- 66: Privacy Analysis Input Parameters
Source: By Researcher

vi. Views of Nature

The analysis of the view to the outdoors from the patient's room is run within the boundaries of the room, measuring the visual access by finding out the intersection of the isovist polygon with the outdoors windows from the vantage point, which is considered from the patient's head, as shown in figure (4-67).

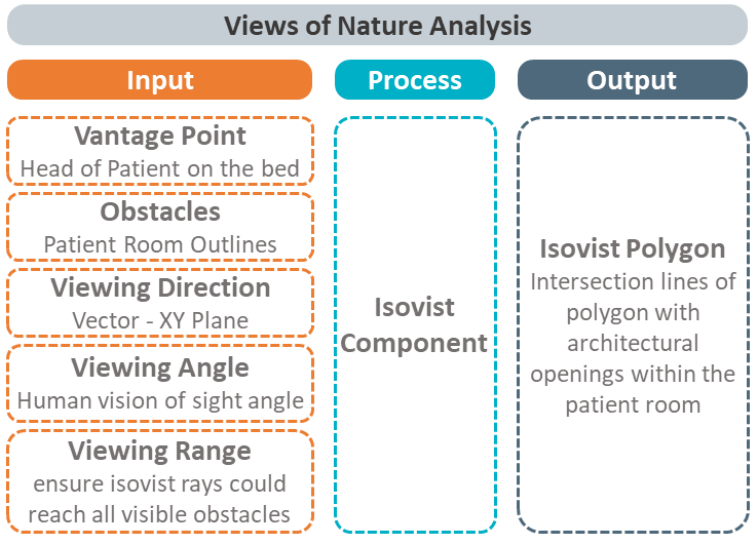

Figure 4- 67: Views of Nature Analysis Components
Source: By Researcher

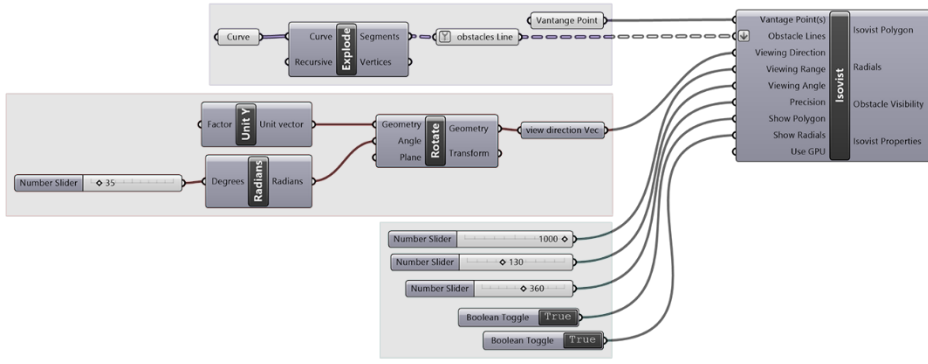

Figure 4- 68: Views of Nature Analysis Input Parameters
Source: By Researcher

vii. Furniture Layout

Furniture Way finding analysis is running for measuring the interaction between patient bed and furniture existed in room for patient's family, also for measuring good visual connectivity between patient bed and room door for the ease of medical observation from the patient room entrance, as shown in figure (4-69).

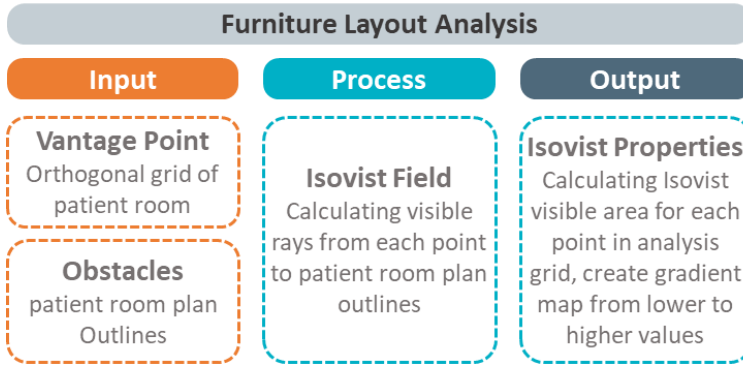

Figure 4- 69: Furniture Layout Analysis Components
Source: By Researcher

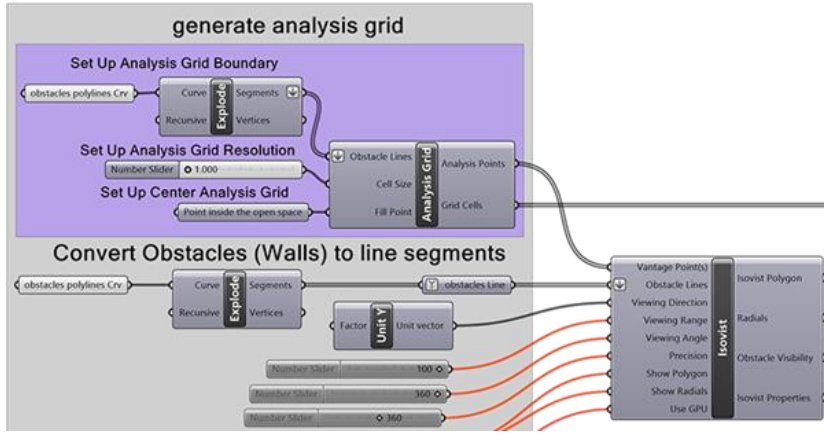

Figure 4- 70: Furniture Layout Analysis Input Parameters
Source: By Researcher

The following figure (4-71) shows the Evaluation Process workflow to evaluate the inpatient department according to previously explained factors that affected the evaluation Process.

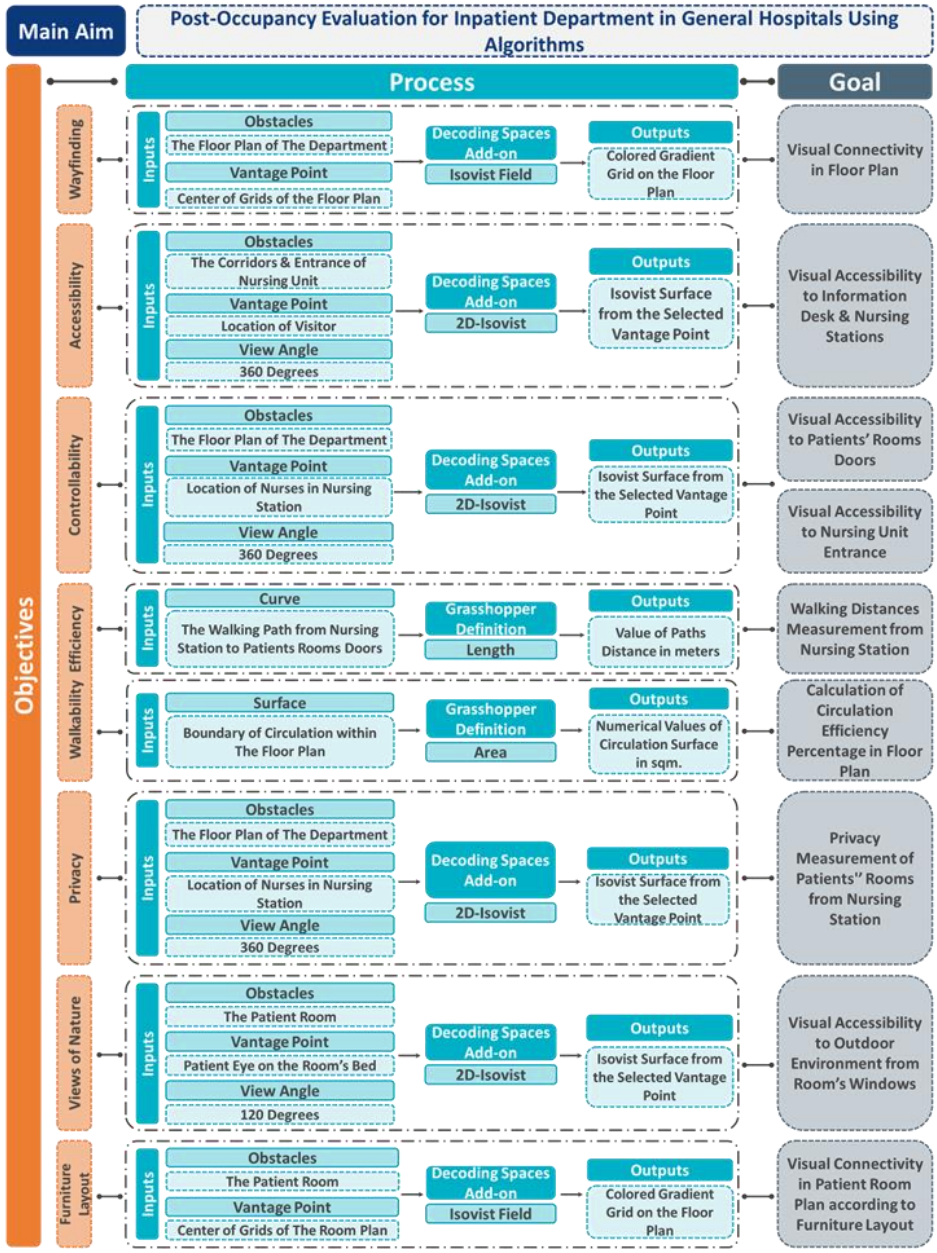

Figure 4- 71: Evaluation Process Workflow Map
Source: By Researcher

4.5. Applying Algorithms in Evaluation of Space Layout Planning

Initially, an abbreviation for the case studies has been established, with the corresponding layout and configuration characteristics, as presented in the following table:

Table 5: Case studies Research Settings

Abbreviation	Hospital Name	Nursing Unit Configuration
H1	Dar El-Fouad Hospital	Centralized Nursing Station (Double Corridor)
H2	As-Salam International Hospital	Decentralized Nursing Station (Double Corridor)
H3	El Sheikh Zayed Al Nahyan Hospital	Decentralized Nursing Station (Single Corridor)

4.5.1.1. Wayfinding Analysis

A 2D Isovist Field analysis generated using Decoding Spaces Software, which is a Grasshopper Add-on linked with Rhino, is applied to the three case studies inpatient department floor plans, as shown in the following figure (4-72).

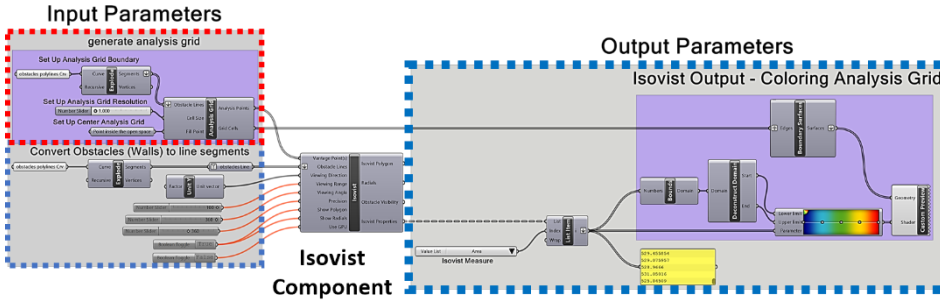

Figure 4- 72: Isovist field Grasshopper Definition Using Decodingspaces Software
Source: By Researcher

The analysis is based on dividing the floor plan into a grid of points and calculating the visibility of each point to all other points and to the obstacles found in the plan, which are the architectural elements such as walls, columns, and the external silhouette of the building. The more adjacent points see each other, the more visual connectivity is achieved, which means that the space is more connected and easier to access for different users. The analysis result is defined in a gradient color scheme from blue to red, where the red color points have the highest values and the blue color points have the lowest values.

- **H1: Dar El-Fouad Hospital**

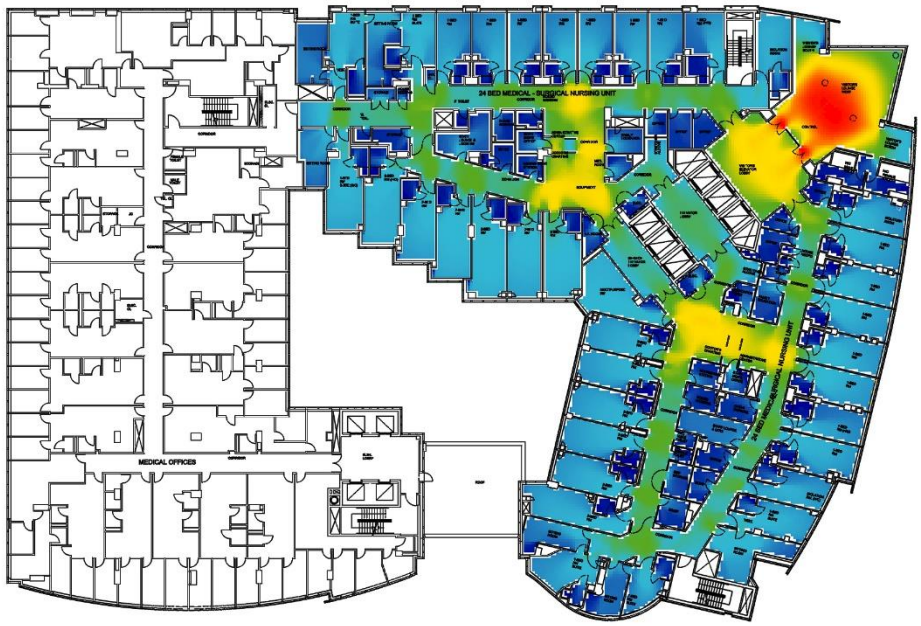

Figure 4- 73: H1 - Isovist field Analysis for Wayfinding
Source: By Researcher

For **H1: Dar El-Fouad Hospital**, as shown in figure (4-73) A higher level of visual connectivity exists in the visitor's lounge. Followed by good visual connectivity in the visitor's reception and lobby, also in the lobbies of each nursing unit in front of the nursing stations, and with direct connectivity to the patients and medical staff's lobby. While the corridors seem also to have good visual connectivity from distribution lobbies.

The inpatient department has a good way of finding behavior for all users, as the allocation of the information desk for visitors' guidance is placed in the most visually connected zone and is easy to find.

- **H2: AS-Salam International Hospital**

Figure 4- 74: H2 - Isovist field Analysis for Wayfinding
Source: By Researcher

For **H2: AS-Salam International Hospital**, as shown in figure (4-74) the inpatient department has a poor value of visual connectivity except for the intersection between corridors that indicates a bad behavior of way finding for users in the department, however the placement of the nursing stations in the zones that have a good visual connectivity value may help to control the accessibility to the patients rooms.

- **H3: El Sheikh Zayed Al Nahyan Hospital**

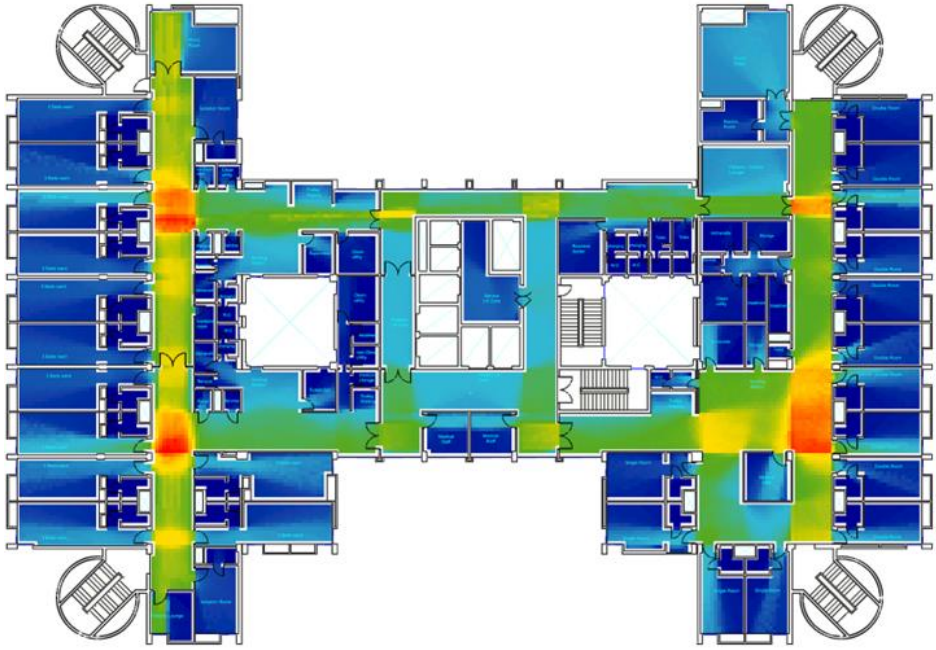

Figure 4- 75: H3 - Isovist field Analysis for Wayfinding
Source: By Researcher

For **H3: El Sheikh Zayed Al Nahyan Hospital**, as shown in figure (4-75) the visual connectivity values are low in the entrances of the inpatient department and in front of two nursing stations out of the existing three stations. Followed by good visual connectivity in front of one nursing station, while the corridors seem also to have good visual connectivity from distribution lobbies, which impacts the behavior of wayfinding within the department layout in a negative manner due to the Divergent allocation of nursing stations that also act as information desks for visitors from the elevators lobby.

4.5.1.2. Accessibility

An 2D Isovist from a vantage point analysis generated using Decoding Spaces Software, which is a Grasshopper Add-on linked with Rhino for measuring the visual access from the visitor's lobby to both of nursing stations and information desks, is applied to the three case studies inpatient department floor plans, as shown in the following figure (4-76).

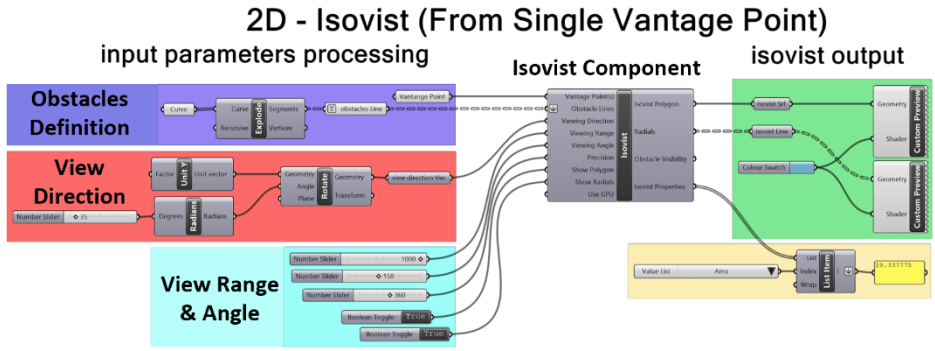

Figure 4- 76: 2D - Isovist Grasshopper Definition Using Decodingspaces Software
Source: By Researcher

- **H1: Dar El-Fouad Hospital**

Figure 4- 77: H1-2D Isovist Analysis for Accessibility
Source: By Researcher

For **H1: Dar El-Fouad Hospital**, as shown in figure (4-77), the visitors lobby is a closed space with an information desk and visitors lounge connected directly to the nursing unit entrances. Despite the proximity of these spaces, there is no visual access from the visitors' lobby entrance to the nursing units, which affects the guidance of visitors in the nursing units to find their intended destination in a bad manner.

- **H2: AS-Salam International Hospital**

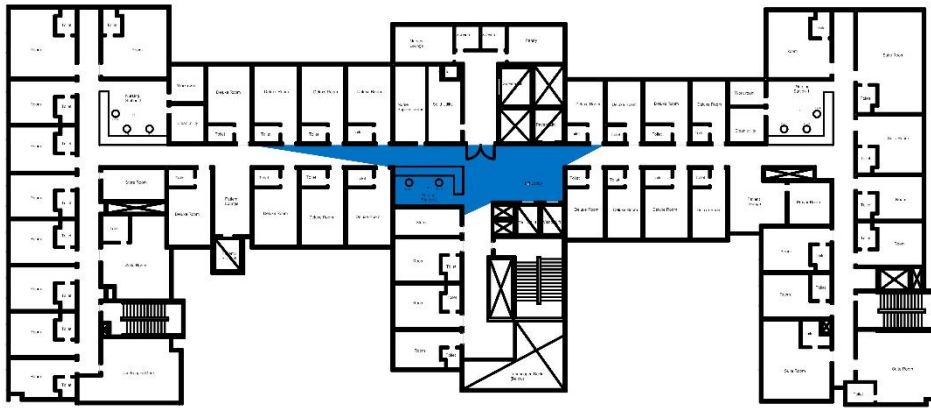

Figure 4- 78: H2-2D Isovist Analysis for Accessibility
Source: By Researcher

For **H2: AS-Salam International Hospital**, as shown in figure (4-78), the visitors lobby is an open space lobby in front of visitors' elevators with a nursing station that also acts as an information desk allocated in the same lobby; therefore, there is a visual access from the visitors' lobby entrance to the nursing units guiding the visitors inside the department.

- **H3: El-Sheikh Zayed Al Nahyan Hospital**

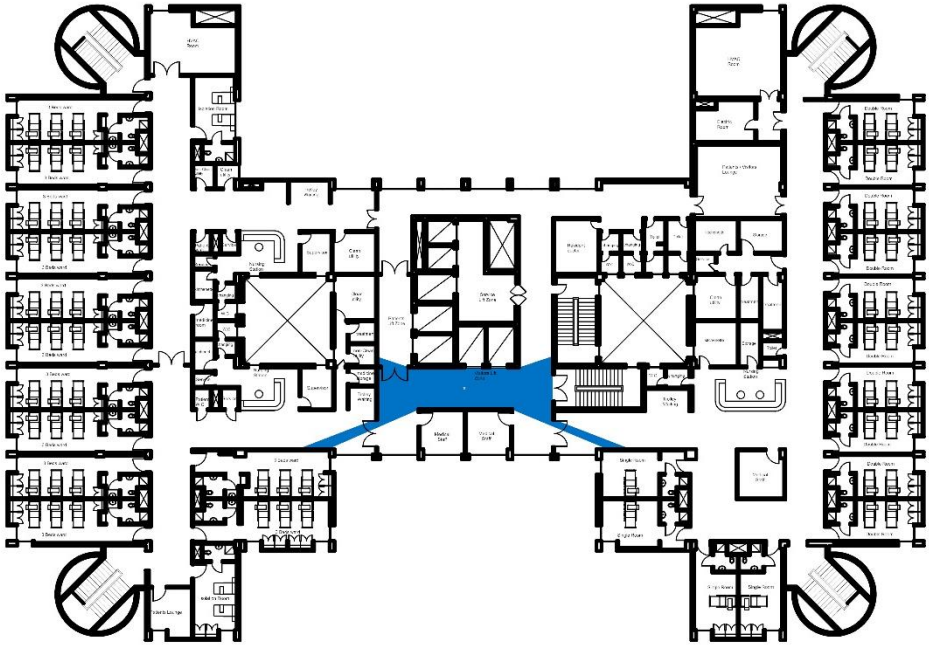

Figure 4- 79: H2-2D Isovist Analysis for Accessibility
Source: By Researcher

For **H3: El-Sheikh Zayed Al Nahyan Hospital**, as shown in figure (4-79), the visitors lobby is an open-space lobby without any information desk and connected directly to the nursing unit entrances. Despite the proximity of the lobby to nursing unit entrances, there is no visual access from the visitors' lobby nursing stations that will be a vital point for the visitor's guidance inside the department, which affects the guidance of visitors in the nursing units to find their intended destination in a bad manner.

4.5.1.3. Controllability

An 2D Isovist from a vantage point analysis generated using Decoding Spaces Software, which is a Grasshopper Add-on linked with Rhino for measuring the visual access from the nursing stations to patients' rooms entrances targeting for full observation to all rooms, is applied to the three case studies inpatient department floor plans, as shown in the following figure (4-80).

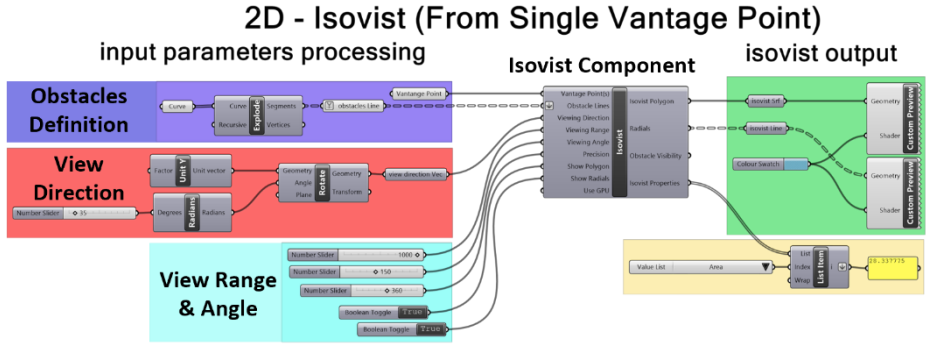

Figure 4- 80: 2D - Isovist Grasshopper Definition Using Decodingspaces Software
Source: By Researcher

For a precise measurement, the analysis was conducted from each nurse's location in the nursing stations for each nursing unit, calculating the number of patients' rooms that have direct visual accessibility from the nursing stations.

- **H1: Dar El-Fouad Hospital**

For **H1: Dar El-Fouad Hospital**, as shown in figure (4-81) (4-82):

1. Nursing Unit 1: **6 rooms** are observed from **18 rooms**, with a percentage of **33.33%**.
2. Nursing Unit 2: **7 rooms** are observed from **18 rooms**, with a percentage of **38.88%**.

Also, Both of the nursing stations has good visual access to the patients' elevator lobby and service elevator lobby entrances but has no access to the visitors' lobby entrance.

Figure 4- 81: H1-2D Isovist Analysis for Controllability (Nursing Unit 1)
Source: By Researcher

Figure 4- 82: H1-2D Isovist Analysis for Controllability (Nursing Unit 2)
Source: By Researcher

- **H2: AS-Salam International Hospital**

For **H2: AS-Salam International Hospital**, as shown in figure (4-83) (4-84) (4-85):

1. Nursing Unit 1: **4 rooms** are observed from **10 rooms**, with a percentage of **40%**.
2. Nursing Unit 2: **6 rooms** are observed from **19 rooms**, with a percentage of **31.57**%.
3. Nursing Unit 3: **4 rooms** are observed from **9 rooms**, with a percentage of **44.44**%.

also, The Nursing units has good visual access to all nursing units entrances from elevators lobbies, except for service elevator from nursing unit 3.

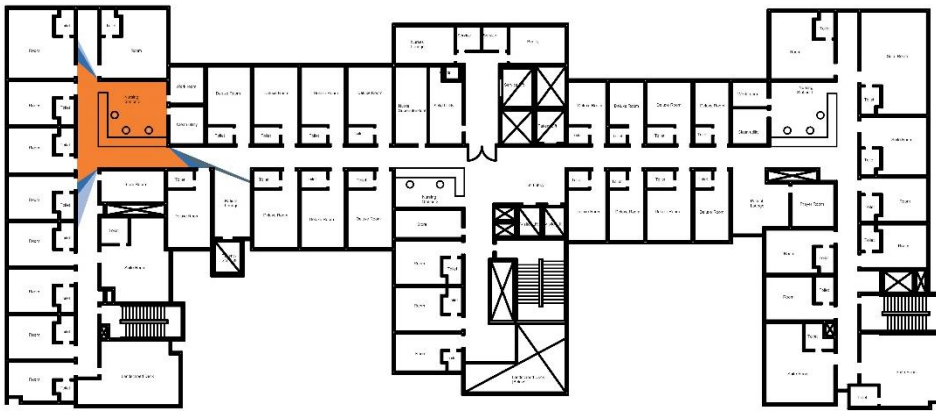

Figure 4- 83: H2-2D Isovist Analysis for Controllability (Nursing Unit 1)
Source: By Researcher

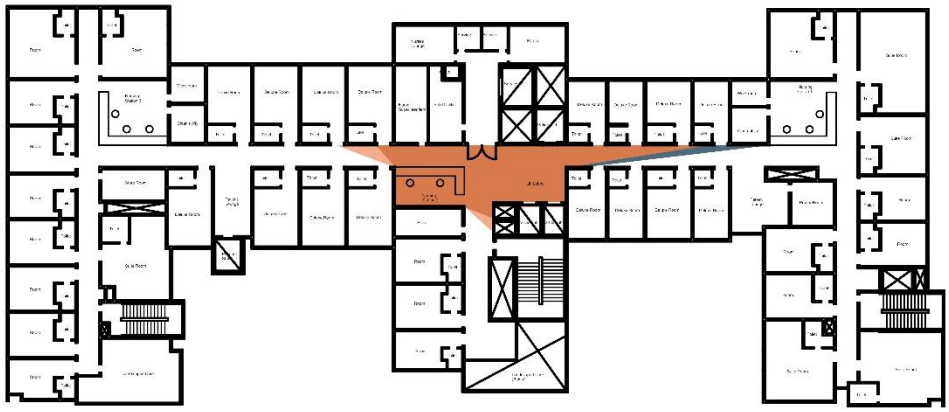

Figure 4- 84: H2-2D Isovist Analysis for Controllability (Nursing Unit 2)
Source: By Researcher

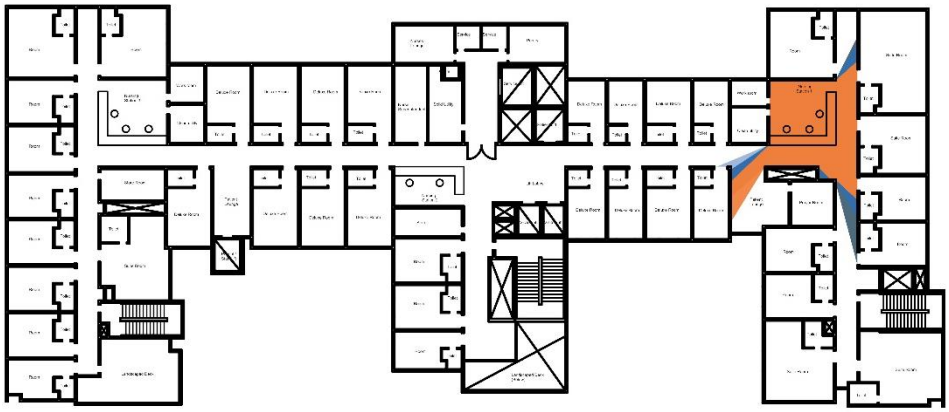

Figure 4- 85: H2-2D Isovist Analysis for Controllability (Nursing Unit 3)
Source: By Researcher

- **H3: El-Sheikh Zayed Al Nahyan Hospital**

For **H2: AS-Salam International Hospital**, as shown in figure (4-86):

1. Nursing Unit 1: **Zero rooms** are observed from **7 rooms**, with a percentage of **0%**.
2. Nursing Unit 2: **Zero rooms** are observed from **7 rooms**, with a percentage of **0%**.
3. Nursing Unit 3: **8 rooms** are observed from **14 rooms**, with a percentage of **57.14**%.

Nursing stations have good visual access for the nursing units entrance as all of the nursing units, but there is no controllability over elevators lobbies as there is no information desk in front of any of them to view the entry to the inpatient department.

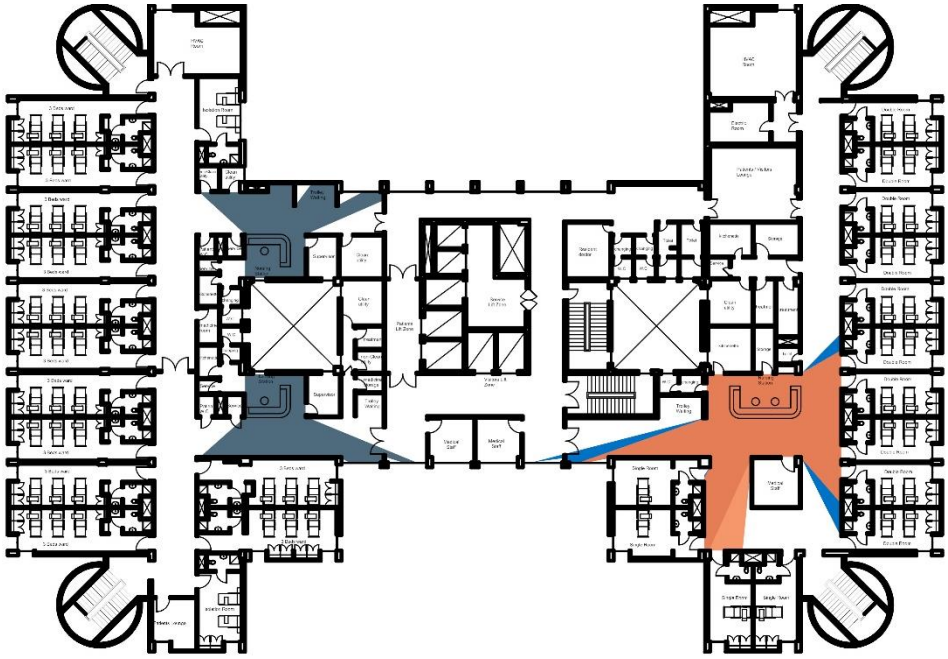

Figure 4- 86: H3-2D Isovist Analysis for Controllability (All Nursing Units)
Source: By Researcher

4.5.1.4. Walkability Efficiency

a. Walkability Measurement

Using a grasshopper definition for measuring the walking distances from nursing stations to the patients' rooms, explore how the layout configuration affects the distance between them based on allocation of nursing units as a starting point of nursing staff movement to the patients' rooms., as shown in the following figure (4-87).

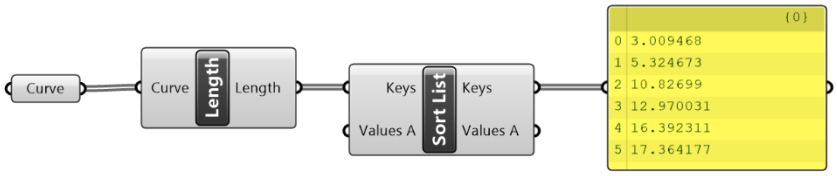

Figure 4- 87: Walking Distances Measurements Using Grasshopper
Source: By Researcher

The walking path is defined as a path between starting and ending points; the starting point is specified from the midpoint of the entrance to the counter of the nursing station, and the ending point is the center of each door of the patients' rooms. The walking path is drawn in the center of the corridors of the nursing unit to get the most precise values possible, taking in consideration all possible rooms pass through this path.

- **H1: Dar El-Fouad Hospital**

Figure 4- 88: H1-Walking paths Definition Analysis for Accessibility
Source: By Researcher

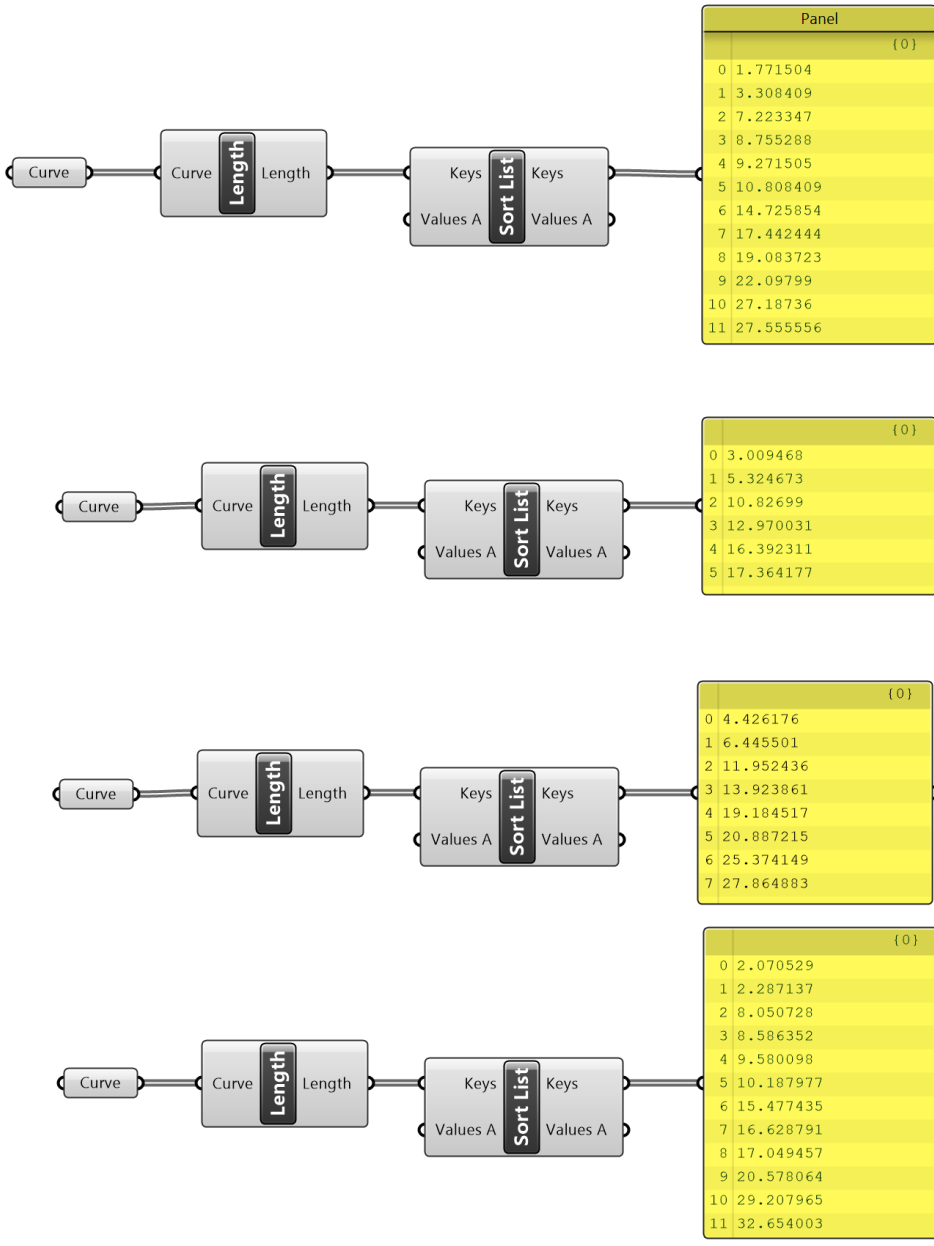

Figure 4- 89: H1-Walking paths Measurement Analysis for Accessibility
Source: By Researcher

The nursing stations consist of four counters for nurses which are defined as a starting point for walking paths to the rooms facing each counter side, as shown in figure (4-88).

Then measure the walking distances in meters as referred in figure (4-89), exploring the minimum and maximum walking distance in each counter.

Table 6: H1 - Walking Distances Measurements

Walking Distance	Nursing Unit 1		Nursing Unit 2	
	N1-S1 (m)	N1-S2 (m)	N1-S1 (m)	N2-S2 (m)
Minimum	1.77	3.00	4.42	2.07
Maximum	27.55	17.36	27.86	32.65
Average	14.09	11.00	16.25	14.35

- **H2: As-Salam International Hospital**

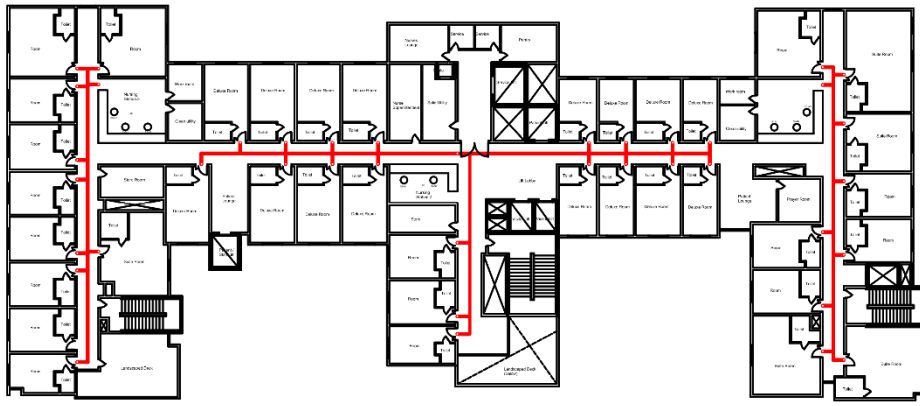

Figure 4- 90: H2-Walking paths Definition Analysis for Accessibility
Source: By Researcher

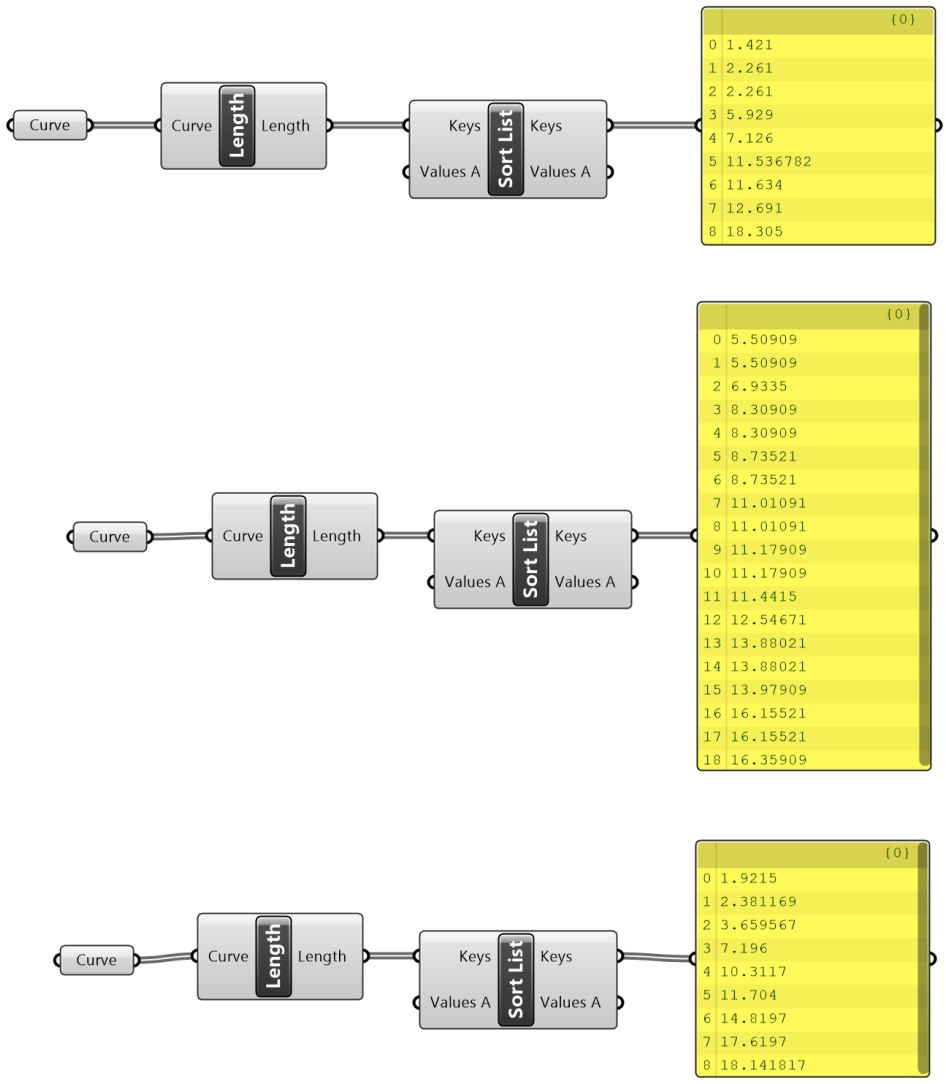

Figure 4- 91: H2-Walking paths Measurement Analysis for Accessibility
Source: By Researcher

The nursing stations consist of three counters for nurses which are defined as a starting point for walking paths to the rooms facing each counter side, as shown in figure (4-90).

Then define the walking distances in meters as referred in figure (4-91), exploring the minimum and maximum walking distance in each counter.

Table 7: H2 - Walking Distances Measurements

Walking Distance	Nursing Unit 1 (m)	Nursing Unit 2 (m)	Nursing Unit 3 (m)
Minimum	1.42	5.50	1.92
Maximum	18.30	16.35	18.14
Average	8.12	10.29	11.39

- **H3: El-Sheikh Zayed Al Nahyan Hospital**

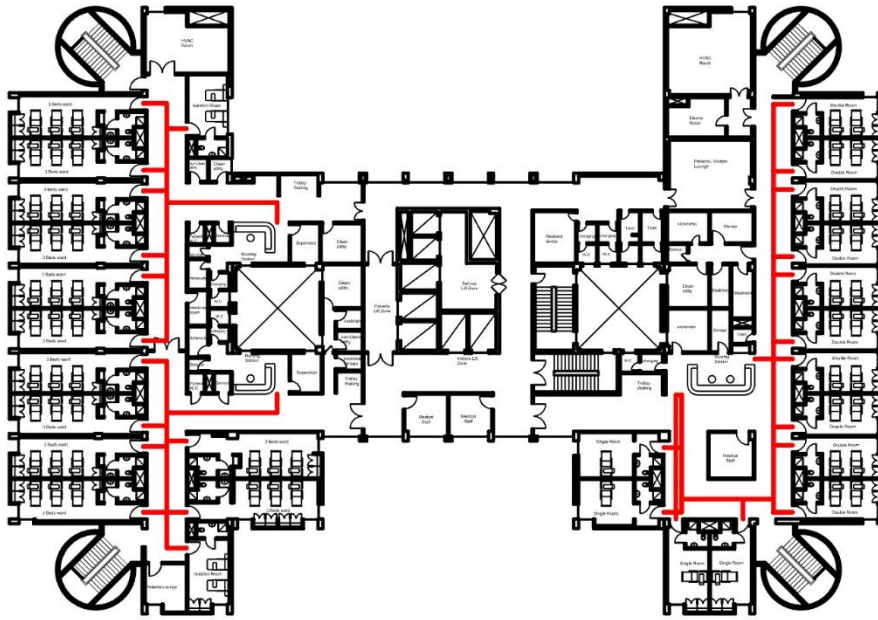

Figure 4- 92: H3-Walking paths Definition Analysis for Accessibility
Source: By Researcher

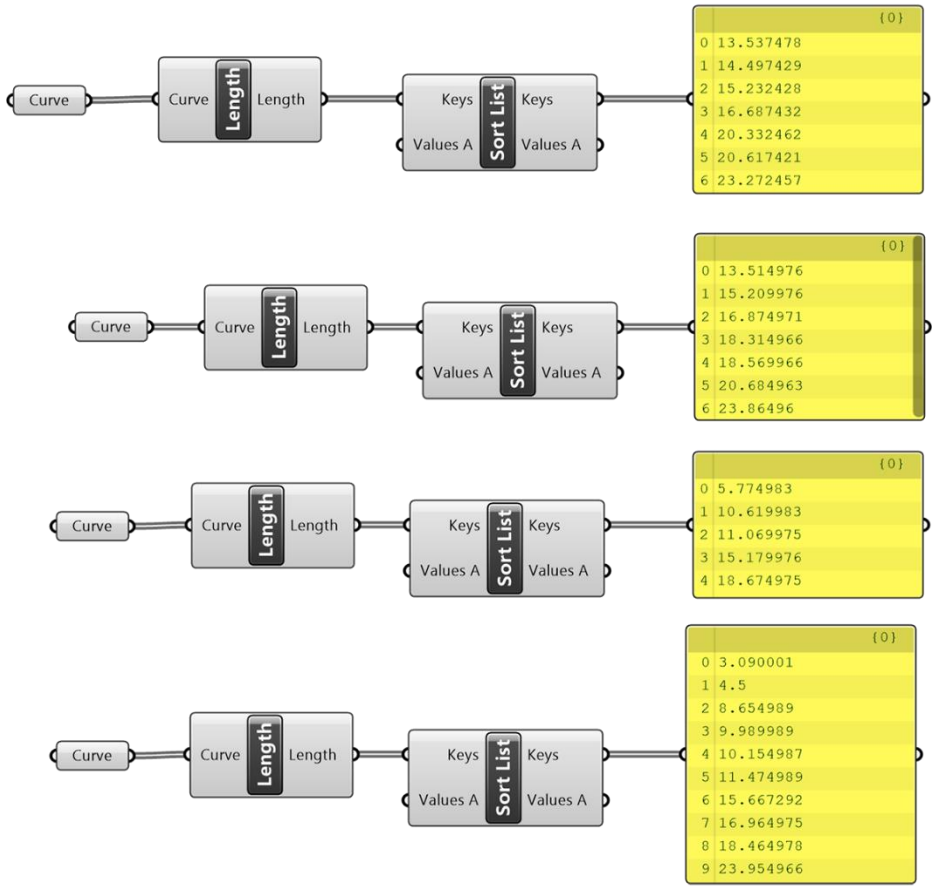

Figure 4- 93: H3-Walking paths Measurement Analysis for Accessibility
Source: By Researcher

The nursing stations consists of three counters for nurses which are defined as a starting point for walking paths to the rooms facing each counter side, as shown in figure (4-92).

Then define the walking distances in meters as referred to in figure (4-93), exploring the minimum and maximum walking distance in each counter.

Table 8: H3 - Walking Distances Measurements

Walking Distance	Nursing Unit 1 (m)	Nursing Unit 2 (m)	Nursing Unit 3 (m)	
			N3-S1	N3-S2
Minimum	13.53	13.50	5.77	3.09
Maximum	23.27	23.86	18.67	23.95
Average	17.77	18.14	12.25	12.28

As a conclusion for all case studies:

Among the three cases, H2 has the lowest values in walking distances for nursing staff from nursing stations to patients' rooms. In comparison to the two hospitals that share the same layout configuration, which are H2 and H3, H2 has the higher number of rooms, which are 38 rooms, relative to H3, which has only 28 rooms, which indicates that the allocation of the nursing stations in H2 is better than H3. As referred to in the following table:

Table 9: Walking Distances Measurements in All Case Studies

Walking Distance	H1	H2	H3
Minimum	1.77	1.45	3.09
Maximum	32.65	18.30	23.95

b. Circulation Usable Ratio:

A grasshopper definition is used for measuring the circulation surface in relation to the whole useable surface in the floor layout in the three case studies ignoring vertical circulation areas from calculations to focus on efficient areas used by target users in the inpatient department.

Among the three case studies, **H2: As-Salam International Hospital** has the lowest percentage of circulation ratio which indicates to be the most efficient layout configuration taking in consideration it has the highest number of rooms.

Comparing the two case studies **(H2 & H3)** which have the same decentralized layout configuration with each other, also **H2** have the more efficient layout configuration.

The following table and figures show the efficiency analysis for each case study:

Table 10: All Case Studies - Circulation Ratio

Case Study	Total No. of Rooms	Total Floor Area (m^2)	Circulation Paths Area (m^2)	Circulation Ratio (%)
H1	36	2403.40	717.55	29.85
H2	38	792.45	213.40	26.90
H3	28	1856.20	745.20	40.15

- **H1: Dar El-Fouad Hospital**

Figure 4- 94: H1-EfficienctyAnalysis
Source: By Researcher

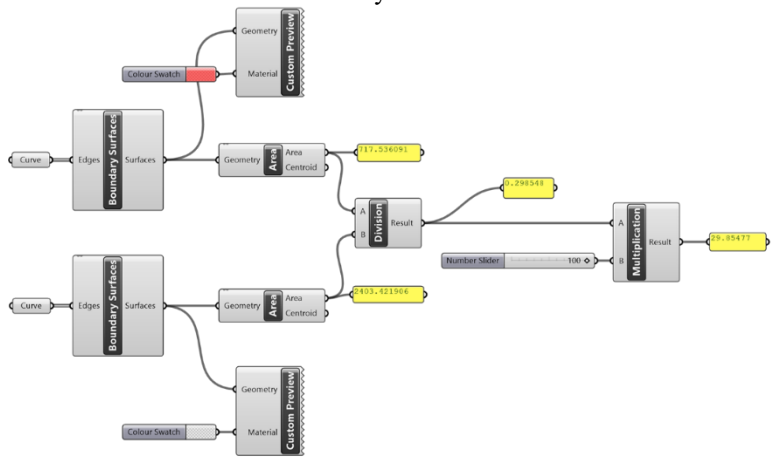

Figure 4- 95: H1 - Grasshopper Definition for Circulation Efficiency Ratio
Source: By Researcher

- **H2: As-Salam International Hospital**

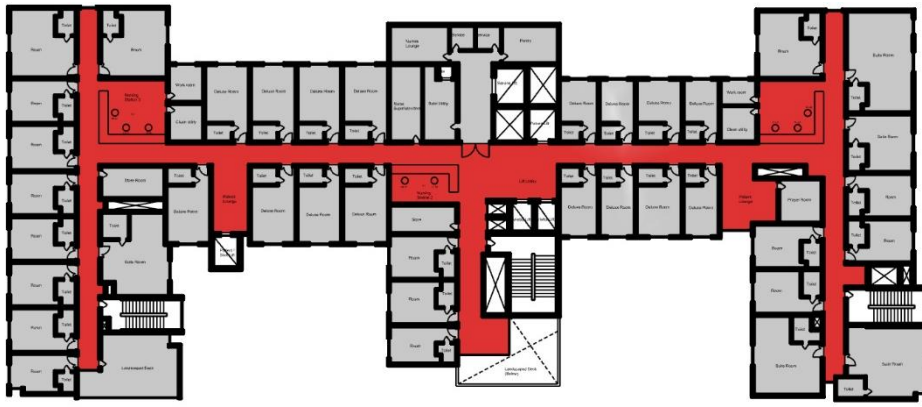

Figure 4- 96: H2-EfficienctyAnalysis
Source: By Researcher

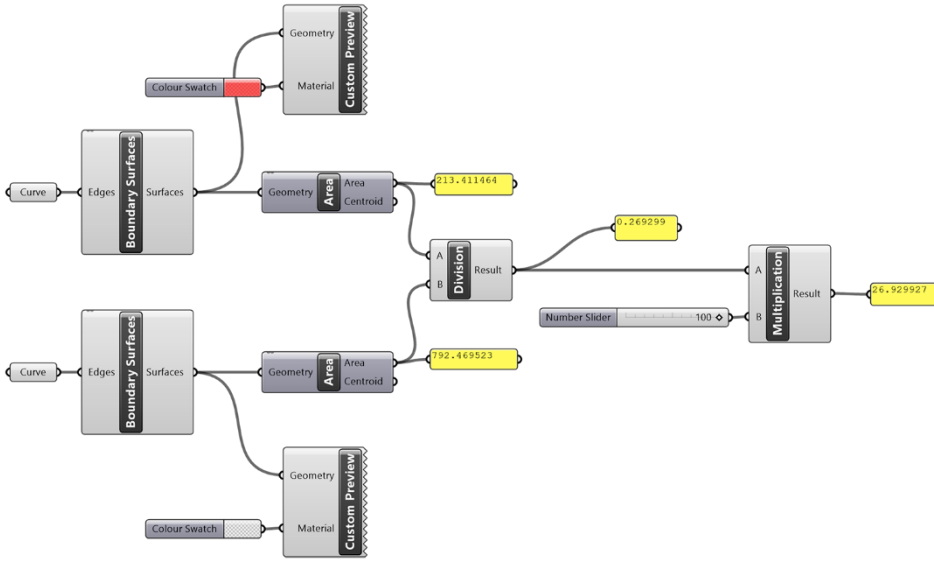

Figure 4- 97: H2 - Grasshopper Definition for Circulation Efficiency Ratio
Source: By Researcher

- **H3: El-Sheikh Zayed Al Nahyan Hospital**

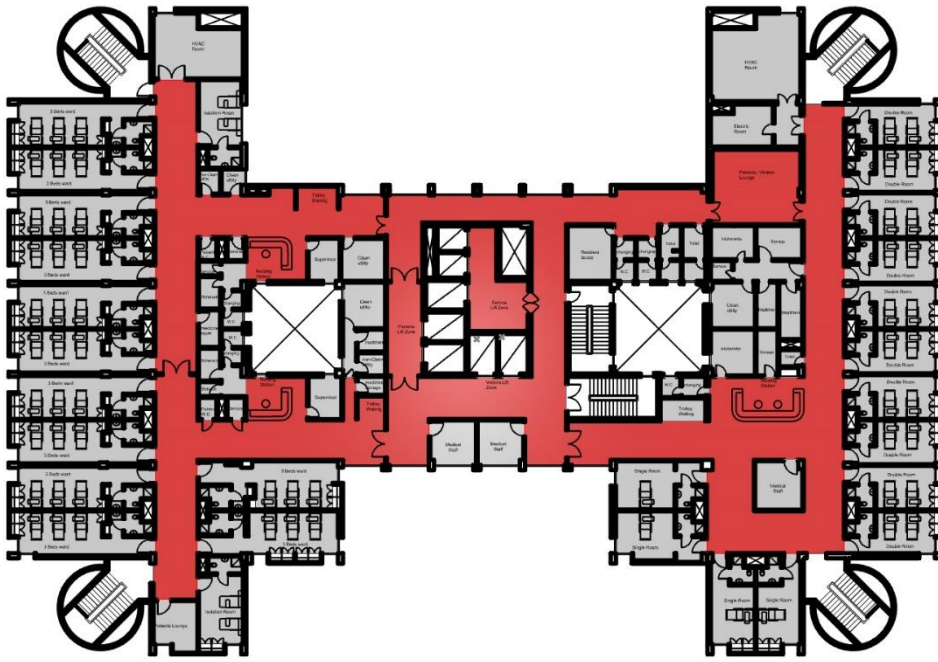

Figure 4- 98: H3-EfficienctyAnalysis
Source: By Researcher

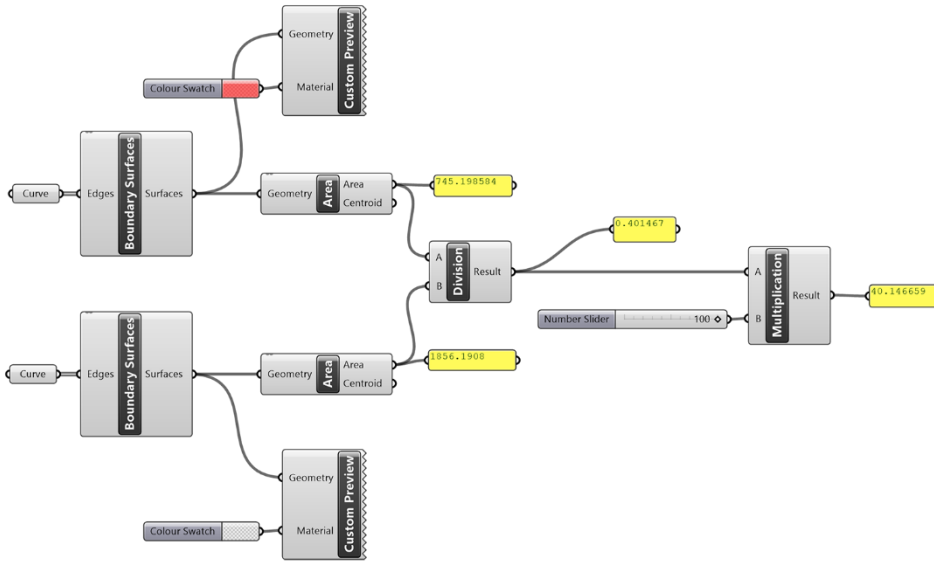

Figure 4- 99: H3 - Grasshopper Definition for Circulation Efficiency Ratio
Source: By Researcher

4.5.1.5. Privacy

An 2D Isovist from a vantage point analysis generated using Decoding Spaces Software, which is a Grasshopper Add-on linked with Rhino for measuring the visual access from the nursing stations to patients' rooms in case of open doors rooms, targeting exploring how privacy of patients is affected by the location of the nursing station that is normally the starting point of movement inside the nursing unit and the location of the patient's bed, as shown in the following figure (4-100).

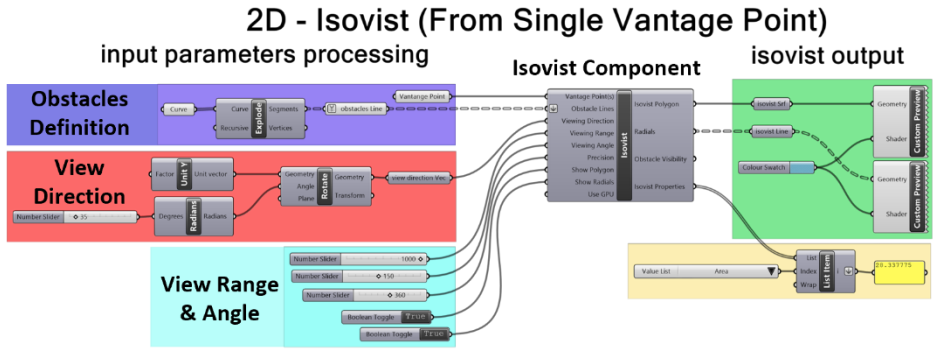

Figure 4- 100: 2D - Isovist Grasshopper Definition Using Decodingspaces Software
Source: By Researcher

- **H1: Dar El-Fouad Hospital**

Figure 4- 101: H1-2D Isovist Analysis for Privacy
Source: By Researcher

For **H1: Dar El-Fouad Hospital**, only in **three rooms** in both of the two nursing units could the patient bed be seen from the nursing stations, compared to **36 rooms** in the total, **which indicates a high percentage of a private environment in the nursing units**, as shown in figure (4-101).

- **H3: El-Sheikh Zayed Al Nahyan Hospital**

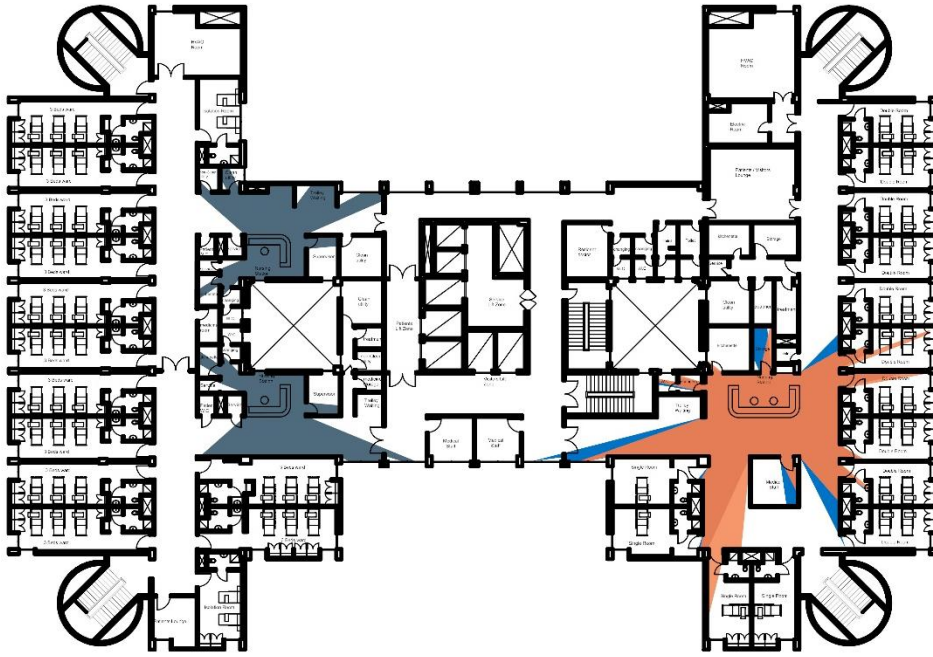

Figure 4- 102: H3-2D Isovist Analysis for Privacy
Source: By Researcher

For **H3: El-Sheikh Zayed Al Nahyan Hospital**, only **one room** in all nursing units could the patient bed be seen from the nursing stations, compared to **28 rooms** in the total, **which indicates nearly a full private environment in the nursing units**, as shown in figure (4-102).

4.5.1.6. Views of Nature

A 2D Isovist from a vantage point analysis generated using Decoding Spaces Software, which is a Grasshopper Add-on linked with Rhino for measuring the visual access to the outdoor environment through the openings in patients' rooms. The patients' rooms were studies with its different typologies, measuring the visual area included from the patient head in the bed for each room typology, as shown in the following figure (4-103).

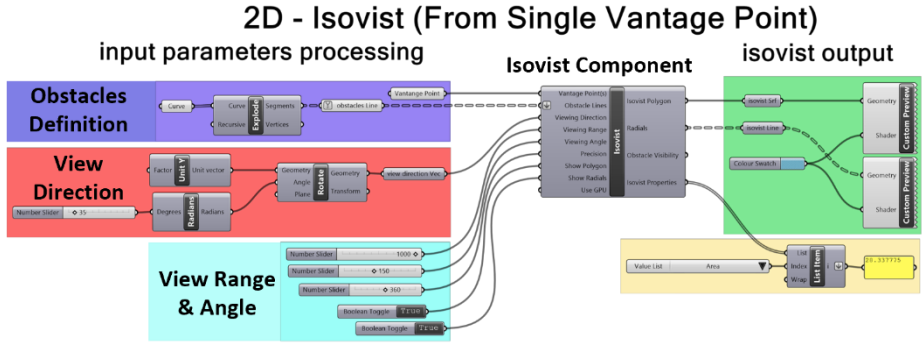

Figure 4- 103: 2D - Isovist Grasshopper Definition Using Decodingspaces Software
Source: By Researcher

- **H1: Dar El-Fouad Hospital**

For **H1: Dar El-Fouad Hospital**, as shown in figures (4-104) (4-105) (4-106), All three-room typologies have good visual access for the architectural openings to the outdoors. Both the double-bed room and suite room have a visual access and control to the room entrance, which increases the feeling of privacy for the patient because he has full visual access and control over his room and knows who can access it, which cannot be found in the single room typology.

a. Single-Bed Patient Room:

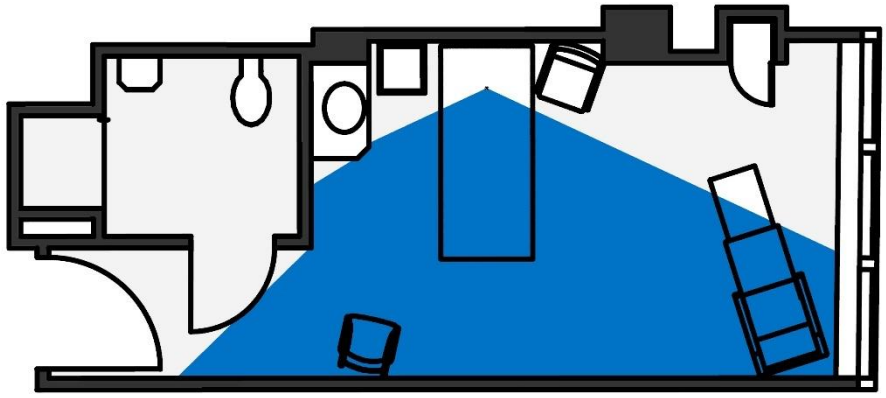

Figure 4- 104: H1-2D Isovist Analysis for View (Single-Bed Room)
Source: By Researcher

b. Double-Bed Patient Room:

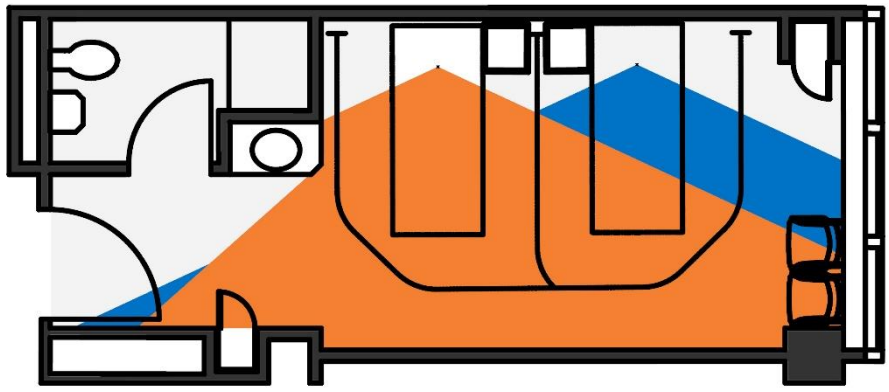

Figure 4- 105: H1-2D Isovist Analysis for View (Double-Bed Room)
Source: By Researcher

c. Suite Patient Room:

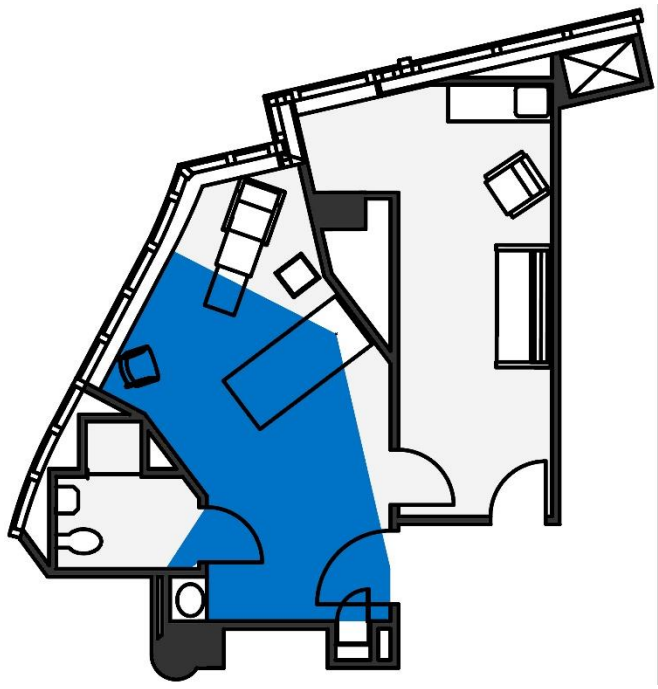

Figure 4- 106: H1-2D Isovist Analysis for View (Suite Room)
Source: By Researcher

- **H3: El-Sheikh Zayed Al Nahyan Hospital**

For **H3: El-Sheikh Zayed Al Nahyan Hospital**, as shown in figures (4-107) (4-108) (7-109), All three-room typologies have good visual access for the architectural openings to the outdoors. But also, all the room typologies have no visual access to the room entrance, which decreases the feeling of privacy for the patient because he has no visual access to and control over his room and knows who can access it.

a. Single-Bed Patient Room:

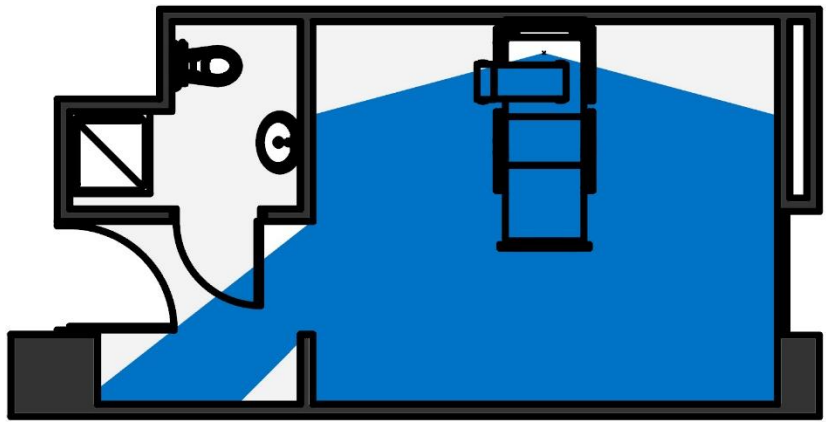

Figure 4- 107: H3-2D Isovist Analysis for View (Single-Bed Room)
Source: By Researcher

b. Double-Bed Patient Room:

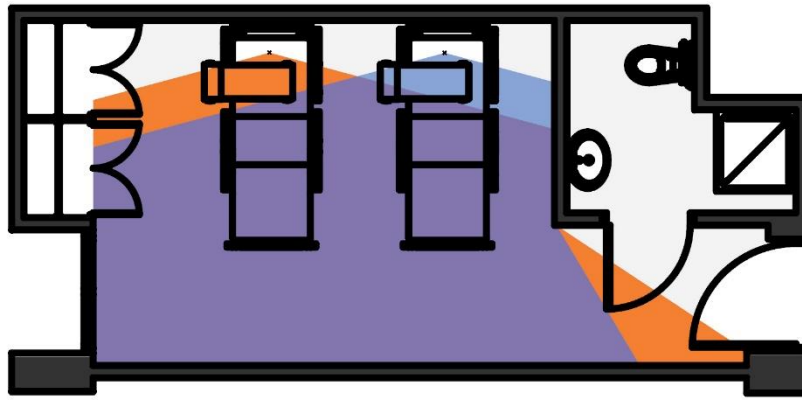

Figure 4- 108: H1-2D Isovist Analysis for View (Double-Bed Room)
Source: By Researcher

c. Patients' Wards of Three Beds Room:

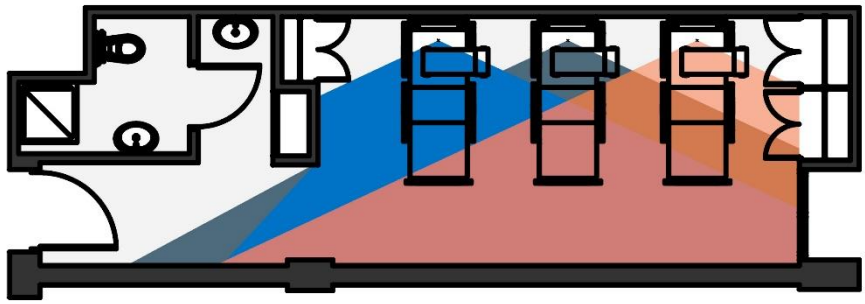

Figure 4- 109: H3-2D Isovist Analysis for View (Patients' Wards)
Source: By Researcher

4.5.1.7. Furniture Layout

An 2D Isovist Field analysis generated using Decoding Spaces Software, which is a Grasshopper Add-on linked with Rhino for measuring the visual connectivity Inside the patient room and how the different furniture layouts affect the communication between the patient and his relatives and the movement circulation in the room, as shown in the following figure (4-110).

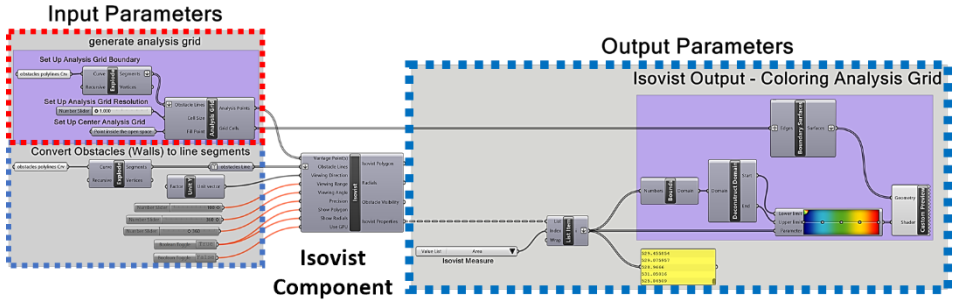

Figure 4- 110: 2D - Isovist Grasshopper Definition Using Decodingspaces Software
Source: By Researcher

- **H1: Dar El-Fouad Hospital**

For **H1: Dar El-Fouad Hospital**, as shown in figures (4-111) (4-112) (4-113), The single-bed room has higher values of visual connectivity between the patient's bed and the furniture in the room that can be used by his family, relatives, or visitors, which would reflect good communication between them. The double-bed room has lower values of visual connectivity as the visitors' chairs are placed away from beds in front of the room door.

All room typologies have high visual connectivity between the patients' beds and the room door, making the observation of the patients by the medical staff easier from the room door, except for the single-bed room, which has the lowest values among them.

a. Single-Bed Patient Room:

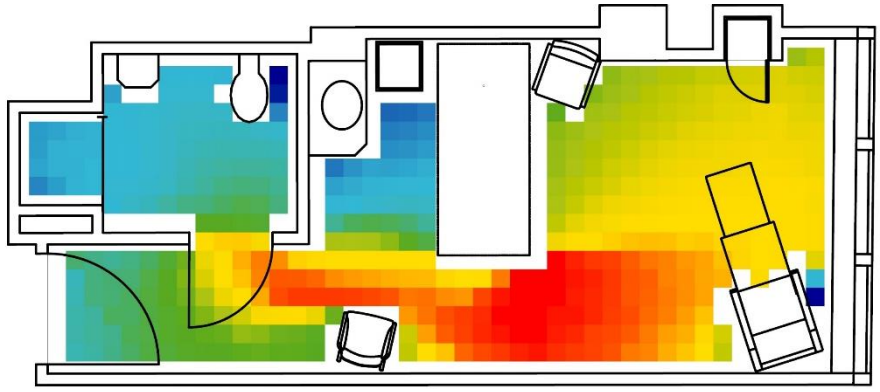

Figure 4- 111: H1-Isovist Field Analysis for Furniture Layout (Single-Bed Room)
Source: By Researcher

b. Double-Bed Patient Room:

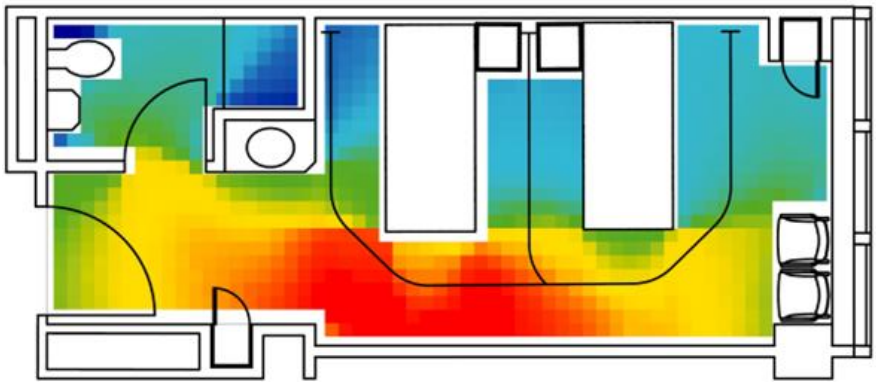

Figure 4- 112: H1- Isovist Field Analysis for Furniture Layout (Double-Bed Room)
Source: By Researcher

c. Suite Patient Room:

Figure 4- 113: H1- Isovist Field Analysis for Furniture Layout (Suite Room)
Source: By Researcher

- **H3: El-Sheikh Zayed Al Nahyan Hospital**

For **H3: El-Sheikh Zayed Al Nahyan Hospital**, as shown in figures (4-114) (4-115) (4-116), all rooms have furnished only with patient bed and the attached toilet. All room typologies have high visual connectivity between the patients' beds and the room door, making the observation of the patients by the medical staff easier from the room door.

a. Single-Bed Patient Room:

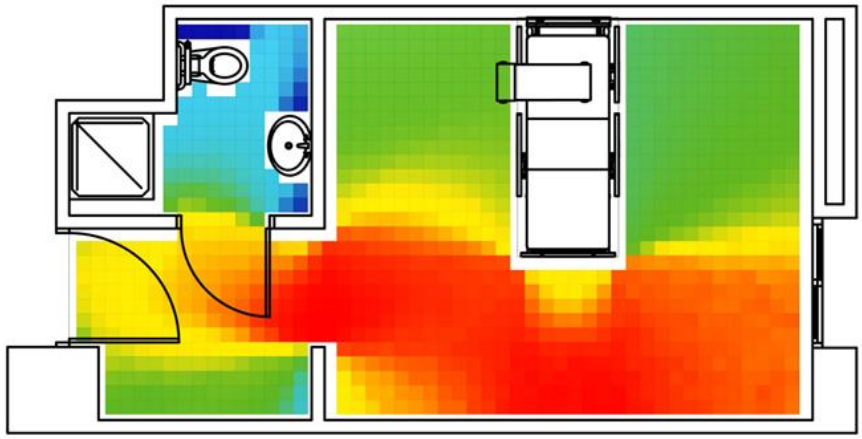

Figure 4- 114: H3- Isovist Field Analysis for Furniture Layout (Single-Bed Room)
Source: By Researcher

b. Double-Bed Patient Room:

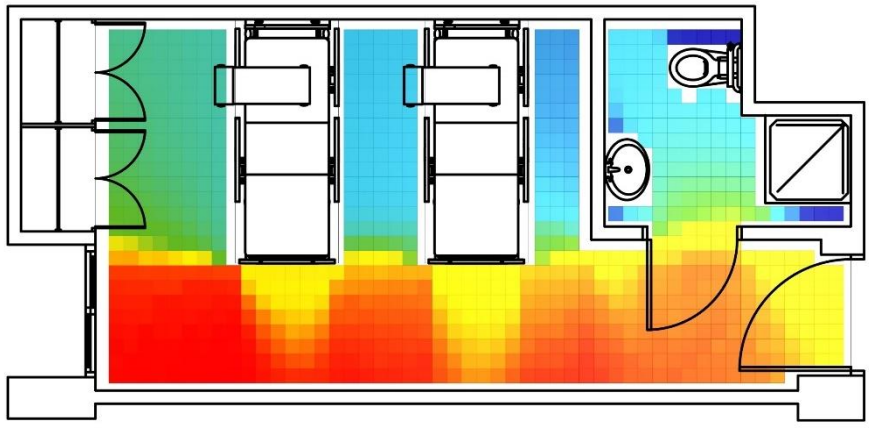

Figure 4- 115: H1- Isovist Field Analysis for Furniture Layout (Double-Bed Room)
Source: By Researcher

c. Patients' Wards of Three Beds Room:

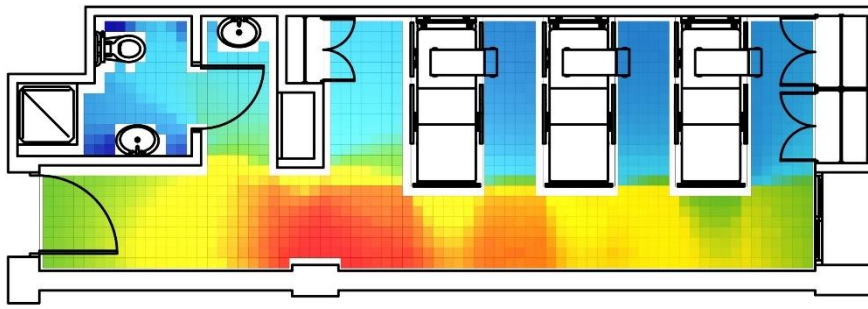

Figure 4- 116: H3- Isovist Field Analysis for Furniture Layout (Patients' Wards)
Source: By Researcher

The following table provides a summary of the evaluation approach utilized for the three case studies, focusing on their space layout planning characteristics and the aspects of evaluation that have been developed:

Table 11: Inpatient Departments Space Layout Planning Evaluation Framework Using Algorithms

Evaluation Aspect			H1	H2	H3
Layout Configuration Typology			Centralized Nursing Station (Double Corridor)	Decentralized Nursing Station (Double Corridor)	Decentralized Nursing Station (Single Corridor)
No. Nursing Unit			2	3	3
Total No. of Rooms			36	38	28
Wayfinding [Visual Connectivity at Nursing Units Lobbies & Info. Desks (or Nursing Stations)]			High Visual Connectivity at Visitors Lobby and in front of Nursing Stations	Good Visual Connectivity in front of Nursing Stations	Low Visual Connectivity in front of Nursing Stations and Visitors Lobby
Accessibility	Visual Accessibility From Visitors' Lobby to Info. Desk or Nursing Stations		Good & Direct Access to The Info. Desk	Good & Direct Access to The Nursing Station	No Visual Access to Any Info. Desk or Nursing Stations
Controllability	Visual Access from Nursing Stations to Patients' Rooms (percentage of Covered Rooms)		13 Rooms Out of 36 Rooms 36.11 %	14 Rooms Out of 38 Rooms 36.84 %	8 Rooms Out of 28 Rooms 28.57 %
	Visual Accessibility from Nursing Stations to Nursing Unit Entrances		No Visual Access to The Visitors Entrances, But To patients' and Services Entrances	Visual Access to Elevators Lobbies to The Unit Entrances	Visual Access to The Three Entrances
Walkability	Walking Distance	Min.	1.77 m	1.45 m	3.09 m
		Max.	32.65 m	18.30 m	23.95 m
	Circulation Ratio		29.85 %	26.90 %	40 %
Privacy	Privacy of rooms from nursing units		3 Room out of 36 Rooms 8 %	-	1 Room out of 28 Rooms 4%
Views of Nature	Single-Bed Room		Access to Architectural Opening In the Room	-	Access to Architectural Opening In the Room
	Double-Bed Room			-	
	3 beds Patients' Ward		-	-	
	Suite Room		Access to Arch. Opening In the Room	-	-

4.6. Conclusion

The application and subsequent findings have effectively established the validity of applying algorithms for the examination of specific visual spatial attributes and measurements within the inpatient department for a post-occupancy evaluation process. This study aims to examine the role of visual connectivity in defining the floor layout plan, evaluating the visibility access from the nurse station, and exploring how the placement and arrangement of the space can impact visibility and the physical environment of the users enhance the overall space quality for patients and their families.

The Research aims to study the efficiency of using Algorithms in space layout planning within a post occupancy evaluation framework, as shown in figure (4-117):

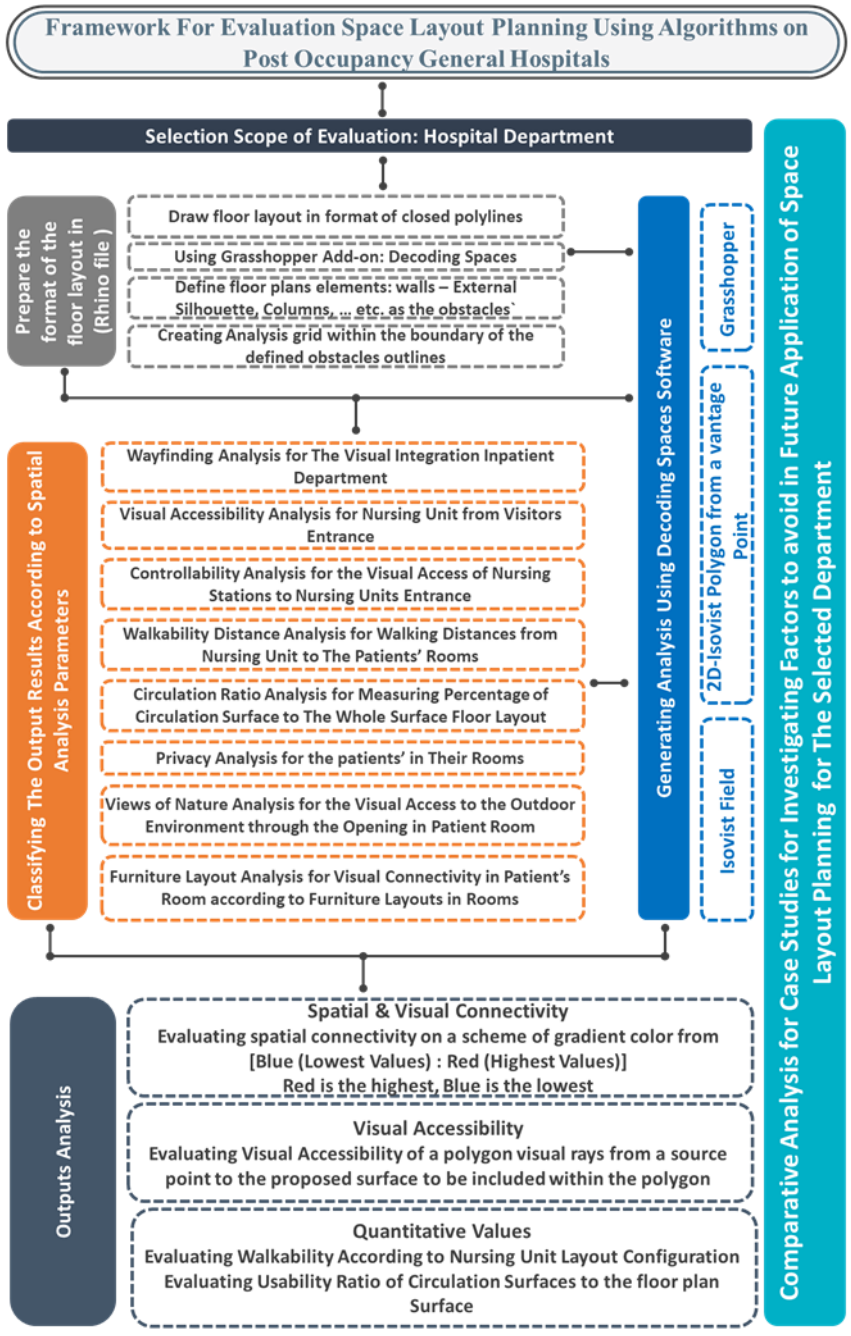

Figure 4- 117: Post Occupancy Evaluation Space Layout Planning Using Algorithms Framework
Source: By Researcher

Chapter 5

Conclusions, Recommendations & Further Research

- Introduction
- Conclusion
- Recommendations
- Further Research

5.1. Introduction

The research was conducted on different approaches that were integrated to achieve the research goal of evaluating the space layout planning in the inpatient departments of general hospitals using algorithms. The main research approaches included inpatient department layout planning design guidelines, the space layout planning process, how the healing environment and different users are affected by space qualities, how the buildings are evaluated after they have been used, and how visibility analysis changes over time to include the observer's view of the surroundings.

Three case studies of different typologies of nursing units in the inpatient department were chosen to apply the post-occupancy evaluation to their layout configurations based on isovist analysis with the aim of assessing visual connectivity and integration within the layout configuration of the department and measuring other spatial qualities based on the spatial qualities related to the users derived from space layout planning process criteria and the spatial qualities that affect the healing environment of the patients.

5.2. Conclusion

According to the approaches and literature studied during this research, the following information has been concluded prior to the research scope:

This research provides an in-depth analysis of the application of a post-occupancy evaluation process utilizing algorithms to various layout typologies of inpatient departments. These typologies have been chosen as case studies in order to establish a framework for the post-occupancy evaluation of space layout planning in the context of inpatient departments:

- This research reviews three different layout typologies of inpatient departments in three different general hospitals, as shown in the following table.

Table 12: Inpatient Department Typologies Case Studies

Hospital Name		Nursing Unit Configuration	No. of Nursing Units
H1	Dar El-Fouad Hospital	Centralized Nursing Unit (Double Corridor)	2 Units
H2	As-Salam International Hospital	Decentralized Nursing Unit (Double Corridor)	3 Units
H3	El Sheikh Zayed Al Nahyan Hospital	Decentralized Nursing Unit (Single Corridor)	3 Units

- The evaluation process is applied using the isovist theory using decoding spaces software and using grasshopper definitions. The aim of the evaluation is to explore the users behaviors within specified layout configuration regarded to some spatial factors derived from the previous chapters in the research, which are Wayfinding Analysis, Accessibility, Controllability, Privacy, Views, Furniture Layout, And Efficiency.

- The evaluation process passes through defined steps, as shown in figure (5-1).

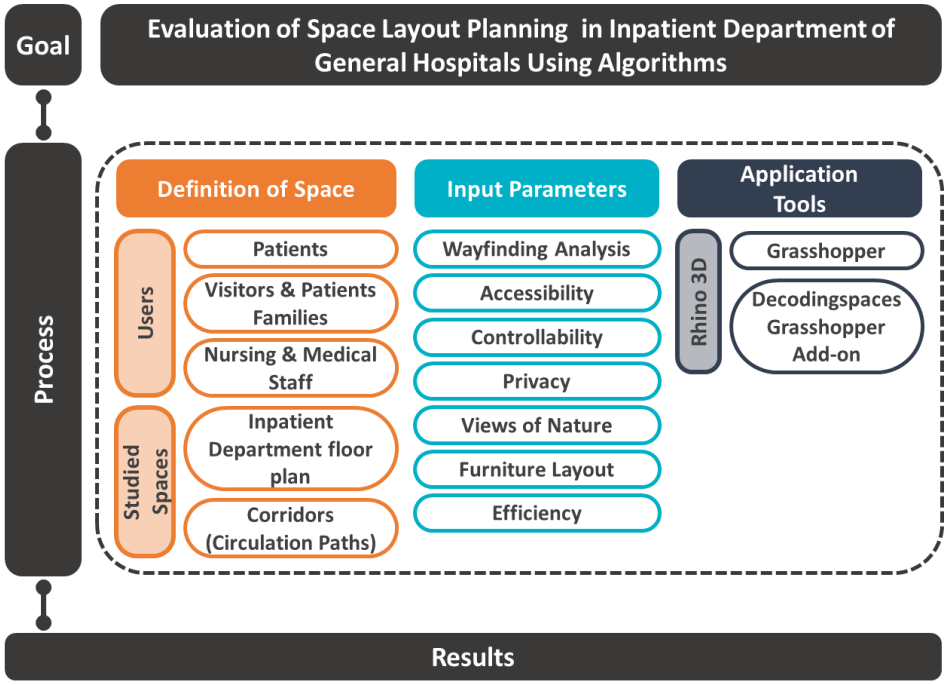

Figure 5- 1: Steps of Evaluation Process Using Algorithms in Inpatient Department
Source: By Researcher

The post-occupancy evaluation process using algorithms is applied to each of the case studies, testing all input parameters for the goal of evaluating the space configuration of different typologies in the inpatient department of general hospitals on the users, and finding the following:

i. Wayfinding:

To measure the visual connectivity of the floor plan of the inpatient department and the effect of space layout configuration on the ease of wayfinding for users, especially for visitors to find out the vital points such as the information desk and the nursing station from the entrance of nursing units in the department. Also, measuring the adjacency of spaces within the floor plan by measuring the plan visual connectivity using isovist field analysis, where the highest values of the isovist field analysis are considered to be the more open spaces, while the least values mean the existence of adjacent spaces beside each other.

- **For H1:** The inpatient department has a good way of finding behavior for all users, as the allocation of the information desk for visitors' guidance is placed in the most visually connected zone.

- **For H2 :** inpatient department has a poor value of visual connectivity except for the intersection between corridors however the placement of the nursing stations in the zones that have a good visual connectivity value may help to control the accessibility to the patients rooms.

- **For H3 :** the visual connectivity values are low in the entrances of the inpatient department. Followed by good visual connectivity in front of only one nursing station, which impacts the behavior of wayfinding in a negative manner due to the Divergent allocation of nursing stations.

ii. Accessibility:

Accessibility is measuring the visitors visual accessibility from the entrance to the nursing units confirmed the results of the wayfinding analysis.

- **in H1:** there is a visual accessibility to information desk and N.U entrances but not to nursing stations.

- **For H2:** there is a visual accessibility to nursing station that also acts as an information desk allocated in the lobby of visitors.

- **For H3:** the visitors lobby is an open-space lobby without any information desk and connected directly to the nursing unit entrances. however, there is no visual access from the visitors' lobby nursing stations that will be a vital point for the visitor's guidance inside the department.

iii. Controllability:

2D isovist analysis is applied, measuring the visibility of the patients rooms entrances, and the good distribution of the nurse stations inside nursing units, as shown in figure (5-2).

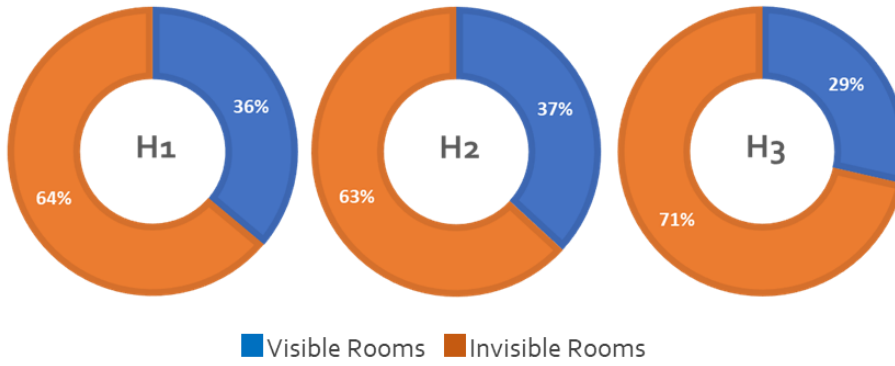

Figure 5- 2: Ratio of Intervisibility Between Nursing Stations and Patients Rooms
Source: By Researcher

iv. Walkability Efficiency:

The evaluation aspect is based on two methods of evaluation:

a. Walkability Measurement

The walking path is drawn in the center of the corridors of the nursing unit to get the most precise values possible. The lowest value exists in **H2** with nearly to the value in **H1**, while the highest values exist in **H1** which increase staff fatigue due to long distance they need to traverse as shown in figure (5-3).

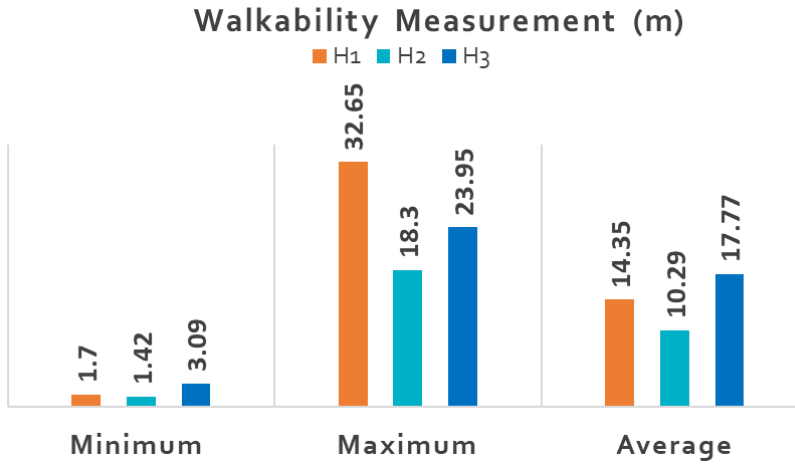

Figure 5- 3: Walkability Measurement Analysis
Source: By Researcher

b. Circulation Usable Ratio

With the goal of Measuring the circulation surface in relation to the whole useable surface in the floor layout, Affect Walking distances and fatigue for medical staff.

H2: As-Salam International Hospital has the lowest percentage of circulation ratio which indicates to be the most efficient layout configuration taking in consideration it has the highest number of rooms Comparing the two case studies, Although **(H2 & H3)** have the same decentralized layout configuration with each other, also **H2** have the more efficient layout configuration as shown in figure (5-4).

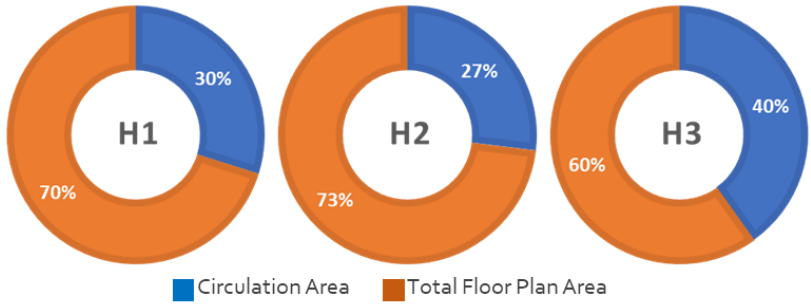

Figure 5- 4: Circulation Ration Analysis
Source: By Researcher

v. Privacy:

Privacy aspect with the goal of measuring privacy of patients' rooms from nursing station, as shown in figure (5-5)

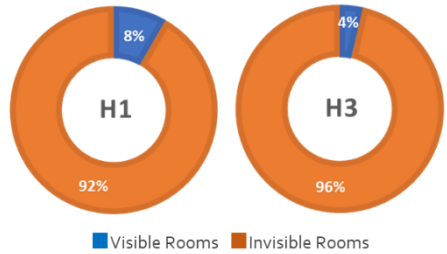

Figure 5- 5: Indication of Creating a Private Environment for patients
Source: By Researcher

- **For H1: Dar El-Fouad Hospital**, no. the patient bed can be seen is only in three rooms compared to 36 rooms in the total, which indicates a high percentage of a private environment for patients.
- **For H3: El-Sheikh Zayed Al Nahyan Hospital**, no, the patient bed can be seen only one room compared to 28 rooms in the total, which indicates nearly a full private environment for patients.

vi. Views of Nature & Furniture Layout :

These aspects are non-primary aspects of evaluation, in which evaluating them will help in creating an adequate healing environment for patients, but it will not affect patients in a bad way if they cannot be fully achieved in their rooms.

Regarding the research scope, some of the evaluation aspects must be spatially modified to achieve the optimal configuration of the inpatient department, and other aspects could be solved by alternative methods for achieving the optimal situation for those aspects. such as:

- **Way finding analysis, walkability measurement, and circulation ratio analysis** are a primary evaluation aspects, these aspects is directly related to the space layout planning of the floor plan and to enhance the evaluated results a change in the existing layout configuration is required.

- **Controllability analysis,** Although this aspect is a primary aspect of evaluation, it depends on other factors that impact the placement of nursing stations within the nursing unit, such as the number of patient rooms per nursing unit, which is also related to the shape of the hospital layout. And to optimize the evaluated results of medical surveillance for patient rooms, another solution rather than spatial solutions could be used, such as adding monitoring screens to the nursing stations that are connected to cameras in patient rooms.

The evaluation framework tests the validity of using algorithms in the post-occupancy evaluation process to explore the effects of space layout planning in the inpatient department on user behaviors instead of using the researcher's own observation of user interactions within the space layout planning of the floor plan. And initiating structured surveys and interviews with the users. Which could be a long-term duration evaluation process, and the long time frame durations are one of the limitations of using post-occupancy evaluation in buildings.

5.3. Recommendations

- The analysis conducted on this research is related to the studied literature related to the inpatient department. More analysis to be applied evaluating the spatial relation between inpatient department and other vital departments such as Emergency department and operation rooms, … etc.

- More research needed to be applied to all departments where the layout configurations could affect users behaviors. Also apply the evaluation frame work on public spaces of general hospitals Such as evaluating visual connectivity of hospital entrances and emergency entrances.

- Integrating the framework of evaluation of the space layout planning using algorithms based on visibility analysis in the earlier stage of the design process, in the phase of analyzing previous projects for collecting data or evaluating the initial layout configuration to improve their spatial qualities, creating an adequate healing environment for the users represent in patients and medical staff.

- Evaluating the use of the framework or the selected tool of visibility analysis by the architects and consultants in design projects, measuring how it could be efficient for them to enhance their projects or if it could be an obstacle for them, and determining their feedback about the framework in order to conduct a complete analysis of the tool before applying it in further research.

5.4. Further Research

- Apply all spatial factors included in the space quality components mentioned in the literature, such as technicality and aesthetic components. And also, environmental factors affect the satisfaction of users in the healing environment. within the evaluation framework using algorithms, even with different tools that have not been used in this research.

- Studying the integration of virtual reality tool as a visualized tool, to assess the behavior of users like the space experience in real life, which can be applied in the evaluation of the new projects in the early stages of the design process.

- Studying the integration visual analysis methodology into the post-occupancy evaluation process for more buildings typologies.

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الملخص

يعتمد تقييم المباني بناءً على تحقيقه لتوقعات المستخدمين باختلافهم مما يضمن تحقيق الوظيفة الأساسية للمبني بشكل جيد. ومن خلال ذلك تم إجراء البحث بهدف دراسة تقييم ما بعد الإشغال للمستشفيات العامة وتأثير التخطيط العام للمستشفيات العامة على تجربة المستخدمين داخل الفراغات وبشكل خاص تم دراسة تقييم التخطيط العام لأقسام الإقامة الداخلية على وتأثيره على المستخدمين من خلال البحث.

وذلك من خلال دراسة تعريف مرافق المستشفيات العامة وفقاً للمنظمات الدولية المختصة بالأمر وكذلك معايير التصميم المصرية الخاصة بالمستشفيات العامة، حيث أن جميع دراسات الحالة تقع في مصر، كذلك أسس التخطيط والعلاقات الفراغية بين أقسام المستشفى العام على وجه التحديد، ودراسة أقسام إقامة المرضى الداخلية بهدف معرفة أساسيات التخطيط العام للقسم، ودراسة الأنماط المختلفة لوحدات التمريض التي يمكن تضمينها داخل القسم.

كما قدم البحث المفاهيم الأساسية بعملية التخطيط العام للفراغات داخل المباني والجوانب التي ينبغي مراعاتها أثناء ذلك. كذلك تأثير هذه العملية على تجربة المستخدمين داخل البيئة المبنية للفراغات المحيطة بهم، ودراسة كيفية تحسين جودة الفراغات الداخلية لتحسين التجربة الفراغية لجميع المستخدمين داخل أقسام إقامة المرضى الداخلية في المستشفيات العامة.

وقام البحث بدراسة استكشافية لدمج الخوارزميات في عملية تقييم ما بعد الإشغال لأنواع مختلفة من وحدات التمريض في أقسام إقامة المرضى الداخلية بالمستشفيات العامة ، وتحليل تأثير نمط التخطيط الفراغي على سلوكيات المستخدمين باختلافهم بناءً على عوامل مختلفة مثل تحديد وإيجاد الطريق، والخصوصية،.... إلخ. ودراسة كيف يمكن أن يكون استخدام الخوارزميات فعالاً في إنشاء تقييم ما بعد الإشغال للأقسام المختلفة في منشأة المستشفى العامة.

الكلمات المفتاحية:

المستشفيات العامة - أقسام الإقامة الداخلية - عملية التقييم - جودة الفراغ الداخلي - التجربة الفراغية - البيئة المبنية - تقييم ما بعد الإشغال - الخوارزميات

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