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Impacts of Developing Indoor Environmental Quality on Patients' Health and Occupants' Productivity in Hospital Buildings

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Abstract Indoor Environmental Quality (IEQ) in healthcare buildings indicates the quality level of an environment of hospital buildings concerning the building occupants' health and well-being and of those utilizing the hospital buildings' amenities. The quality of the indoor environment of a hospital buildings is determined by many aspects, comprising internal natural and artificial lighting, air quality, damp environments, thermal conditions, visuality, the comfort of acoustic level, the approach of emissions-based (low-emission materials), controlling source, and observing for occupant-determined contaminants (superior strategies of indoor air quality), and advanced metrics of natural lighting (daylight). Occupants and patients inside hospitals building are often worried about the exposure to contaminants causing prospective symptoms and health conditions and dissatisfaction inside hospital buildings where they perform duties or pay visits. Most of these concerning symptoms get better when building occupants are not inside the hospital buildings. Although the previous studies related to the research context have addressed some respiratory symptoms and infections that are associated with damp spaces in hospital buildings, the concern is still unclear especially since indoor contaminants' measurements indicate that occupants and patients are at risk of disease. In most cases, wherever the occupants and physicians doubt that the hospital buildings' environment is affecting the occupants' health condition, the available information from medical investigations about the surrounding environment is unclear and insufficient for establishing which contaminants are accountable. Despite uncertainty concerning what to measure and how to explain what is measured, research shows that the symptoms related to hospitals are associated with characteristics of buildings including dampness, sanitation, and ventilation as well. Therefore, this demand focuses on increasing indoor quality contaminant and infection levels within hospital buildings spaces for patients, employees, visitors, and all occupants, including for differently-abled air and surface temperature, humidity, air movement, and quality view. The study highlighted providing better indoor environmental quality and promoting sustainability for healthy patient rooms within hospital buildings to face any prospective pandemic with a minimum negative impact on buildings' occupants and Energy Consumption. Developing internal spaces of hospital buildings with the proposed parametric design framework in the design stage will reduce the risk of air pollution exposure, and infection, and sustain public health.

Keywords Indoor Environmental Quality (IEQ), Healthcare, Well-being, Air Quality, Public Health, Sustainability, Patient, Energy Consumption

2. Research Problem

2.1. Limitations of Hospital Facilities

The outcomes of the 2008 Egypt Demographic and Health Survey (EDHS) jointly with service-based data are extremely significant for measuring the achievements of the health program to date as well as for the development of future involvements to address Egypt's health experiments. Based on the above-mentioned considerations, the outcomes of the 2008 EDHS must be extensively publicized at diverse levels of health management, in the crucial offices as well as local governments, and to the community [5].

The Egyptian healthcare field faces numerous challenges in developing and ensuring the health and well-being of the Egyptian people. The healthcare system faces not only the burden of struggling illnesses related to poverty and the absence of relevant education, but it must also respond to emerging diseases and illnesses associated with the modern, urban lifestyle. In addition to that the emerging approach to global communications and commerce is the growth potential of the population for more and better well-being and innovative healthcare technology [6]. The high birth level and the longer life expectancy are escalating the population burden on the Egyptian healthcare system. By the year 2030, the estimated annual population of Egypt will have grown to around 1 million and 150 thousand persons. All of these indications will increase the limitations of hospital facilities in Egypt as it relates to health facilities and outpatient services. As mentioned, Egypt has a healthcare facility system that had been classified based on the management levels, number of beds, and types of provided services. Nowadays, there are many types of healthcare facilities ranging from general hospitals to specialized hospitals, which have been built either in major cities or in small towns in rural areas, and the healthcare facility network has been improved significantly. However, due to many causes and conditions, the design and construction of the majority of hospital facilities are inadequate. The following statements will show the limitations of healthcare architecture and design in Egypt recently. The number of specialty architects from different companies interviewed about the problems they had while planning spaces for a general hospital is 10 and 7 healthcare educators [7]. The statistics of the interviewees' responses are shown in tables 2 and 3, along with figures 2 and 3.

Table 2. Statistics on the Interviews of Problems about Space Planning with Architects

Problems in Space Planning for a General Hospital	Count		Percentage (%)	
Problems in Space Planning for a General Hospital	Yes	No	Yes	No
No local clear and detailed standards and guidelines	8	2	80	20
Lack of reference on hospital planning and design in Egypt	9	1	90	10
Requirement of following the current standards	9	1	90	10
Sustainability consideration in the design stage of Healthcare Building	2	8	20	80

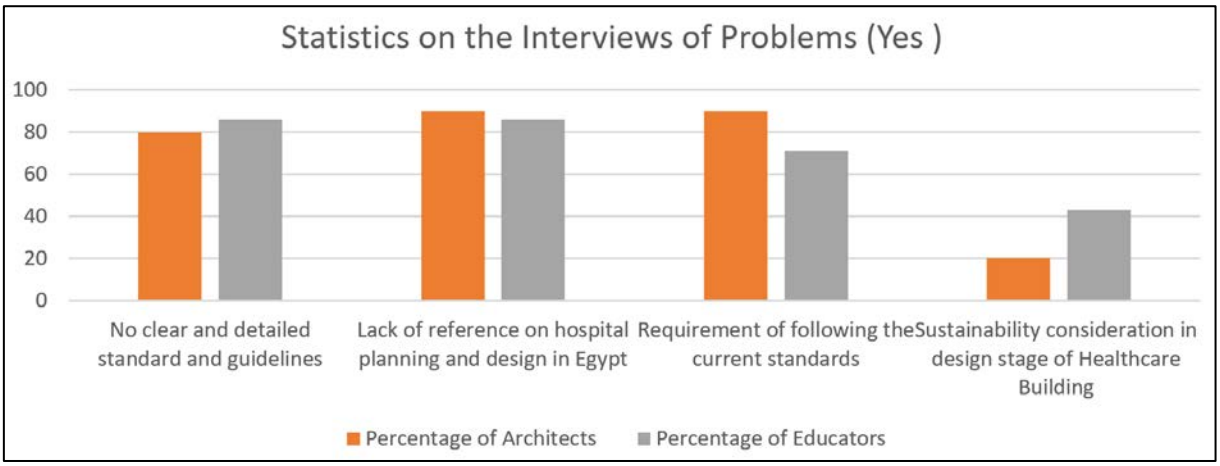


Figure 2. Statistics on the Interviews with Architects and with Educators Yes – researcher

Table 3. Statistics on the Interviews of Problems about Space Planning with Educators- researcher

Problems in Space Planning for a General Hospital	Count		Percentage (%)	
Problems in Space Planning for a General Hospital	Yes	No	Yes	No
No local clear and detailed standards and guidelines	6	1	86	14
Lack of reference on hospital planning and design in Egypt	6	1	86	14
Requirement of following the current standards	5	2	71	29
Sustainability consideration in the design stage of Healthcare Building	3	7	43	57

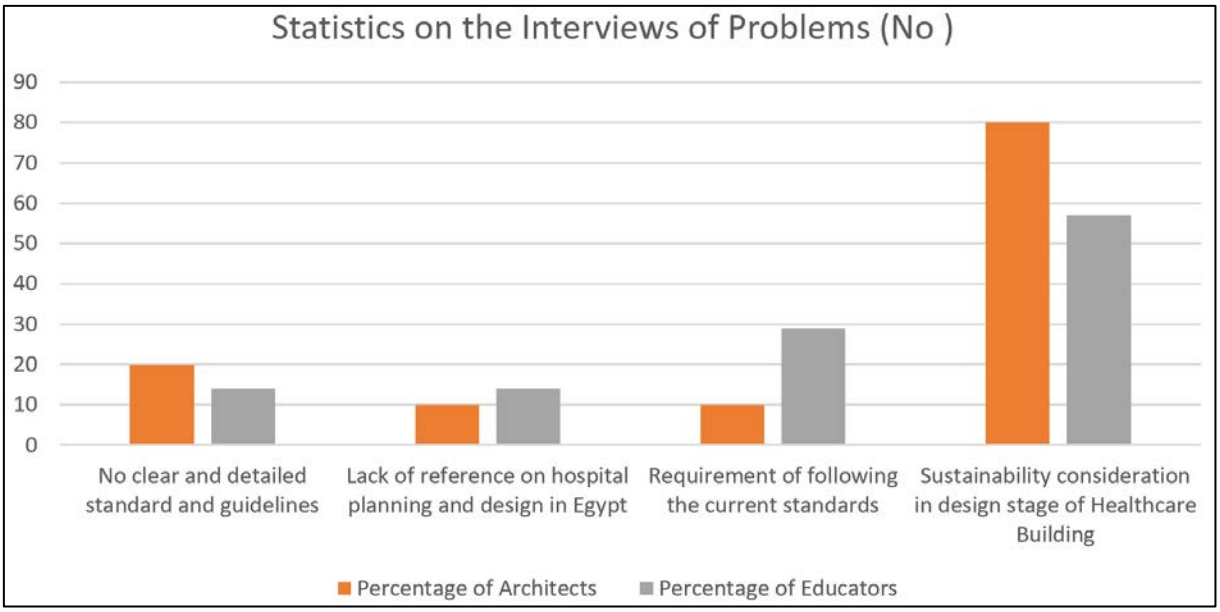


Figure 3. Statistics on the Interviews with Architects and with Educators No – researcher

2.2. Inadequate reference guide for Hospital Planning and Design

The current standard for hospital facility design guide in Egypt regarding general hospital design standards is derived improperly from the former guidelines as referenced in published official, guidelines for the design and construction of healthcare facilities, the Facility Guidelines Institute "FGI". Based on a profound study of the current issued Egyptian standard for hospitals, the design is still not strengthened for protecting hospital buildings' occupants from prospective infection versus the Facility Guidelines Institute "FGI", especially after the COVID-19 pandemic that raised again in December 2019, a pneumonia outbreak was reported in Wuhan, China which showed that most of the currently existing healthcare and hospital buildings are not qualified to receive COVID–19 patients due to the absence of infection precautions in the design stage and the operated hospital building itself consequently to secure a healthy indoor environmental quality for all the building's occupants. To develop Egyptian hospital buildings with well and healthy designs according to the latest and accurate standards, all relevant strengthened standards and requirements are to be considered in the Egyptian hospital codes and facility guide to enable the existing and operated healthcare buildings to provide a better and healthier indoor environmental quality for patients and buildings' occupants as well. Along with a theoretical study for the exact problem in hospital buildings that results in increased infection among building occupants, the researcher ran interviews with hospital users through a questionnaire to investigate the actual sources of increased infection rated between hospital buildings' users as mentioned below in table 4 and figure 4.

Table 4. Limitations of the Former Guidelines and the Current Standard - researcher

Problems in Space Planning for a General Hospital	Count		Percentage (%)	
	Yes	No	Yes	No
The current standard and the former guidelines are not flexible	14	3	82	18
The formation is not rational and difficult to understand	16	1	94	6
The information is unclear and duplicated	16	1	94	6
The functional space programs are inadequate	16	1	94	6
The functional relationship diagrams are unclear	13	4	76	24
The future expansions are not mentioned	15	2	88	12

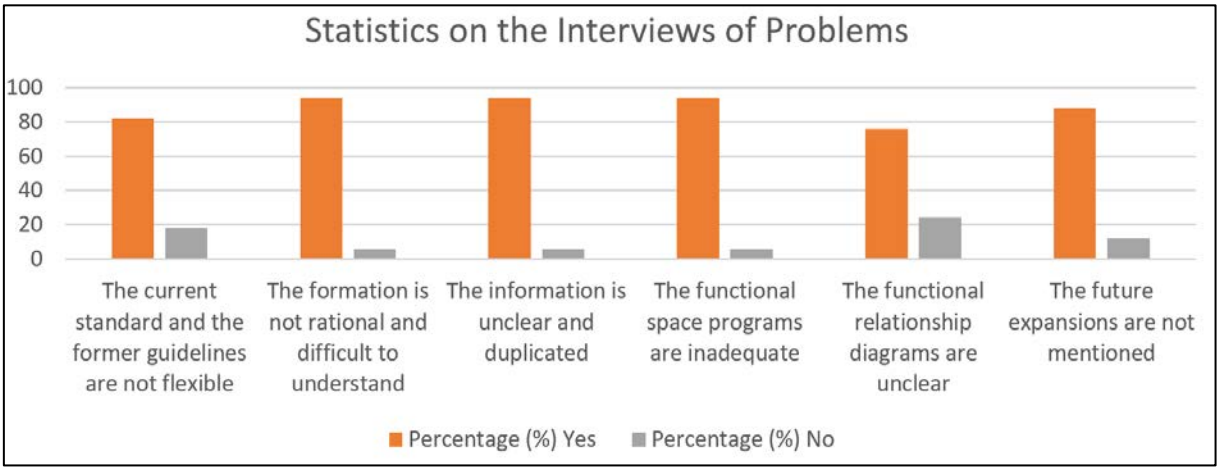


Figure 4. Limitations of the Former Guidelines and the Current Standard - researcher

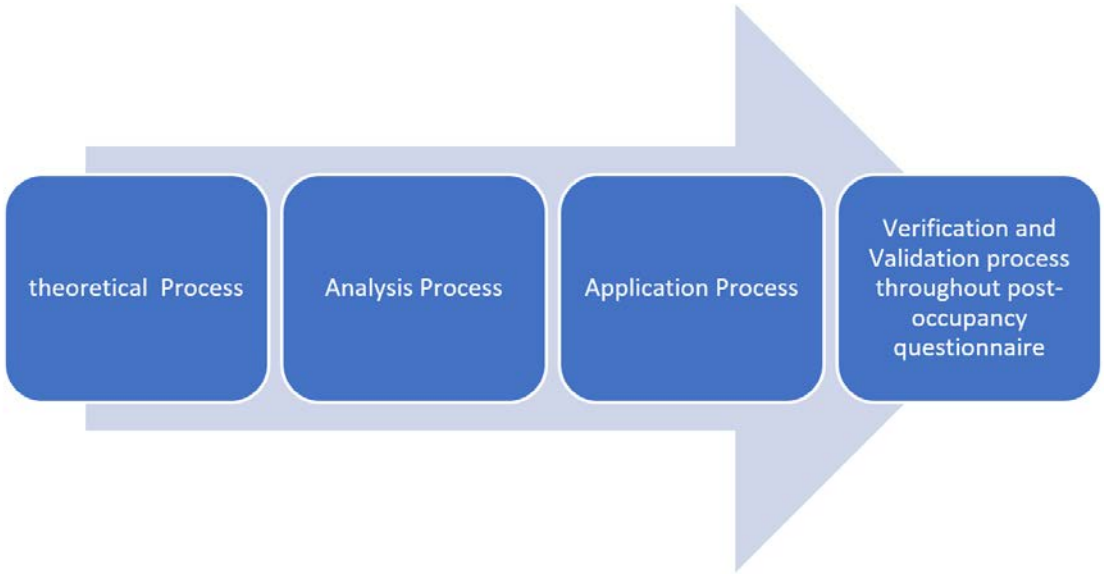


Figure 5. Structure of Research Methodology -adopted by the researcher

3. Research Methodology

The research methodology will be addressed in four parts, the first part is theoretical which will address the research problems for Indoor Environmental Quality of Patient rooms along with the related studies. The second part is an analytical methodology for an existing case study which will be a reference for the practical part at a later stage. This analytical study will address all related sustainable criteria and principles which will be applied to the nominated case study. The verification and validation process will be implemented via the taking questionnaire process. At the end of the research study, the conclusions and recommendations parts will be addressed as outcomes accordingly. See figure 5.

4. Case-study and Result

4.1. Case-study

Central Hospital building is a part of Dakahlia Governate and it is located in Meniet Alnasr City, which is serving more than 250 thousand persons, representing the total population of 18 villages. The Main Hospital's building has a 197-bed capacity and is consisted of 3 buildings in addition to a dialysis building, an outpatient building, an inpatient building, and an administrative building. The outpatient building comprises one floor with outpatient clinics and Emergency Department. The inpatient building has five floors in which Patients' rooms are exposed in the north and south Direction.

4.2. Analysis Process

As a part of all medical and public health commitment to control the COVID-19 pandemic consequences, it is also imperious to identify and investigate environmental measures such as air pollution, airborne pollens, ventilation, and thermal comfort which could enhance and reduces the severity of COVID-19 pandemic. However, our understanding is that new scientific contributions expedite development from day to other on the track of progressing with the new expectation to medicate the unexpected COVID-19 crisis. A statistically meaningful association between COVID-19 and short-term exposure to numerous air quality parameters, meanwhile designers and architects especially have myriad roles and contributions in improving hospital indoor quality through guiding and orienting occupants of hospital buildings to the positive methodology during the concept and design stage to reflect and implement strategies which ensure that hospital building patient and occupants are connected with external Environment to achieve quality view along with thermal, visual, and acoustic comfort as well. Improved access to daylight has constructive human behavioral and health effects since it reinforces patient circadian rhythms and access to sufficient daylight has value impact to increase healing times in hospital buildings [8,9]. Emerging design strategies of providing ventilation and thermal control including emissions-based approach (Low-Emitting Material), source controlling and monitoring for building's user that determined contaminants (Enhanced Indoor Air Quality Strategies), requirements for lighting quality (Interior Lighting), and advanced lighting metrics (Daylight), These strategies will improve indoor environmental quality, shorten the patient recovery period and increase employee satisfaction which, in turn, shall improve the caring facilities that provided to the patient. Hospital buildings with good IEQ is protecting the health and comfort of the building's patients and occupants. High-quality indoor environments also sustain productivity, decrease absenteeism, and promote the hospital building's significance as well.

4.3. Site Analysis

Meniet Alnasr Central Hospital is located in the city's Centre, Dakahlia, Egypt. Exiting building is located in a congested area and has only one operating entrance and an Emergency Entrance that is located on an inaccessible road for Ambulance vans or private cars. Being a hospital building in this prime and congested area in the absence of proper infection plan parameters and considerations resulted in increasing the possibility of speeding infection outside the hospital itself, especially during the COVID-19 pandemic. See figure 6.

Figure 6. Hospital Location

4.4. Building Orientation

From project location and site analysis, Hospital building mass has been oriented as usual for conventional methodology due to site condition, related facility, and prime location benefits not as per specific requirement from implemented energy model at the beginning of the design stage to target a specific amount of saving energy

consumption and for optimum building performance.

4.5. Local Climate

The local Climate (31° 7' 15.070" N, 31° 38' 44.774" E) of Dakahlia is classified as a moderate climate. Summer months are hot with average temperatures in July and Aug that range between 23 and 35°C. Winters are warm with cool and windy nights. The overall climate is moderate, and the city experiences little rainfall. See figure 7.

4.6. Average Hourly Temperature

The hottest month is July, with an average of 35 °C, and the coldest is January at 9 °C. During the entire year, the dry-bulb temperatures never reach zero degrees, and the minimum is about 4-5 °C. The maximum reaches about 45 °C. See figure 8.

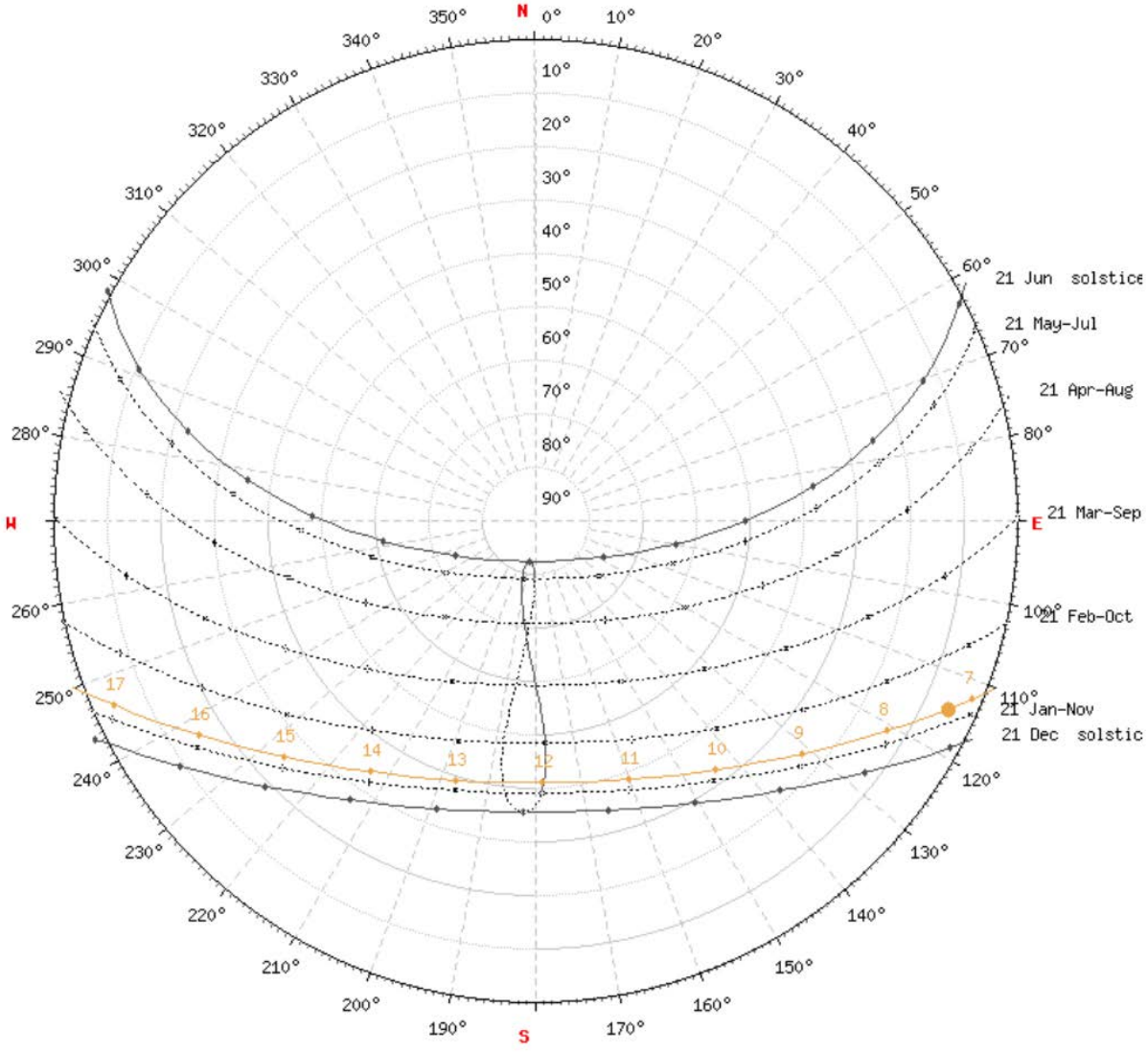
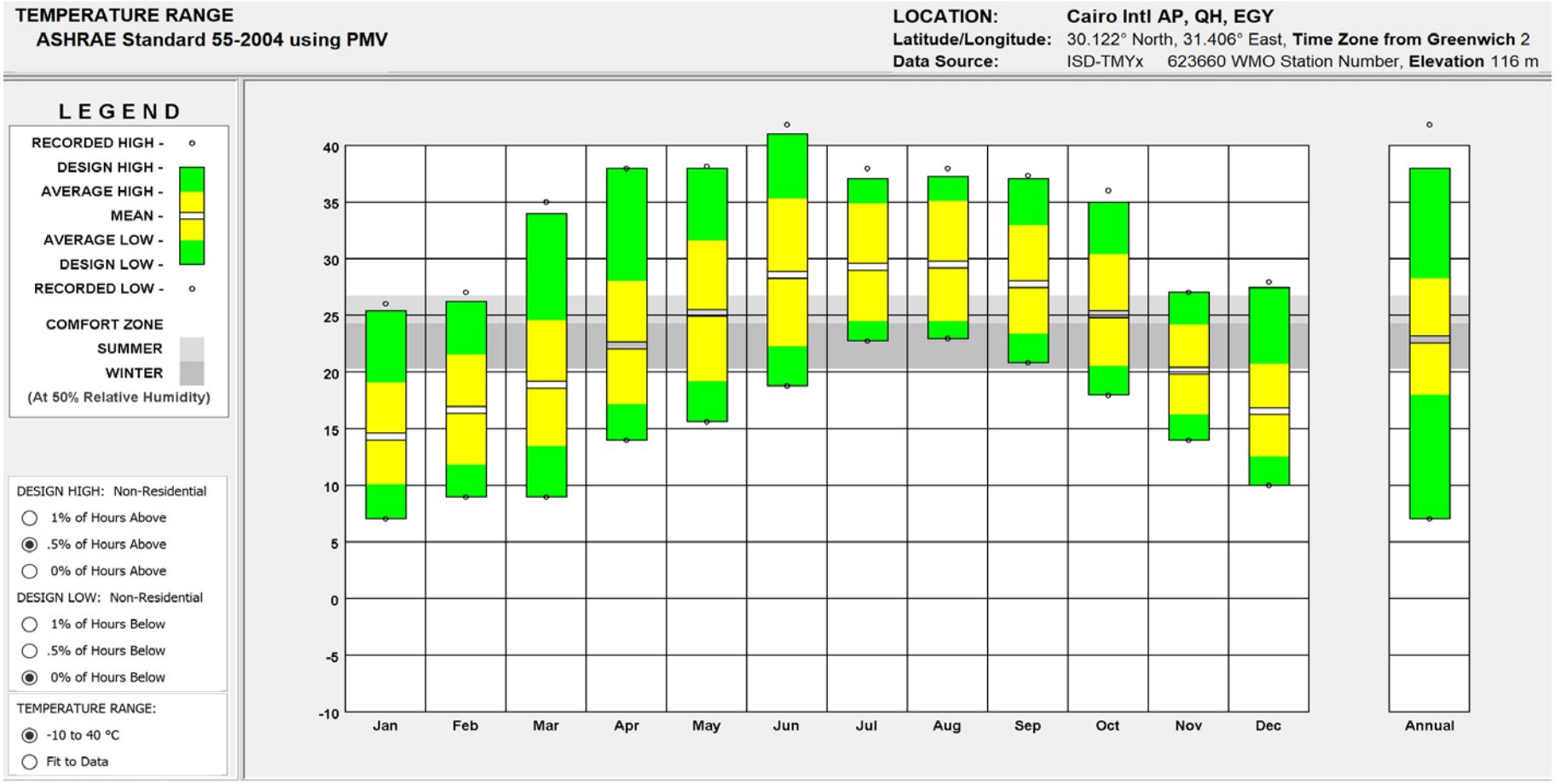


Figure 7. Sun path - researcher



Dry Bulb Temperature (Avg Monthly)	14	16	18	22	25	28	29	29	27	25	20	16	degrees C
Dew Point Temperature (Avg Monthly)	7	4	7	9	11	16	19	18	17	17	11	6	degrees C
Relative Humidity (Avg Monthly)	64	50	52	49	46	51	59	56	56	63	60	53	percent

Figure 8. Temperature Ranges – researcher

The chart shows the number of hours with a given wind direction and speed in Cairo in different seasons See figures 9 and 10. It can be noted that the main direction in which the wind blows is from the northwest although a large part of the wind blows from the southwest. See figures 10 and 11.

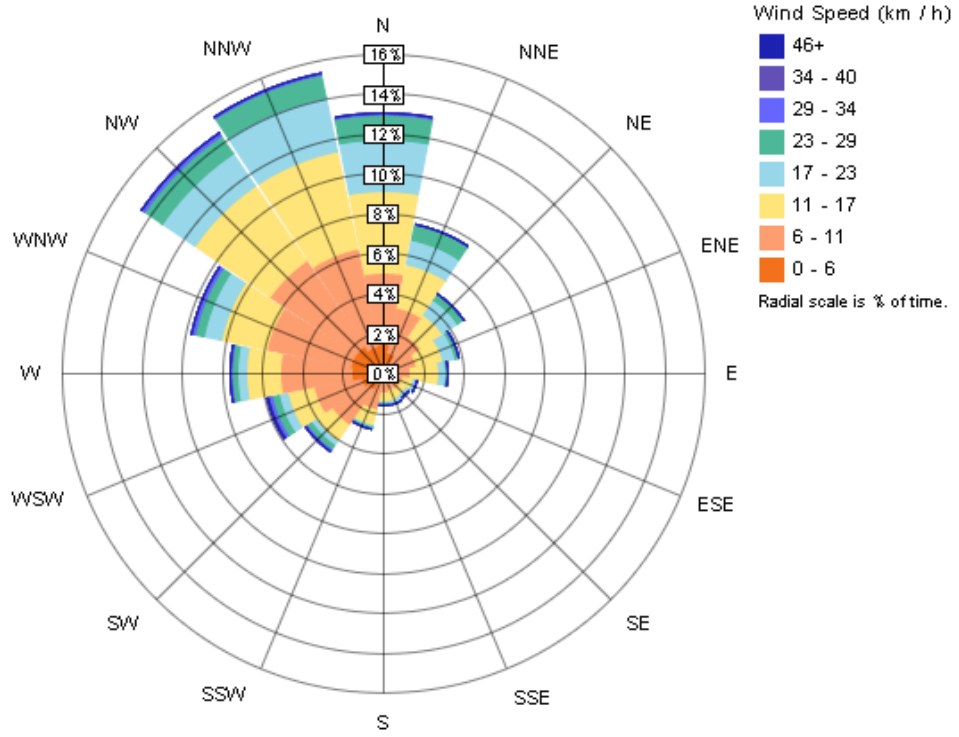


Figure 9. Annual Wind Rose (Speed Distribution) - researcher

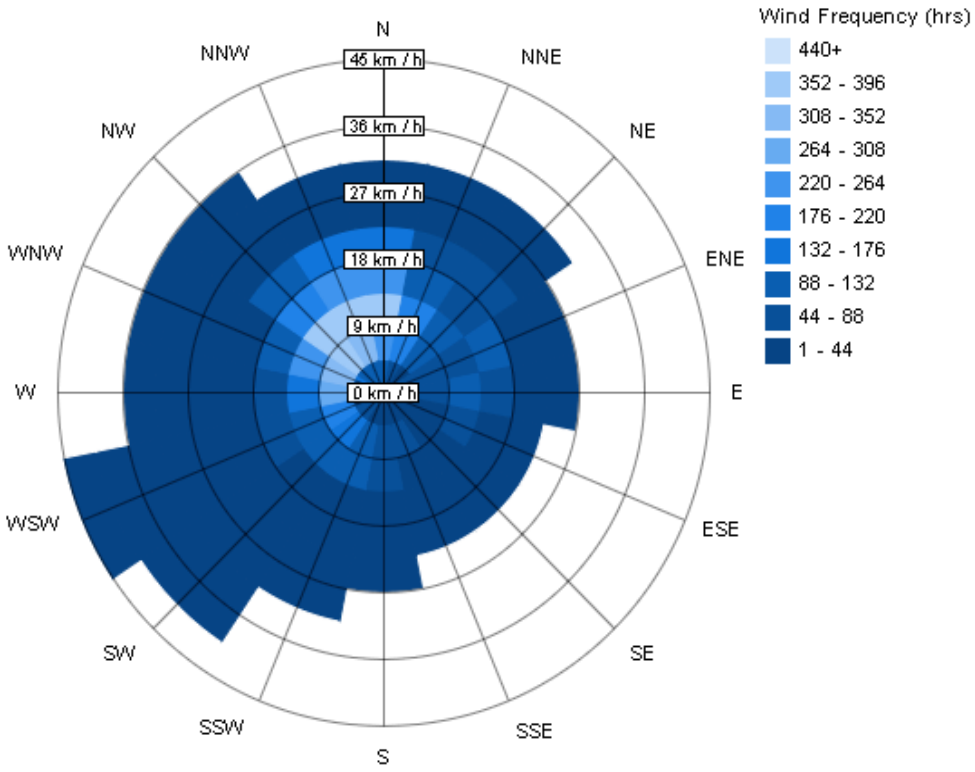


Figure 10. Annual Wind Rose (Frequency Distribution) – researcher

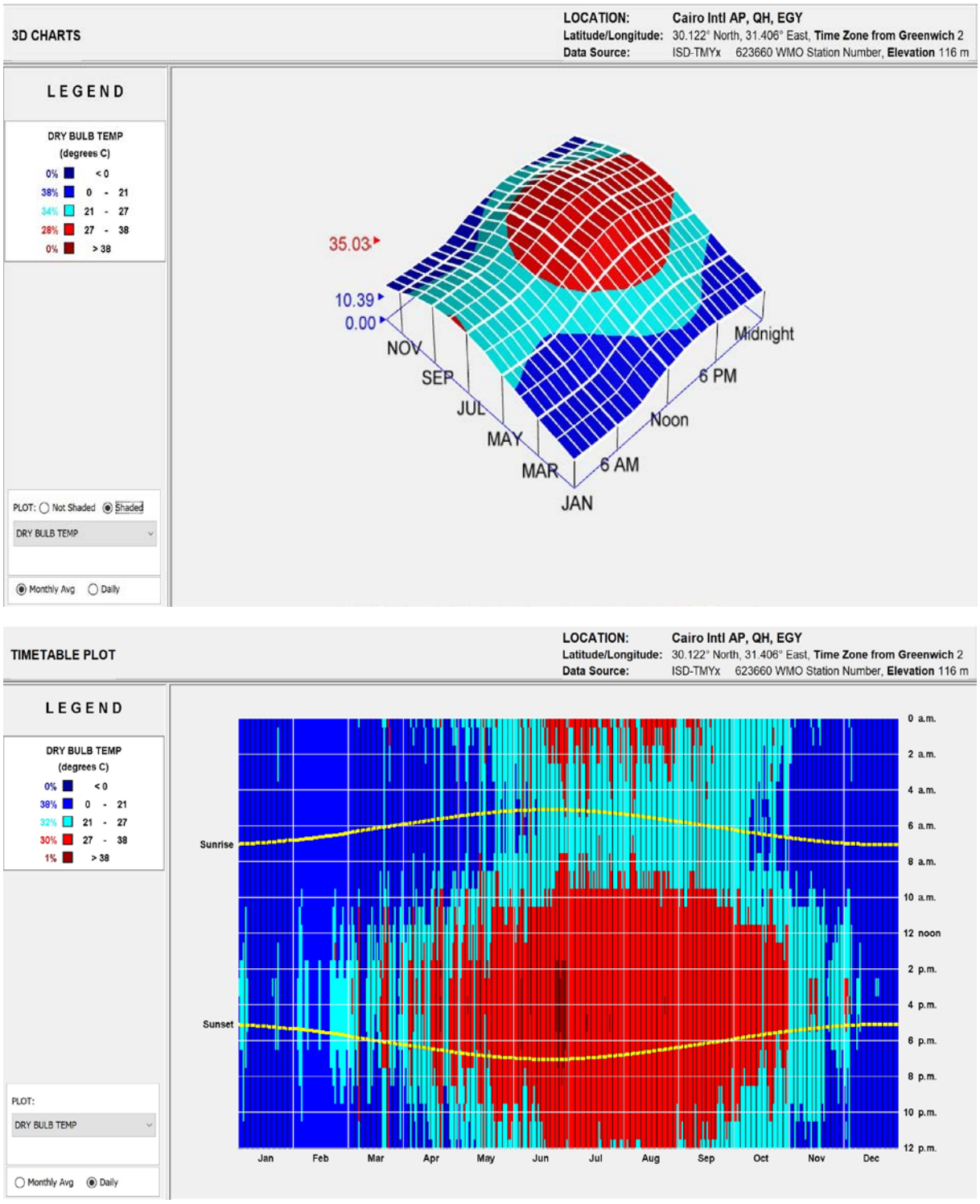


Figure 11. Direction, period, and wind speed

Figure 12. Main Entrance of Existing Hospital - researcher

Figure 13. Traffic flow at the main entrance - researcher

4.7. Existing Hospital Building Analysis

Existing Hospital building analysis indicates that there is no physical barrier (External Doors with Airlock) between the External Environment and internal spaces to control the indoor environmental quality level inside the hospital building. This results in improper indoor air quality and thermal comfort as well for building occupants. See figures 12 and 13.

Such irrelevant design considerations in a hospital building during the COVID-19 Pandemic, lead the hospital building to become a source of infection instead of controlling the infection within internal spaces [11,12]. Most internal spaces don't have sufficient natural ventilation, daylight, or artificial lighting due to the absence of accurate design parameters and calculations at an early stage, or due to implemented modifications or required changes within inner spaces in the absence of engineering and environmental studies in advance as studied. See figures 14 and 15.

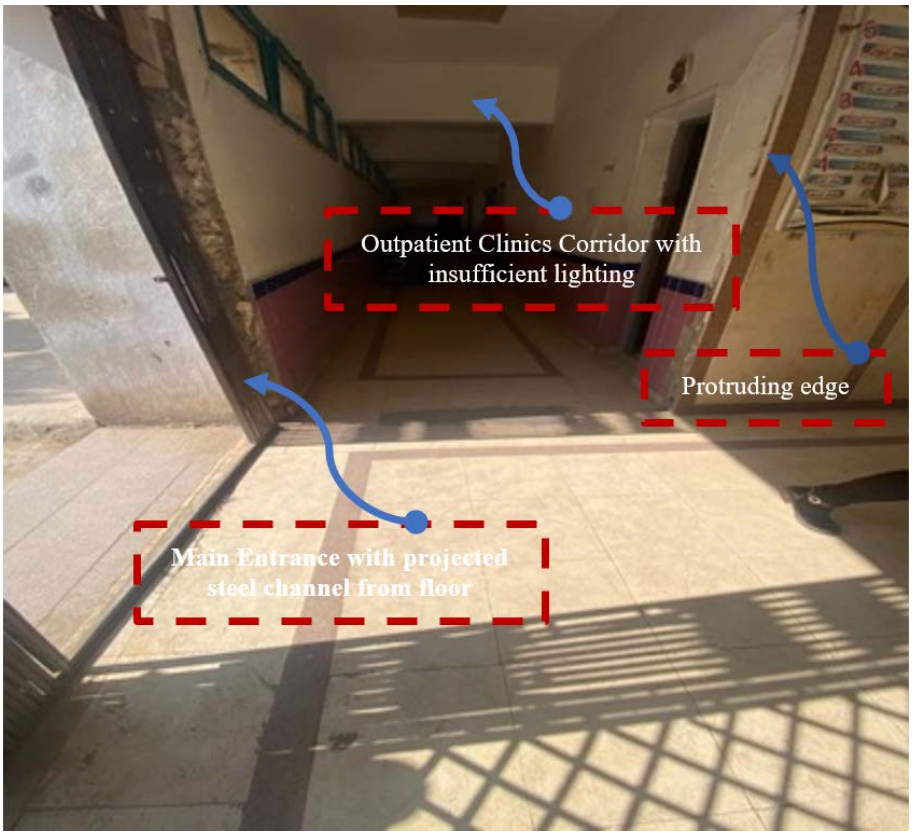


Figure 14. Outpatient Clinics Corridor – West Wing - researcher

Figure 15. Outpatient Clinics Corridor East Wing – researcher

The design considerations inside the hospital building for handicapped individuals didn't consider or secured the special circulation as per relevant standards (ADA) or relevant local code requirements in the design stage or throughout applied modification, such being ramps with irrelevant inclination inside the buildings and without a safe handrail (figures 16 and 17). The ground floor is provided with different levels that interrupt secured smooth flow and circulation for patients and building occupants instead of locating this ramp outside the building and adjacent to the main entrance with relevant facilities and design considerations as per relevant standards (figures 18 and 19). Patient, visitors, and administrative staff circulation are mixed and there is no tangible segregation area to control functioning circulation and reduce infection and avoid increasing pandemic consequences. Furthermore, there is no direct connection with the external natural environment or natural daylight on the ground floor especially noticed in the reception and nurse station area which made a negative impact on patient health and building occupants and decreased employee productivity. These parameters mainly increase the spreading of infection between building occupants, especially in the absence of proper ventilation within internal spaces. As illustrated in Figures 18 and 19, there is no direct connection with the external natural environment or natural daylight on the ground floor especially in the reception and nurse station. This has a negative impact on patients' and visitors' health and decreases occupants' and employees' productivity as well and mainly increases the spreading of the infection in the absence of proper ventilation within indoor spaces [13, 16-18]. C.T. scan room is ventilated with a split-unit air conditioner. This indicates that there is no fresh air supplied inside that critical space and meanwhile, there is no fenestration or opening with an external environment for ventilation or daylight. These irrelevant design criteria resulted in an improper indoor environmental quality that increases the possibility of infection within hospital internal spaces. The existing building envelope is designed to confirm that the concept for the external envelope is designed in compliance with the principle of little building penetrations reducing the heat transmittance and saving energy consumption (figures 20 and 21). That concept nowadays is invalid, especially with recent innovation in glazing system that is capable of reducing heat transmittance with better connectivity with the external environment. This shows that the external openings for most of the existing hospital buildings are insufficient to allow daylight to penetrate internal spaces with better connectivity. Such irrelevant strategies reduce the possibility of keeping building occupants connected with the external environment.

Figure 16. Outpatient Clinic assembly area without barriers with external contaminants/ atmosphere - researcher

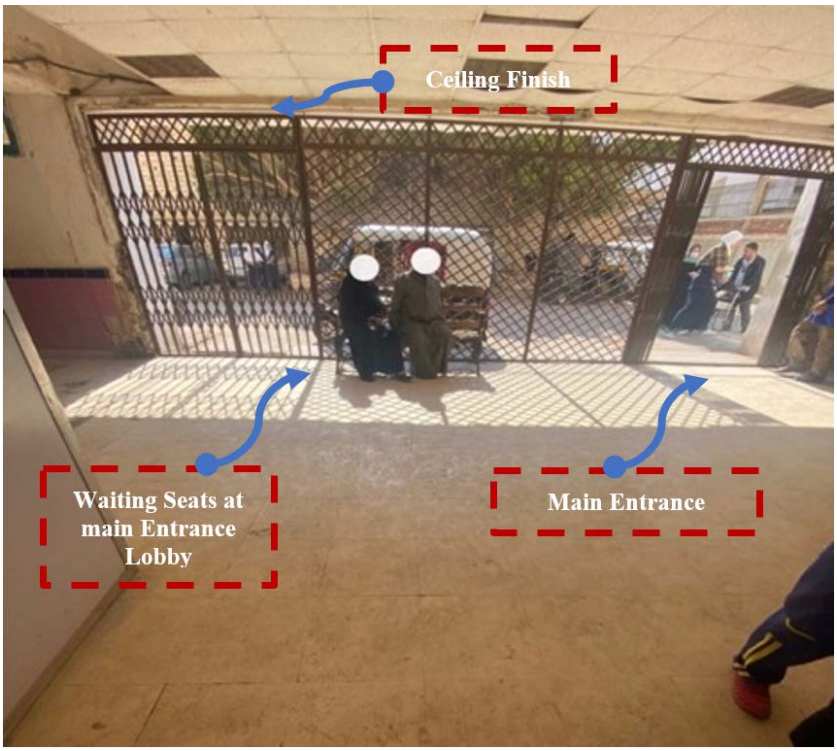


Figure 17. Outpatient Clinic assembly area without physical segregation with medical staff - researcher

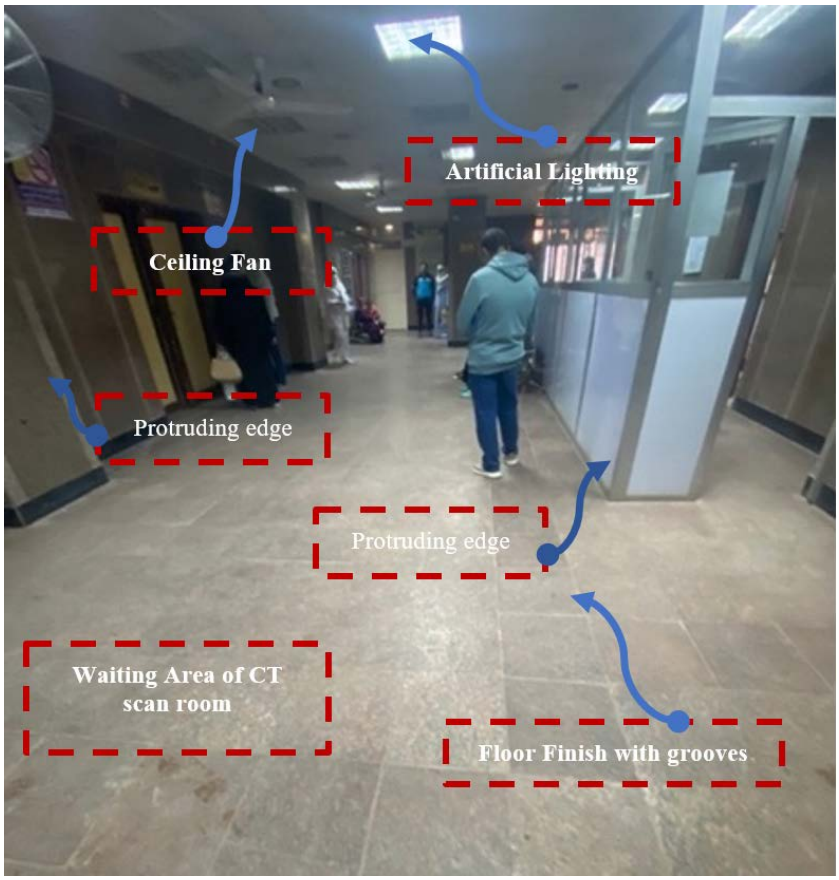


Figure 18. Reception and nurse station area with improper ventilation system - researcher

Figure 19. Corridor guiding visitors and patients to reception and nurse station - researcher

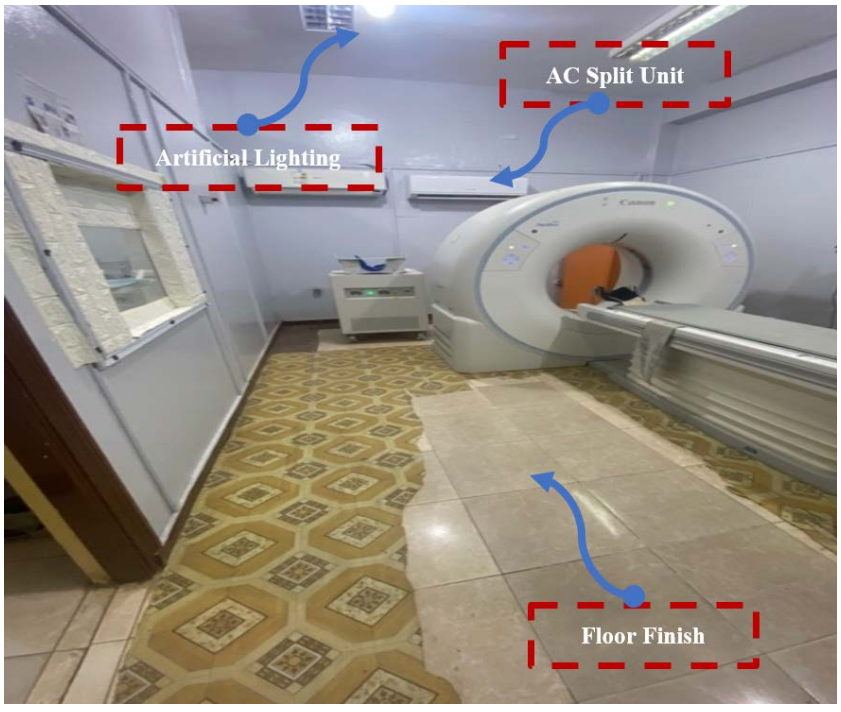


Figure 20. CT scan room with irrelevant ventilation system - researcher

Figure 21. CT scan room with direct access for patient and visitor - researcher

Figure 22. North and East Elevation – researcher

As illustrated in the above figure 22 for external hospital elevations, the window-to-wall ratio is insufficient to allow natural ventilation and daylight to penetrate inside internal spaces properly to sustain and satisfy the health of the hospital building occupants [10,14]. This issue of insufficient fenestrations at external elevations results in the external building envelope blocking the quality view between patients and the external environment, in addition to daylight prevention to internal spaces. All of these irrelevant design aspects, keep the indoor environmental quality at a low level with unhealthy spaces within the internal spaces of the hospital building (figures 23 and 24).

Patient Rooms have a 6-bids capacity per each. Patient rooms have been functioned to be operated as isolation rooms during the COVID-19 Pandemic, while they are not ready to accommodate that function for which they were not designed. Actually, they didn't consider the specific requirement to be achieved in an isolation room for minimizing infection from the unknown virus at the beginning of the COVID-19 pandemic. Most internal spaces are provided with artificial lighting lambs which are installed at the soffit of the patients' rooms and that is not sufficient to provide the area with satisfactory luminaires that make the space an uncomfortable zone which is supposed to be convenient for the patients and medical staff [15]. Lighting control is located collected in one place beside the main door Entrance and not controlled individually by the patient which creates a prospective interruption for the other occupants. See figures 25 and 26.

Figure 23. South Elevation – researcher

Figure 24. West Elevation - researcher

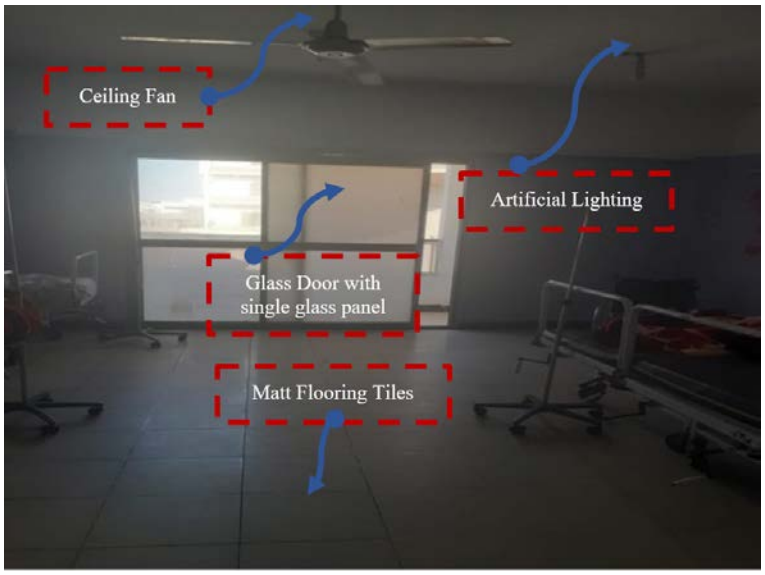


Figure 25. Isolation ward with ceiling fan - researcher

Figure 26. Isolation room with insufficient natural daylight-researcher

Figure 27. Patient/ isolation room indicates the improper indoor environmental quality - researcher

Through figures 27 and 28 the patient room is provided with exposed wall-mounted medical gas outlets for a patient with required respiratory gases as needed and many wall-mounted linear fluorescent lightings are installed randomly.

Changing the function of patient rooms to be operated as isolation rooms in the absence of infection control considerations causes increased infection level\rate among the inpatients within an isolation space as each patient's case differs from the other patients. See figure 29.

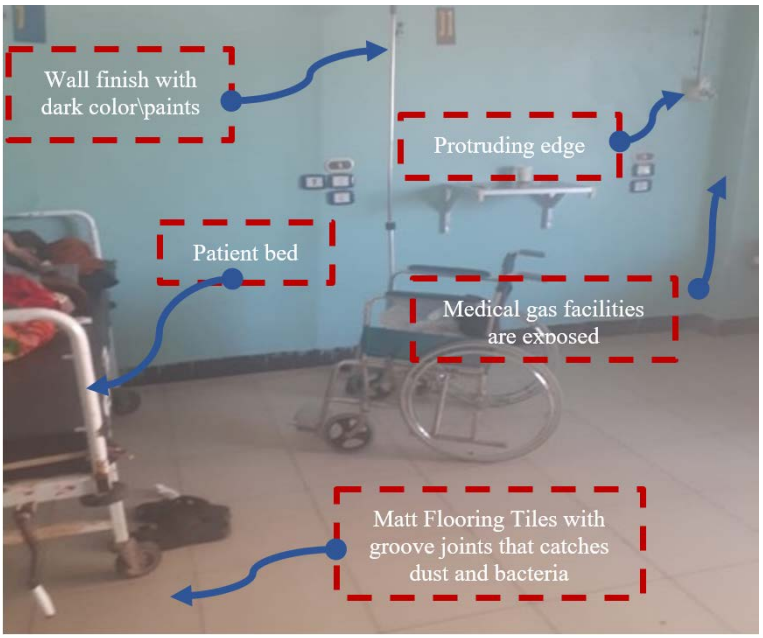


Figure 28. Isolation ward without privacy between patient - researcher

Figure 29. Public toilet for inpatient room – researcher

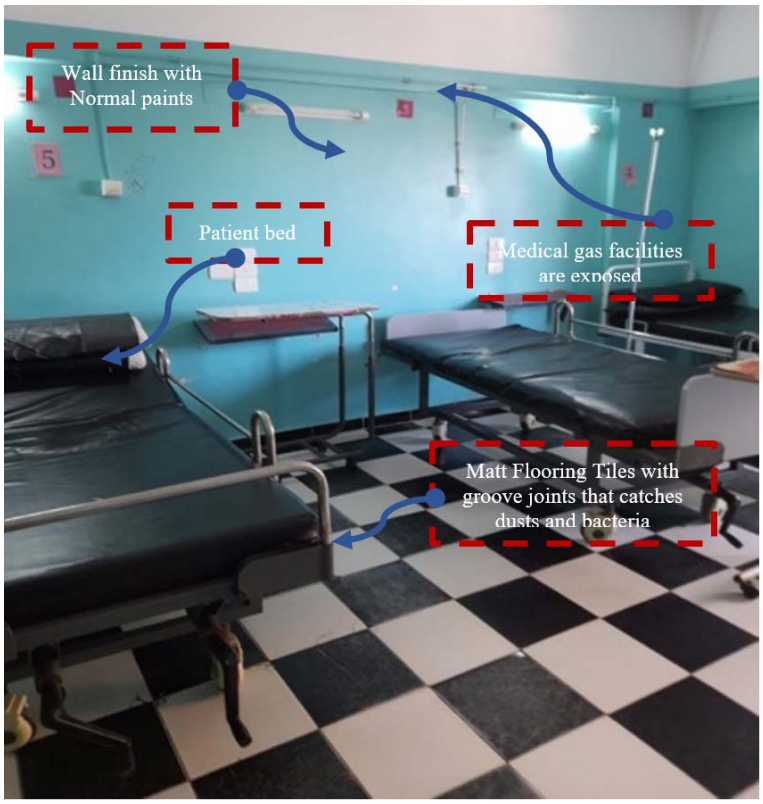


Figure 30. Isolation ward without privacy between patients – the researcher

Figure 31. Isolation room with improper environmental quality – the researcher

On the other side, internal ventilation from operable windows\ Balcony glass doors, and ceiling fans are increasing the infection rate (See figures 30 and 31). Those rooms (isolation) are to be ventilated separately by a dedicated ventilation system for better ventilation and to control infection and shorten the patient recovery period as well. See figures 32 and 33.

Figure 32. Inpatient Corridor without guardrail for patient - researcher

Figure 33. Inpatient Corridor with improper environmental quality - researcher

4.8. Conclusion of Hospital Building Analysis

The existing hospital building is suffering from unhealthy indoor environmental quality in different criteria as mentioned in the below Occupants' satisfaction questionnaire. See figure 34.

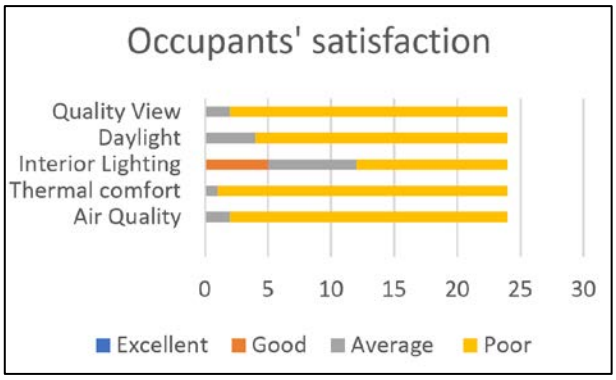


Figure 34. Occupants' Satisfaction of existing hospital building

5. Integrated Environmental Design Approach for Hospital Building

5.1. Building Envelope

The envelope building has the construction of solid red clay bricks with plastering on both sides of the exterior wall, this construction has a U-value of 4.051w/m2k, which means that the perimeter wall has good connectivity to heat transmittance which will increase heat transfer to internal spaces and will have negative impacts on thermal comfort parameters. External Windows are made of aluminum with transparent single glass 6 mm that doesn't provide a proper barrier for direct sunrays for reducing heat transfer which resulted in increasing internal space temperature and having negative impacts on thermal comfort for Hospital building's occupants. As for top roof construction detail, liquid bituminous paint is applied on the top roof concrete slab and it is covered with cement mortar with terrazzo tiles without thermal Styrofoam material that promotes insulation criteria to reduce heat transfer to internal space at a higher level.

5.2. Direct Exterior Access and Open Space

Direct Exterior access features are not considered at all in the current hospital building due to the absence of green areas or outdoor spaces or being of exterior gardens as indicated in the site layout of the Hospital building.

5.3. Green and Low Emitting Materials

Hospital buildings' materials in the current renovation stage were specified with no specific requirements of VOCs emission as a conventional design process without specified limitation of reduced concentration of chemical contaminates. Such a process will result in increasing the exposure possibility of building occupants to a prospective risk to health, especially the patients. Indoor air quality within the hospital building became unhealthy renovation process during hospital Building operation without precaution and compliance with regulations and standards

in such cases of construction due to the existence of contaminates particles that resulted from emitted VOCs materials which increases the opportunities for negative impacts on the hospital building occupants, especially the patients.

5.4. Indoor Air Quality

Indoor quality is not satisfactory inside the hospital building due to the absence of proper ventilation for indoor air. Most of the existing hospital building's spaces are provided with ceiling fans for a little improvement of human thermal comfort. Such ceiling fans in hospital buildings are increasing the possibility of infection among building occupants, especially when there is no exhaust system for the indoor air even with operable windows. The main reason for the reduction of indoor air quality is using an air conditioning split-unit air conditioning system that is not improving air quality with make-up air and only recirculates indoor air with the same quality level.

5.5. Thermal Comfort

Thermal comfort parameters in existing hospital buildings are not considered in design such as air conditioning systems with controlling temperatures to keep indoor temperature satisfied to building occupants and controlling the humidity with building spaces in acceptable levels as recommended by relevant regulations and standards ASHRAE 55-2010 and local code requirements. Specifying a glazing system with a clear single glazing layer without sunshade devices resulted in increased heat transmittance which made a negative effect on occupants' thermal comfort within hospital spaces. Natural ventilation within the patient room is insufficient for all inpatients due to window opening size versus to total floor area as specified in the FGI reference guide as mentioned in (2.1-7.2.2.5 Windows). Operable windows are not required in patient rooms [19]. If operable windows are provided in patient rooms or suites, the operation of such windows shall be restricted to inhibit possible escape or suicide.

5.6. Interior Lighting

The hospital building is designed with artificial lighting provision without dedicated lighting power density calculation for each space as requested by relevant regulations and standards and local code requirements where each area has a specified amount of light density power depending on room function. External walls are designed and constructed from the brick wall with integrated windows which provide the hospital building with insufficient natural daylight that promotes indoor artificial lighting all day and night. Sufficient daylight with control detectors that are controlling artificial lighting in case of being satisfactory natural daylight with a relevant opening size of fenestration, which will result in promoting inpatient health and sustaining indoor environmental quality, and increasing energy efficiency for the Hospital Building.

5.7. Natural Daylight

Daylight in hospital buildings is considered in the design stage by specifying curtain exterior walls with fenestrations to provide natural daylight inside internal spaces and to secure connectivity between hospital building occupants and the external environment but actual fenestrations opening size are not sufficient to achieve and maximize natural daylight due to deep floor plate for inpatient room. Daylight penetration inside internal spaces did not consider in energy saving due to the absence of daylight control detectors that can make operation shifting with artificial lighting which will promote energy saving and improve building performance.

5.8. Quality View

Quality views are attained partially through window openings that are provided in external walls at the hospital building perimeter. Most views are limited with a direct line of sight to the external outdoors through glazing for the inpatients' spaces.

5.9. Acoustic Performance

Acoustic performance hasn't been specified in the design stage and Acoustic performance was partially attained for the existing hospital building from the material itself without additional study or calculation for further improvement of Acoustic performance. The Hospital building is a noisy place based on actual site visits and most of the inpatient and building occupants are suffering from those critical issues. Exterior noise is penetrating internal spaces without further architectural treatments or other medication processes to promote indoor environmental quality. External walls are not insulated with relevant construction detail at all to reduce noise penetration for building occupants and inpatients as well. External glass windows are provided with a clear single layer of 6 mm which has good connectivity to sound penetration that makes interior spaces noisy. Acoustic performance in most spaces if not all is not compliant with regulations and international standards or local code requirements [20]. Sound isolation of the proposed façade glazing in this hospital project is to be defined with the metric Rw. The Façade glazing sound isolation is determined by one of two methods. The first method involves measuring the noise from traffic and other elements at the façade. The second involves calculating and predicting the future noise level at the site. The perimeter of the window frame should be acoustically sealed into the window opening so there is no leakage of noise between the window frame and the building opening.

The proposed construction detail to achieve the required acoustic performance is as follows in figures 35, 36 and 37.

The sealing method as proposed should allow for any movement of the window frame relative to the building opening so that the acoustic performance is maintained. The researcher recommends a method of sealing the gap between the window and the building opening. A 10mm to 15mm wide gap should be left between the window frame and the building opening. The gap between the window frame and the building opening should be caulked with non-hardening flexible mastic. Often the construction elements between the room and the façade are overlooked and lead to noise leaks between two different tenancies. To prevent this issue, we recommend that the architecture team coordinate these details between the façade consultant and the acoustic consultant. Given below is a sketch of a typical mullion and wall interaction detail. See figure 38.

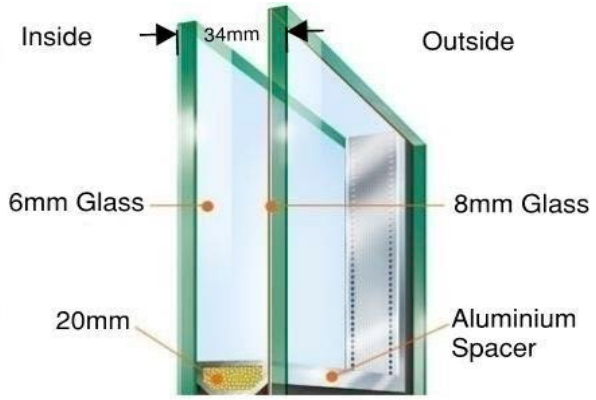


Figure 35. Double glazing type 1

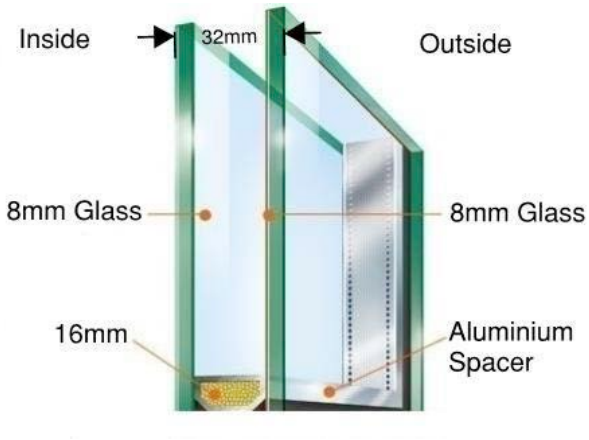


Figure 36. Double glazing type 2

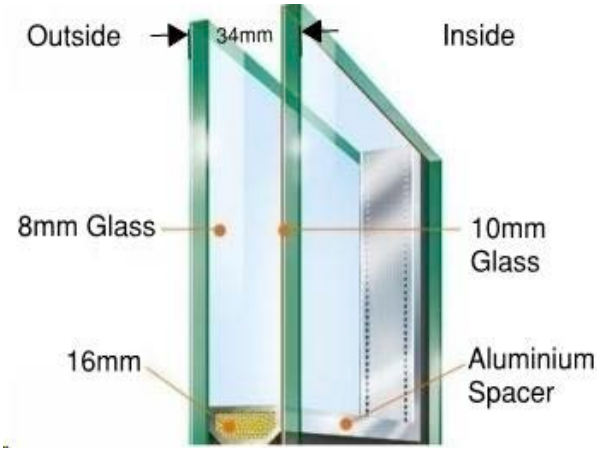
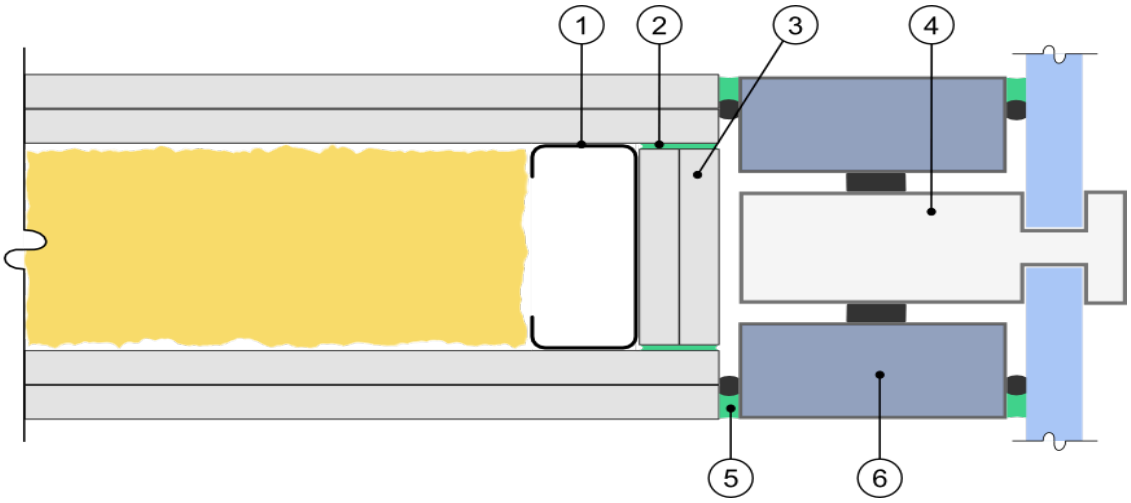


Figure 37. Double glazing type 3



1) Steel stud with back towards mullion

2) Acoustical caulk (green)

3) 16mm gypsum wallboard: number of layers to match partition design (minimum of 2 layers on either side)

4) Vertical curtain wall mullion, typically an aluminum extrusion

5) Acoustical sealant supported with foam backer rod on both sides

6) RSIC-AMI noise control mullion assembly (both sides) from floor deck to floor deck

Figure 38. Typical mullion and wall interaction detail

6. Proposed Guideline of Indoor Environmental Quality for Hospital Building

Hospital buildings need a sustainable methodology to get a good indoor environmental quality of healthcare buildings for better and safer performance and operation safely via providing indoor air quality and thermal, visuality, and acoustic comfort to safeguard the health and comfort of the hospital building's occupants. High-quality of indoor environments within hospital building supports productivity, reduces absenteeism, promotes the building's value, and decrease liability for building designers and owners as well.

Hospital buildings with better quality of indoor environments conserve the health and comfort of hospital building occupants. That commitment and as outcomes of a research study the following is the principle of the guideline of Indoor of Environmental Quality for Hospital Buildings. See figures 39 and 40.

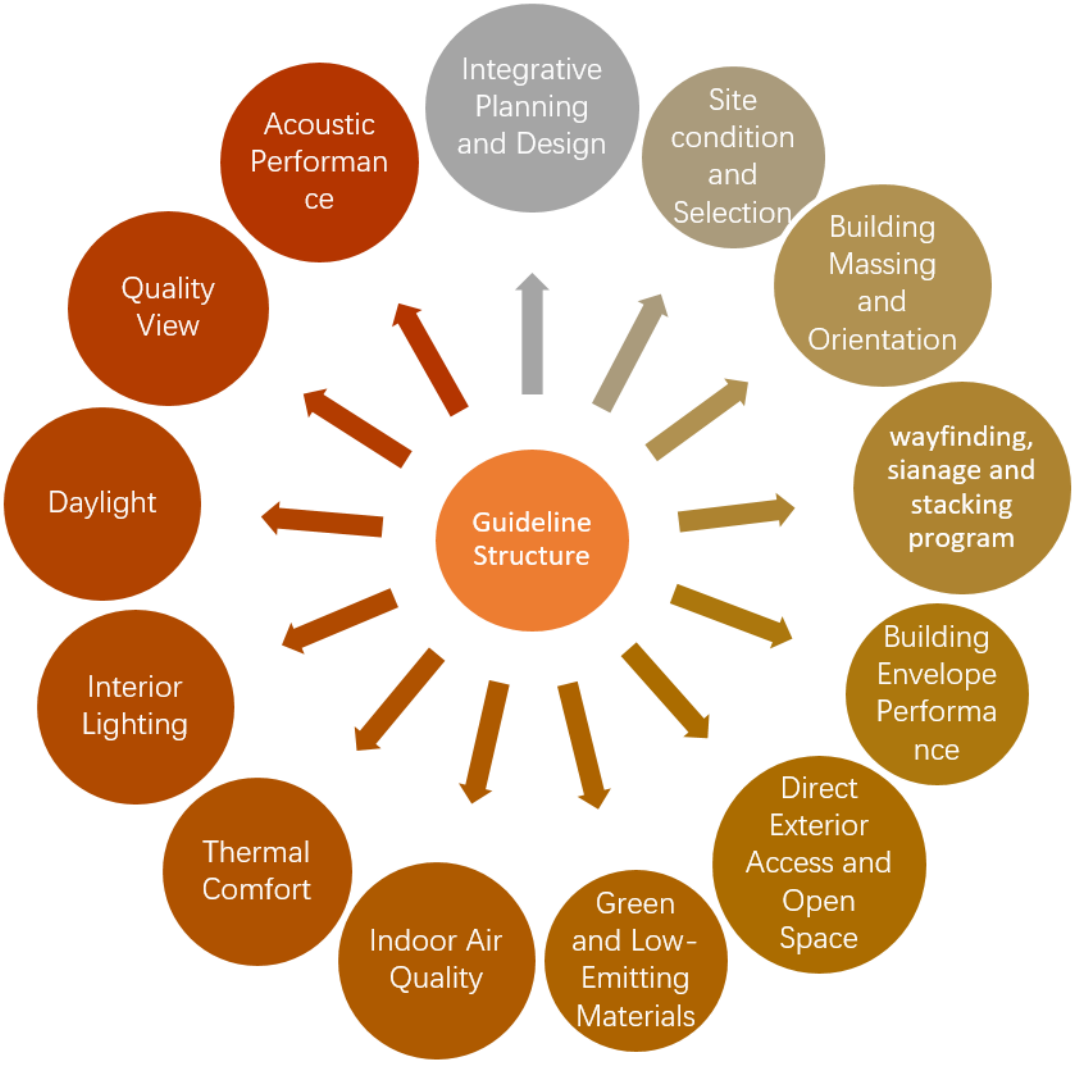


Figure 39. Proposed guideline and Framework Structure

Figure 40. Proposed Parametric Design Guide of Indoor Environmental Quality

7. Application Process

7.1. Proposed Framework for Better Indoor Environmental Quality

Patient room location and orientation is a major and critical points in the hospital building design stage for getting better building performance in Building function or circulation via harvesting natural daylight and easy ventilation which, in turn, results-in improving in building performance and optimization. Better thermal comfort along with securing a good view will improve indoor environmental quality that will support and achieve patient satisfaction and well-being and increase employee productivity.

Occupants' comfort is myriad criteria in the design stage and will be achieved successfully by Environment respect and by promoting Indoor Environmental Quality. Keeping the main corridor and waiting for areas connected with the natural environment in Hospital Building will result in increasing the employees' productivity and comfort. The Nurse station is to be located at a prime location between the patients' rooms and isolation rooms to serve medical services professionally as planned for all inpatients and to be well communicated throughout the proper facility (nurse call system) with all patient\ isolation rooms as needed to monitor all cases carefully as categorized. Providing interior spaces with better Indoor air quality and sufficient lighting in corridors and nurse stations will promote occupants' comfort and shall result in increasing employees' productivity which will be reflected positively in providing medical services for all patients and will also lead to a short patient staying period in the hospital building. As illustrated in figure 41, the corridor of patient rooms and isolation rooms is provided with satisfactory artificial lighting and is well distributed to promote indoor space quality and is also penetrated by the external natural daylight from the end of the corridor.

Figure 41. Proposed Patient and isolation room - designer Norman Foster and adopted by the researcher

Corridor space is provided with supply and return AC diffusers and returned air is ducted to reduce air contaminates and infection as well. All of these considerations will improve and promote indoor environmental quality within the hospital building's spaces and will result in getting better indoor air quality and well-being, which increase occupants' productivity and patients' satisfaction, in addition to energy conservation and environmental respect. As shown in figure 42, a Patient room with direct connectivity to external natural daylight is promoting indoor environmental quality and subsequently patient has better health with a shortened staying period in the hospital. Selected finishing materials considered the light color for better reflectivity to distribute lighting inside the space properly and nominated green material with low emitting to support and promote indoor environmental quality. An operable Curtain is installed on external fenestration to reduce natural lighting glare and reduces heat emittance that increases energy consumption. Patient and Isolation rooms are designed to provide well-being and to promote Indoor Environmental Quality by making the patients connected to External Environment through curtain wall\ windows opening that allows natural daylight to penetrate inside the rooms. These design criteria are supporting environmental respect and preservation of natural resources throughout reliance on natural resources, daylight, sunlight, and natural ventilation throughout fresh air or mixed fresh air with air-conditioning. The revised and final product\ design of patients' rooms and isolation rooms promotes and supports infection reduction inside hospital buildings which, in turn, shortens the staying period of patients and healing recovery during the COVID-19 Pandemic.

Figure 42. Proposed Patient and isolation room - designer HDR and adopted by the researcher

7.2. Hospital Building Questionnaire for Occupants' Satisfaction with Applied Proposed Design Parameters of Indoor Environmental Quality

A questionnaire for evaluating proposed Hospital Building Satisfaction with Indoor Environmental Quality after the implication of the proposed indoor environmental quality of design parameters on patient rooms and related facilities. The questionnaire was distributed to hospital occupants (administrative staff, medical staff, visitors, patients, Architects, educators, and others) to evaluate indoor environmental quality and survey the developed hospital building. The questionnaire has been analyzed in

detail by direct field observation of Indoor Environmental quality within the hospital buildings that were developed according to the proposed framework and methodology. A set of proposed design parameters were included in the questionnaire to assess the proposed condition of indoor environmental quality of developed spaces of the hospital building and to discover building users' and occupants' satisfaction (figure 43). The evaluation depends on the four degrees of occupant satisfaction [levels 1,2,3,4]. Grade 1 is Excellent, grade 2 is Good, grade 3 is Average and grade 4 is Poor. See Table 5 and figure 44.

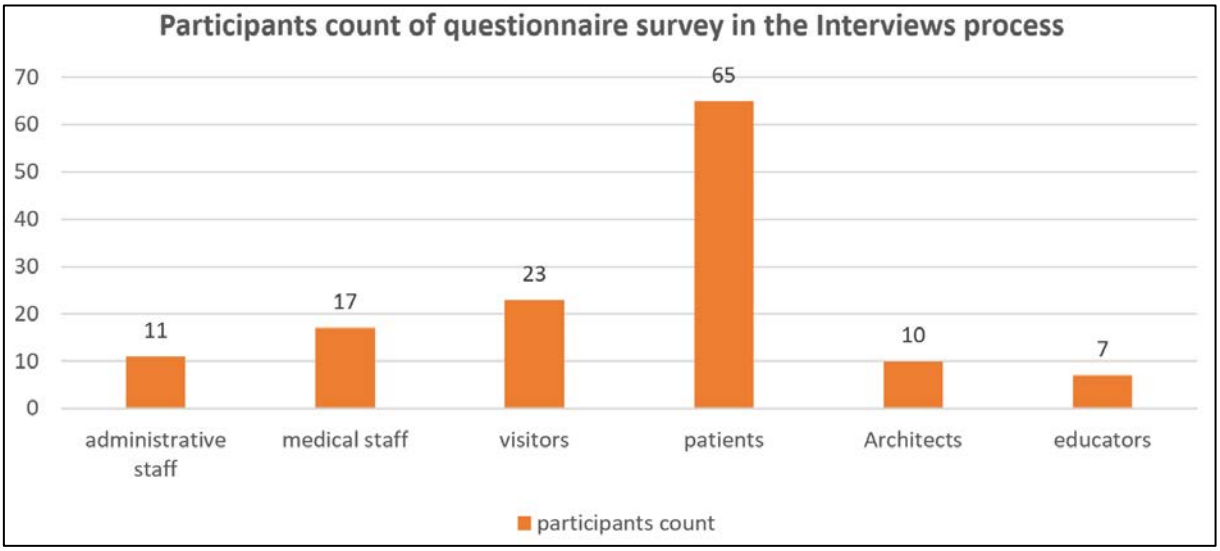


Figure 43. Participants count of a questionnaire survey in the Interviews process – researcher

Table 5. Building Occupants Satisfaction Survey - researcher

Problems with IEQ inside developed Hospital Buildings	**Count**				**Percentage (%)**	
Occupants' satisfaction for a developed Hospital Building	Grade 1	Grade 2	Grade 3	Grade 4	Good	Bad
Building Formation and orientation	120	11	2	0	100	0
wayfinding, signage and stacking program	120	13	0	0	100	0
Finishing Materials	125	8	0	0	100	0
Low-Emitting Materials	130	3	0	0	100	0
Direct Exterior Access and Open Space	115	18	0	0	100	0
Building Envelope Performance	117	16	0	0	100	0
Indoor Air Quality	128	5	0	0	100	0
Interior Lighting	110	18	5	0	100	0
Daylight	133	0	0	0	100	0
Quality View	133	0	0	0	100	0
Thermal Comfort	107	20	6	0	100	0
Acoustic Performance	99	34	0	0	100	0

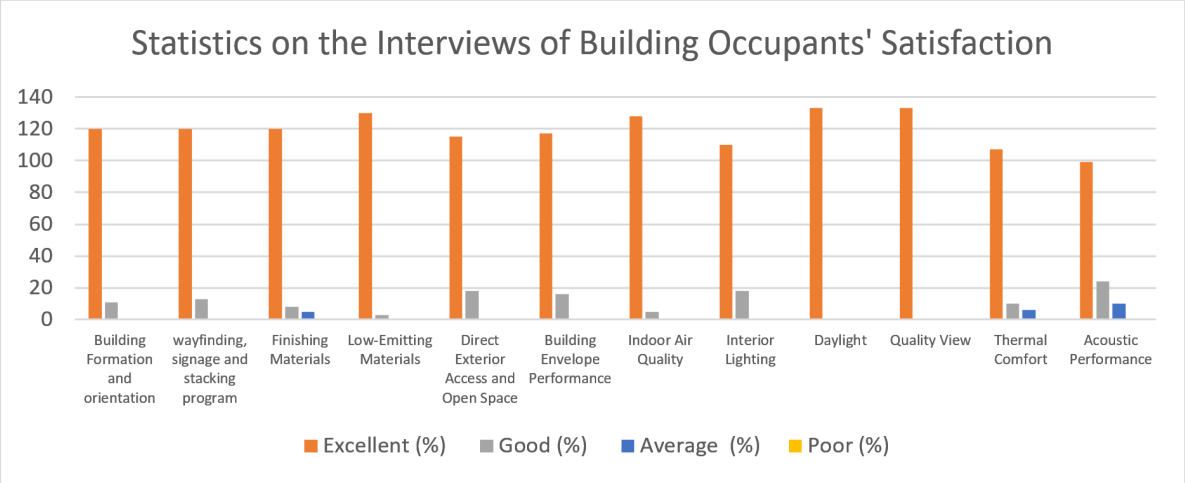


Figure 44. Occupants' Satisfaction Chart – the researcher

8. Discussion

This paper uses a qualitative and quantitative approach to present a developed sustainable framework for better and healthy Indoor Environmental Quality in healthcare facilities. As healthcare facility design is complicated, and medical planning with accurate decision-making is highly precious at the early stage of design to facilitate sustainable parameters for better hospital building function and performance, contributions from healthcare building experts were acquired to get a complete assessment. The review of related literature and gathered opinions from the experts, Buildings occupants, and concerned parties as indicated in the questionnaire process after and before building occupancy sustained the development of a sustainable framework. Developed Indoor Environmental Quality in healthcare buildings as studied in this paper has positive potential impacts on patient health and improving building occupants' productivity.

9. Conclusions

This research paper examines the theory and practice of sustainable methodology of Indoor Environmental Quality in healthcare Buildings in Egypt, the research has justified and provided a proposed framework and guidelines for integrating sustainable indoor environmental quality into healthcare buildings. This proposal is in line with the holistic approach to green hospital criteria which aims toward sustainable development for Healthcare Buildings. It is significant to preserve the main benefits behind promoting the strategy of indoor environmental quality within healthcare and Hospital Buildings, as follows:

- Sustainability experiment in Hospital Buildings Design through Sustainability application is an integrative effort to transmute the way and approach build environments from an individual building to get neighbourhoods and even whole communities designed, constructed, and operated with full esteem of environment conservation which is a shift practice towards higher performance, lower environment negative impacts, and ultimately reformative Healthcare and Hospital buildings.
- The green hospital building is a method that is fulfilled and implemented in hospital buildings, Sites selection, Interior spaces, operations performance, and the communities in which they are placed and considers holistically natural, human, and economic systems and reaches solutions that encourage quality of life for all whole occupants.
- The indoor environmental quality system as addressed throughout the research study is a significant tool that a design team uses to ensure that a project's green features are accurately designed, constructed, and accounted for.
- Healthcare buildings with a better-quality indoor environment protect human health and comfort and sustain the well-being of building occupants that affect how people learn, work, and live.
- High-quality indoor environments enhance employee productivity, decrease absenteeism, promote the Hospital building's value, and decrease liability levels for building designers and owners.
- Hospital Buildings considering sustainable design criteria of indoor environmental quality at an early stage of design are diluting pollutants caused by a building's occupants and other pollutant sources that create better air quality, contributing to the occupants' comfort and well-being.
- The research outcomes, confirm that the Sustainability integration in healthcare building design is the capability of the current generation to congregate its requirements without compromising the capability of future generations to fulfill their requirements.10. Recommendation

This research is discussing how indoor environmental quality is a critical solution to the problem caused by the

woeful condition of most of the current hospital buildings in Egypt. To activate and validate the proposed sustainable methodology for indoor environmental quality in hospital buildings as a result of the research study, below is the list of recommendations for better adaptation to most of the current hospital situations in Egypt. Finally, it is important to keep the main reasons behind developing the indoor environmental quality system within healthcare buildings in perspective during the elaboration, review, and evaluation of the process, namely:

- Early consideration of potential impacts (Precautionary Preventive and corrective action principles), including cumulative and synergistic impacts that are often difficult to identify at low tiers/project levels.
- Better consideration of alternatives.
- Enhancing the accountability and the efficiency of strategic decision-making (clear and verifiable procedures/independent review);
- Stakeholder involvement for more transparency and better governance.

Declaration of Competing Interest

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

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