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كلية الدراسات العليا

Low daylighting performance in hospitals

(Case study Alomalem medical city –Khartoum)

انخفاض اداء الاضاءة الطبيعية في المستشفيات

(دراسة الحالة مدينة المعلم الطبية- الخرطوم)

A Thesis by

Alaa abdalatif Altahir Algemeabi

Supervisor

Dr. Mustafa Haj Abdalbagi

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Dedication

This research is dedicated with gratitude:

To my parents and my sisters who helped and encouraged me to be here.

To Sudan University of science and technology.

To all who strive to improve this country.

To all who helped me in my life.

Acknowledgement

First of all. My deep thanks to Allah who give me the power and patient to complete this work. I am deeply grateful to my supervisor Dr. Mustafa Haj Abdalbagi for his patiently listening, valuable advices and encouragement throughout the research. I would also like to thank all the doctors who teach me in master program.

Another thank to Department of Architectural Engineering in Sudan University and Al-moalem medical city administration for their collaborating. My big thanks also goes to every person helped me in this research.

Abstract

Many studies and researches proved that daylighting has positive effects on human's Psychology, health and performance in addition to it's role in improving indoor environment quality, energy saving and building's sustainability. In hospitals daylighting is very important factor to create a good healing environment because daylighting contribute to patients' outcomes such as shorter length of stay, reduced stress, increased patients satisfaction and other, but in Sudan, hospitals daylighting is a neglected issue although it's important role in penitent's health , staff performance and visitor impression , is a must.

This research aims to improve performance of daylighting in hospitals in Sudan and investigate the reasons behind the low performance of daylight in hospitals. In order to achieve that, experimental method is used to assess the current situation in Almoalem medical city.

The research concludes that the performance of daylighting in Almoalem hospital is signifcantly poor. That result from firstly design problems such as space's design , orientation , materials and colours used inside spaces in addition to windows distribution and glass type. Secondly legalizations problems such as many hospitals are not designed as hospitals but they are converted later on to be hospitals without consideration to the health building requirements.

Therefore, the research recommends giving more consideration for daylighting in design process from planning up to interior design, making daylighting legalization clearer and more effective in list of building's organization. In addition to Further studies needs to be done to provide more data.

المستخلص

أثبتت الدراسات والأبحاث أن الإضاءة الطبيعية لها آثار إيجابية علي نفسية الإنسان وصحته وأدائه , بالإضافة الي دورها في تحسين جودة البيئة الداخلية وحفظ الطاقة وإستدامة المباني . في المستشفيات الإضاءة الطبيعية عامل مهم جدا في خلق بيئة علاجية جيدة لأن الإضاءة الطبيعية تساهم في تحسين النتائج المتعلقة بالمريض مثل تقليل فترة بقاء المريض في المستشفي , تقليل الضغط النفسي عند المريض , زيادة الاحساس بالرضي عند المريض و فوائد أخري. لكن في السودان الإضاءة الطبيعية أمر مهمل بالرغم من دورها المهم في صحة المريض و أداء الطاقم الطبي وإعطاء الانطباع الجيد للزوار.

هذا البحث يهدف الي تحسين أداء الإضاءة الطبيعية في المستشفيات في السودان وكشف الأسباب وراء ضعف أدائها ولتحقيق ذلك تم إستخدام المنهج التجريبي لتقييم الوضع الحالي في مدينة المعلم الطبية.

خلص البحث الي أن أداء الإضاءة الطبيعية في مستشفي المعلم ضعيف للغاية وذلك نتيجة للآتي: أولا مشاكل تصميمية مثل تصميم فراغات المستشفي , التوجيه , المواد والألوان المستخدمة في الفراغات الداخلية بالإضافة الي توزيع الشبابيك ونوع الزجاج المستخدم فيها. ثانيا مشاكل تشريعية مثل أن معظم المستشفيات لم تصمم كمستشفيات ولكن تم تحويلها لاحقا الي مستشفيات بدون مراعاة متطلبات المباني الصحية.

كما أن البحث يوصي بإعطاء إهتمام أكثر للإضاءة الطبيعية في عملية التصميم من مرحلة التخطيط الي مرحلة التصميم الداخلي , كما يوصي بجعل معايير الإضاءة الطبيعية أكثر وضوحا وتأثيرا في لائحة تنظيم المباني , ويوصي بضرورة عمل دراسات إضافية تقدم تفاصيل إضافية.

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CHAPTER ONE

GENERAL INTRODUCTION

1.1 Introduction

Hospital environments present special challenges continuously during the running time of the hospitals. Several studies that are related to healthcare design showed dissatisfaction from hospital environment, such as comfort, lighting, IAQ (indoor air quality), temperature, humidity, and noise (Sahar Diab eta ,2017). In this research we will focus on lighting specially daylighting in hospitals which considered one of the important factors influence directly on human functioning and healing environment quality.

Light is critical to human functioning in that it allows us to see things and perform activities. But it is also important because it affects human beings psychologically and physiologically. Several studies have documented the importance of light in reducing depression, decreasing fatigue, improving alertness, modulating circadian rhythms, and treating conditions such as hyper-bilirubinemia among infants. Further, the presence of windows in the workplace and access to daylight has been linked with increased satisfaction with the work environment. Studies also show that adequate light levels are linked to reduced medication- dispensing errors in pharmacies. (Mehrotra, Basukala,Devarakonda, 2015,p 54-55). for hospitals Numerous studies have indicated that daylight has significant effects on the wellbeing of humans both physically and psychologically. Campbell et al. (1988) imply that light is the most important environmental input in controlling bodily function after food (La Grace, 2004). Similarly, CABE (2004) clearly indicate that access to natural light is one of the crucial factors affecting patients' recovery. The presence of visible light in an indoor environment does influence the physiological responses, mood as well as visual needs (S. ARIPIN, 2007,p.174). also Daylighting and external view can contribute significantly to patients' healing, and help reduce pain and length of stay in hospitals , moreover daylighting could help increasing effectiveness in delivering care, patient safety and overall healthcare quality (Sherif, etal, 2015, p 1383).

As a matter of the fact, natural daylight is often regarded as part of the healthy environment. Therefore, daylight is required in most areas in hospital buildings as one of the crucial physical aspects to be considered in the healing environment .and it plays an important role and an integral part of the hospital's healing environment (S. ARIPIN, 2007,p.174).

1.2 Problem Statement

The growth of the workplace in the nineteenth century had seen buildings requiring higher levels of light , the pressure to increase the levels of light in buildings came from the utility companies further the economies of structure had meant that ceiling heights had been lowered and the decision of architects to plan buildings depend on electric sources made daylight disregarded as a functional source. Hence we became see the location and form of windows more formalized, often being less well related to the interior spaces they served . . . the elevation and the appearance of the building seen from the outside, became of prime importance, a consideration which lingers on today. so appear low daylight performance as a problem in buildings in this decades in addition to it consider one of factors cause sick building syndrome (SBS).But now the world goes toward sustainability which considers daylight one of the most important factor in sustainable design but the problem of low daylighting performance still exist in many countries especially the developing countries. in this research this problem will be studied in hospitals in consideration of it's high sensitivity toward daylight which effects on many aspects in hospital such as:-

- Biological aspect (reducing Cancer Possibility, normal Bone Formation, regulization normal circadian rhythms, increase sleep quality, increment of energy……ect).

-psychological aspect (prevent from Depression, Stress, Sadness, Violent Behavior and reducing Mental Performance ……ect).

-Economical aspect (decreasing energy consumption, increasing individual productivity, reducing running cost).

-Environmental aspect (decrease combustion of greenhouse gases, thus indoor and outdoor environment quality has been meliorating).

Sudan is not far from world in this side .It is noted that daylighting design in Sudan hospitals does not take sufficient concern for daylighting design in hospitals and compatible with users needs (Visual, biological and Psychological needs). So this research will discuss the problem of low performance of daylighting in Sudan hospitals.

1.3 Importance of the Research

The importance of this research is:-

1- Limited studies and researches in this field especially in Sudan.

2- Finding solutions and practical steps to assist improving investment of natural lighting in Sudan hospitals.

3- This research will contribute in finding solutions for energy consumption problem in hospitals.

4- Highlighting the design of hospitals in an attempt to find specifications for improving visual and healthy environment in hospitals in Sudan.

1.4 Research Aim

The research aims to improve daylighting performance in Sudan hospitals.

1.5 Research objectives

1. To identify the problem of low daylighting performance in hospitals.
2. To explain the great importance for daylighting in building design as general and hospitals especially.
3- To study Parameters influencing daylighting performance.
4-To propose design recommendations that help improving natural lighting in hdspitals in terms of quality and quantity.

1.6 Research questions

1- Is daylighting important for hospitals?

2- Is the decreasing or increasing of daylighting's levels has direct impact on users?

3-Is proper daylighting design reduce energy consumption in hospitals?

4- What are the causes of poor daylighting design in hospitals?

5-What are the solutions to provide suitable daylighing's levels in hospitals?

1.7 Research limits

-This research examines hospitals in Khartoum; it focuses on hospitals, which suffers from natural lighting design problems.

-In this research the daylighting assessment supposed be achieved by daylighting assessment device and daylighting analysis program but for many international websites are locked, the assessment process was achieved just by daylighting assessment device.

1.8 Methodology

The research is carried out using experimental method.

CHPTER TWO

LITERATURE REVIEW

2-1 History of Architectural Daylight

Man likes natural light and he desires to have it in the house at all times. Light is as important as water and air for human health. In primitive period, man lived in the trees receiving air and sun-light. After he came down from the trees in order to escape the wild, beasts, numbing cold, enervating heat, drenching rains and bitter winds, he went into a cave -a dark environment-. Then, he emerged to a hut. Caves and huts were windowless and gloomy. There was no material at hand to keep the weather out and let light in at the same time, however, man innovated a means to admit light. He brought light into his home through the doorway at first, and then from the smoke outlet of the roof. It was the beginning of that centuries - long struggle for lighting (Yip , 1972 , p.4).

Later on, the primitive householder built a small " window " in the wall; he modified his door to a hatch or half-door arrangement, by which he gained a certain amount of illumination and protection against the weather at the same time. These first " window ", wall or roof openings, were constructed, without covering or were covered by opaque materials, such as wood, woven thatch, rushes, leaves or stone sheets, which then they were covered with animal skins or cloth, and as a result, light was kept from the room. Gradually, these materials were supplanted by translucent stone, such as gypsum, or translucent sheets of marble, or by sheets, mica, or alabaster, or parchment, oiled paper or oiled linen (Yip , 1972 , p.4).

Glass had been discovered as early as 3000 BC in Egypt (Phillips, 1997, p.3), with its discovery man had an increasingly efficient means of admitting light to his home. The Romans were likely the first people to use glass for windows, They learned the manufacture of glass from the Egyptians, and was used for decorative objects and its development was not sufficient to displace stone, cloth, shells entirely as a window covering, because glass was deemed mysterious and it was produced in extreme secret, At that time glass was a precious item that only the rich and powerful could use, During the early Middle Ages, the church began to use glass for windows in a host of edifices, Clear glass was combined with small pieces of coloured glass to admit coloured light thereby producing a holy, religious environment, But the use of glass for domestic homes was still economically impossible and far away, In the latter years of the sixteenth century, when glass became economically available and common, it began to be extensively used for domestic windows(Yip , 1972 , p.5).

However, the proper evolution of natural lighting was limited and bound by the window tax which lasted from 1695 to 1851 in Europe, In nineteenth century, it also was restricted by the deliberate rejection of its technical possibilities by the architects, since the late Victorian era, a growing appreciation of the scientific principles of admitting daylight to buildings has gradually influenced architectural design, After the eighteenth century architects have been free to use as much daylight as possible (Yip , 1972 , p.5).

The history of windows is really the history of architecture, from the crude openings in the sides of early domestic buildings open to the atmosphere, or openings in the roof construction, allowing the entry of rain collected in a central pool. (Phillips, 2004, p.3)

The appearance of buildings of all periods reflects the nature of the windows, in some cases such as the mediaeval period, the shape and location of the windows being functionally related to the role played by daylighting, whilst in the renaissance period the location and form of windows became more formalized, often being less well related to the interior spaces they served (Phillips, 2004, p.4) .

Daylighting remained the primary means of lighting to all types of building until the early twentieth century, when for various reasons, not least the greater efficiency in the development of electric sources, the primary role of daylighting was beginning to be questioned. The growth of the workplace in the nineteenth century had seen buildings requiring higher levels of light, and this was achieved by planning long horizontal windows, where the daylight close to the window wall would have been sufficient, but with the pressure to reduce The floor to floor height for economies of structure, even this became insufficient (Phillips, 2004, p.4).

The pressure to increase the levels of light in buildings came from the utility companies, who saw this as a means of increasing the sale of electricity, and for the manufacturers the sale of lamps and equipment. Up to a point this was a benign influence, although the effect in the USA went too far, with levels of 1000 Lux and above recommended where far less was sufficient (Phillips, 2004, p.5).

By the 1960s the concept had grown that ultimately, if not immediately, artificial or electric lighting would supplant natural light as the primary source during the day in the work situation (Phillips, 2004, p.5).

There was in fact substantial evidence to support this view for the lighting in offices, factories and other buildings where difficult visual tasks need to be done. Economies of structure had meant that ceiling heights had been lowered, reducing the penetration of daylight into buildings. A government ‘low cost energy policy’ determined that the price of electricity was not a major factor in the running costs of such buildings, and that therefore an economic case could be made.

By the 1960s a professor of architecture stated that the first decision an architect had to make when planning a new building was the level of light and the nature of the electric light source to achieve this. daylight was to be disregarded as a functional source. This led to windowless factories, and even windowless schools. It was even mooted that buildings could be heated by the means of lighting, leading to artificial lighting being used at all times of day, even when the heat generated had to be wasted, by dispersal (Phillips, 2004, p.5).

It was not until the energy crisis, and the realization that our reliance on fossil fuels had limitations, that people started to question this high energy approach, and began to look at ways to reduce the electricity load in buildings, and one of the more obvious ways was to return to an understanding of the natural resource of daylight (Phillips, 2004, p.5).

2.2 Definitions of daylighting

-Daylight is a source which can save the energy and able to create a pleasant visual environment for occupants. According to Illuminating Engineering Society of North America (IESNA).

-Daylighting is a technique to bring natural light into a room by manipulating this free resources to achieve required illumination level in that room. By having a good daylighting strategy, it helps to create a visually stimulating and productive environment for building occupants (Husin, &Harith, 2012).

- Daylighting is the use of direct, diffuse, or reflected daylight to provide full or supplemental lighting for building interiors (Abboushi, 2013).

-Daylighting describes the controlled use of natural light in around buildings (Reinhart, 2014).

Table (2-1) presents a five sample list of definitions for daylighting that were presented to participants in a recent survey on the use of daylighting in sustainable building design (Reinhart &Galasiu 2006).

Architectural definition: the interplay of natural light and building form to provide a visually stimulating, healthful, and productive interior environment.
Lighting Energy Savings definition: the replacement of indoor electric illumination needs by daylight, resulting in reduced annual energy consumption for lighting.
Building Energy Consumption definition: the use of fenestration systems and responsive electric lighting controls to reduce overall building energy requirements (heating, cooling, lighting).
Load Management definition: dynamic control of fenestration and lighting to manage and control building peak electric demand and load shape.
Cost definition: the use of daylighting strategies to minimize operating costs and maximize output, sales, or productivity.

Table 2-1 Five Sample Definitions for Daylighting
Source: (Reinhart &Galasiu, 2006)

2.3 Benefits of daylight

Among the many elements that impact building occupants, lighting seems to have the most influence. Light is an essence for humans and it is known that has physical, physiological, and psychological influences (Shishegar, Boubekri, 2016, p.72).for example ,Scientists at the Lighting Research Center (LRC), have reported that daylit environments increase occupant productivity and comfort, and provide the mental and visual stimulation necessary to regulate human circadian rhythms (Wymelenberg , 2014) .in the flowing paragraphs we will customize more in Benefits of daylight .

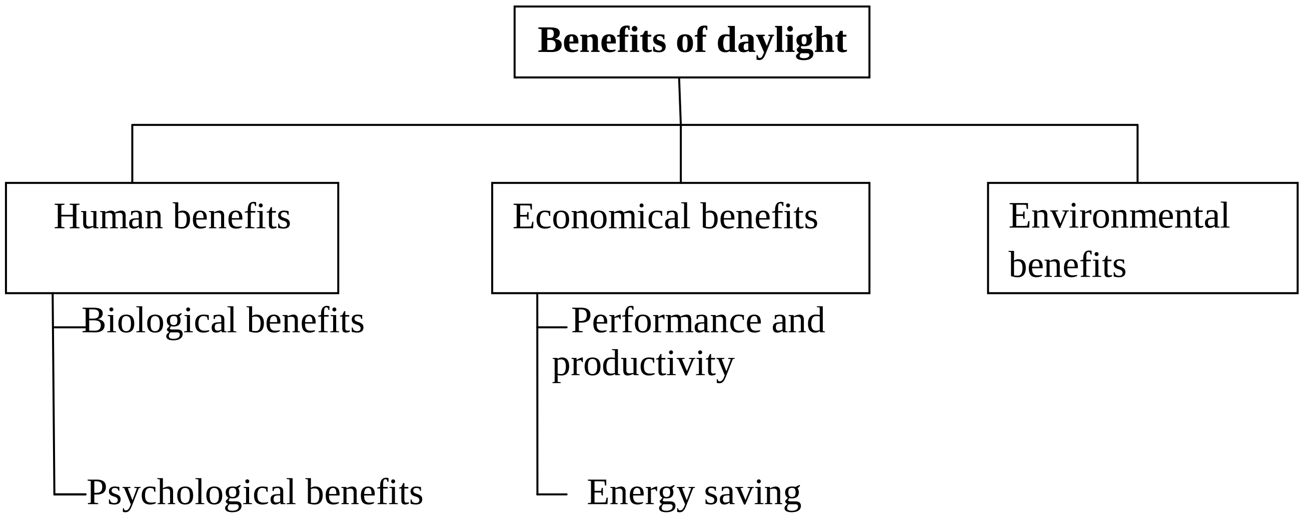


Fig 2.1 Benefits of daylight
source: (the researcher)

2.3.1 Human benefits:

2.3.1.1 Biological benefits:

Biological functions of light How our biology responds to light intensity, duration, timing, and spectrum (Daylight, Energy and Indoor Climate Basic Book,2014 , p.21) such as:-

1-dalight helps our bodies to manufacture vitamin D through photosynthesis of ultraviolet from the sun (Boubekri,2008).

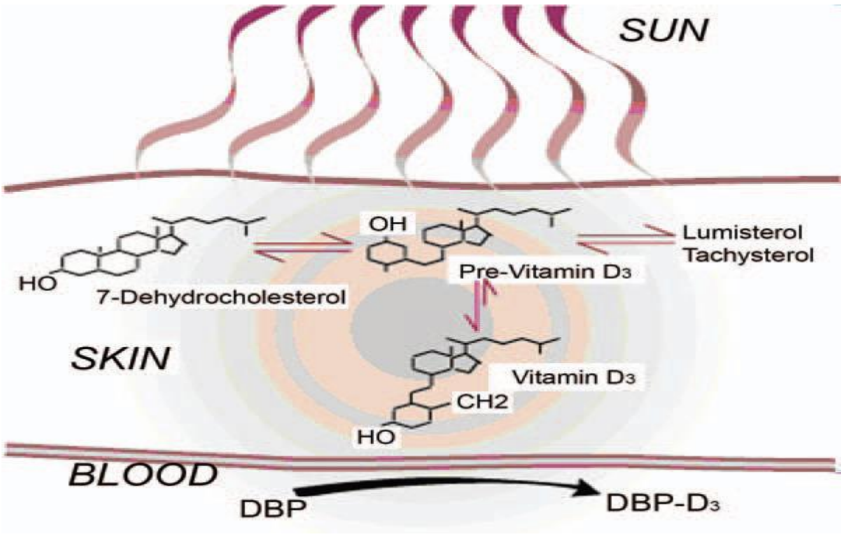


Fig 2.2Vitamin D production through skin photosynthesis
source: (Boubekri ,2008).

Sunlight is the primary source of vitamin D, which is good for the body's internal system(Mirrahimi, Ibrahim, M.Surat, p.128). We receive 80–100% of our vitamin D needs through our skin by way of photosynthesis which has many benefits such as regulates the absorption of nutrients in the small intestine and their re-absorption in the kidneys, It helps maintain serum calcium and phosphorus concentrations within the normal range, which are essential elements for the growth and development of bone structure. Also the vitamin D decreasing can cause several diseases such as:

- Heart failure.
- Multiple sclerosis (MS).
- Cancer.
- Diabetes (Boubekri ,2008).

2-daylight regulates our circadian rhythm. (Boyce; Hunter; Howlett , 2003). Many aspects of human physiology and behavior are dominated by 24-hour rhythms that have a major impact on our health and well-being. They control sleep/wake cycles, alertness and performance patterns, core body temperature rhythms, as well as the production of the hormones melatonin and cortisol (Pechacek et al., 2008). These daily rhythms are called circadian rhythms and their regulation depends very much on the environment we live in. The dynamic variation of light, both daily and seasonally, is a critical factor in setting and maintaining our 24-hour daily rhythms – our circadian rhythms – (Daylight, Energy,2014 , p.20).

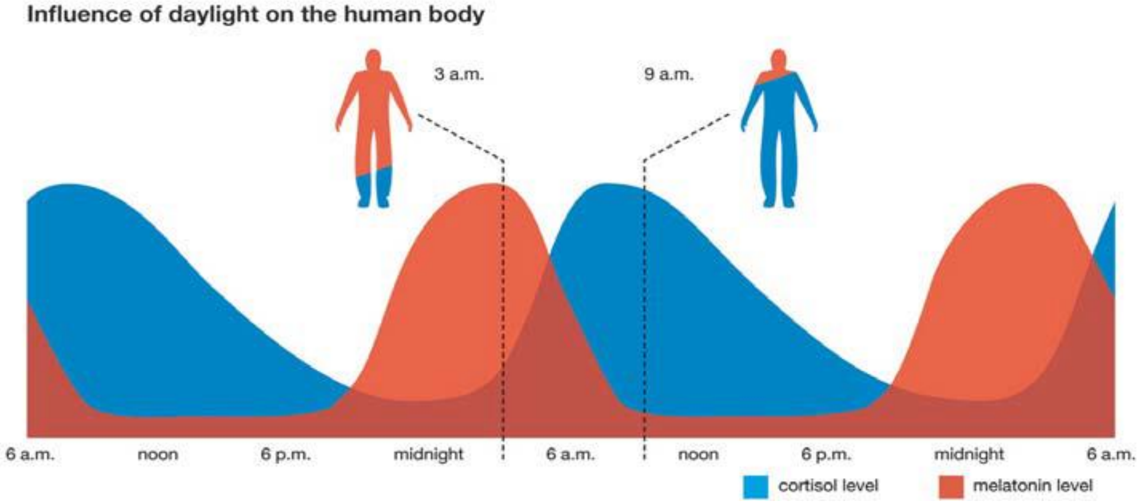


Fig 2.3the variations in Production of the hormones melatonin and cortisol with light

source: (Brainard, 2002).

3- The proper integration and management of daylighting in buildings provides the best spectrum of light for the eye. Eyestrain is related to the spectrum of light present in a workspace and the ability of the eye to Refocus. When the eye is not allowed to refocus to different distances over long periods of time, the dilating muscles are conditioned to a limited range of perspective, promoting near or far sightedness. Eyestrain is diminished with landscape views through windows because the combination of short- and long- range views allows the eye to refocus (L. Edwards and P. Torcellini , 2002,p9).

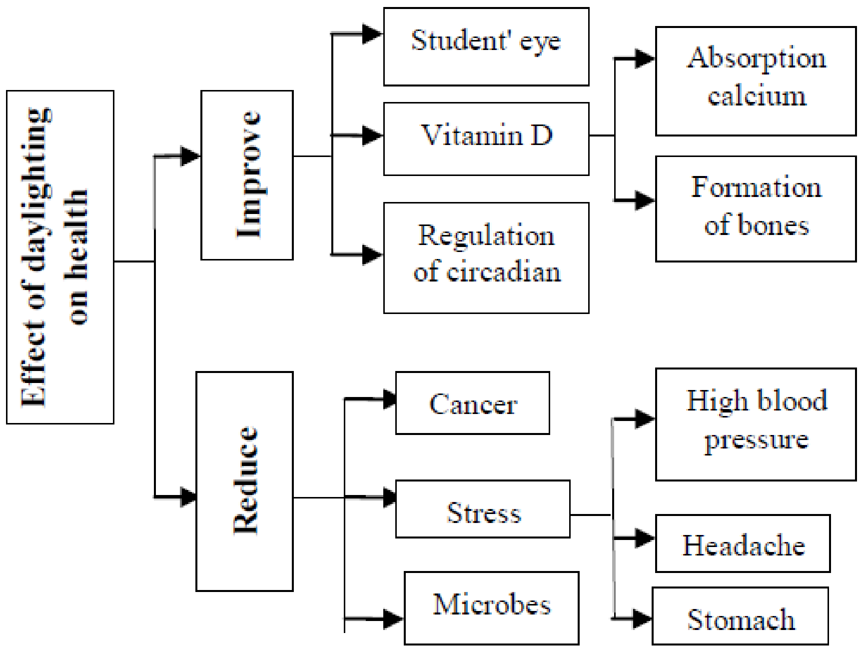


figure 2-4 effect of daylighting on health

Source: (Mirrahimi, Lukman ,Ibrahim, M.Surat)

2.3.1.2 Psychological benefits

- Daylighting has been associated with improved mood.

Small changes in lighting can alter the mood and the emotional state of the building occupants. Evidence suggests that light affects mood and that mood influences or mediates the problem-solving process that people use at work. When people are upbeat and in a good mood, they perform better and *vice versa*.

- daylight decrease stress because cortisol ‘stress hormone, effected by light .Too much or too little cortisol has been implicated in numerous illnesses such as depression. so It is important to keep it in proper balance that which daylight does(L. Edwards and P. Torcellini , 2002,p 60).

-Daylight Prevent from Seasonal Affective Disorder (SAD).

Seasonal Affective Disorder is a depression related illness linked to the availability and change of outdoor light in the winter. Reports suggest that 0.4% to9.7% of the world's population may suffer from SAD, with up to three times that number having signs of the affliction (called sub-syndromal SAD (or S-SAD) without being classified as a major depression (primarily in Northern America and Northern Europe (Daylight, Energy,2014 , p.28).

Because the availability of outdoor light affects SAD occurrences, light can play a vital role in preventing and curing SAD (L. Edwards and P. Torcellini , 2002,p 60).

Researchers now speculate that light therapy can be effective for 80% of SAD sufferers(Boubekri,2008 , p 60).

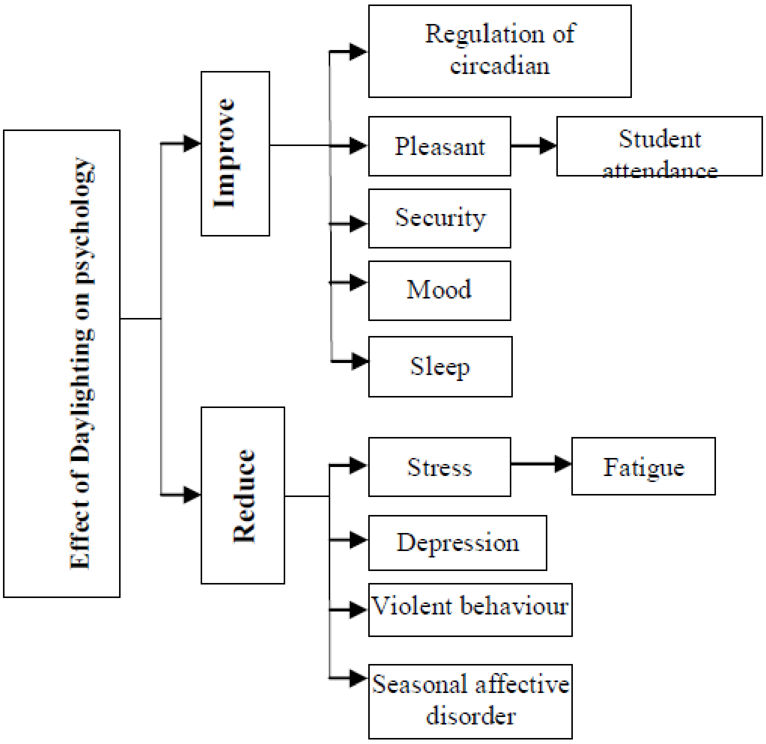


figure 2-5 effect of daylighting on psychology

Source: (Mirrahimi, Lukman ,Ibrahim, M.Surat)

2.3.2 Economical benefits

2.3.2.1 Performance and productivity

Bright lighting is generally believed to make people more alert, and well-daylit spaces are generally perceived by occupants to be "better" than dim gloomy ones (Mardaljevic et al., 2012). Daylighting has been associated with improved mood, enhanced morale, less fatigue and reduced eyestrain (Robbins, 1986). Many studies show that the performance and productivity of workers in office, industrial, and retail environments can increase with the quality of light (Ahmet Çakir, p4- p5).

-in offices Studies show that of applying of daylighting techniques in offices can increase worker productivity 5-15% and total product output increased 25%–28% and 15 -47% decrease in absenteeism (L. Edwards and P. Torcellini , 2002,p 10).

-in retail buildings Studies show that using daylight in stores would improve store performance by 31%–49%.

- Companies have recorded an increase in productivity of their employees of about 15% after moving to a new building with better daylight conditions which resulted in considerable financial gains(Daylight, Energy,2014 , p.25).

- Studies also show that daylit environments lead to more effective learning It was found that students in classrooms with the most window area or daylighting produced 7% to 18% higher scores on the tandardized tests than those with the least window area or daylight (Daylight, Energy,2014 , p.25).

– Classrooms with maximum daylight improved math (20%) and reading tests (26%) of students compared with those under minimum daylight (Mirrahimi; Lukman ; Ibrahim; M.Surat, p.129) .

2.3.2.2 Energy saving

Another benefit of using daylighting for ambient and/or task illuminance in a space is that it can save energy by reducing the need for electric lighting. Several studies in office buildings have recorded the energy savings for electric lighting from using daylight in the range of 20-60%, but it depends on the lighting control system used, how well the space is daylit during occupied hours and the intended functions of the space. and in domestic buildings The study shows that increased daylight is estimated to reduce the need for artificial lighting by 16-20%, depending on the location and orientation of the house (Daylight, Energy,2014 , p.29).

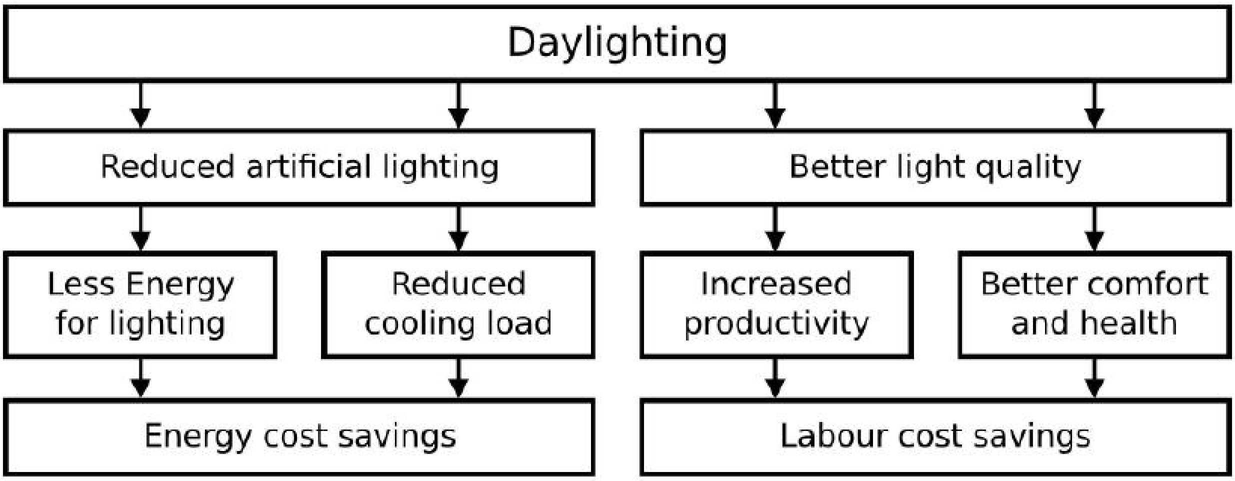


Figure 2-6 effect of daylighting on economy

Source: (the researcher)

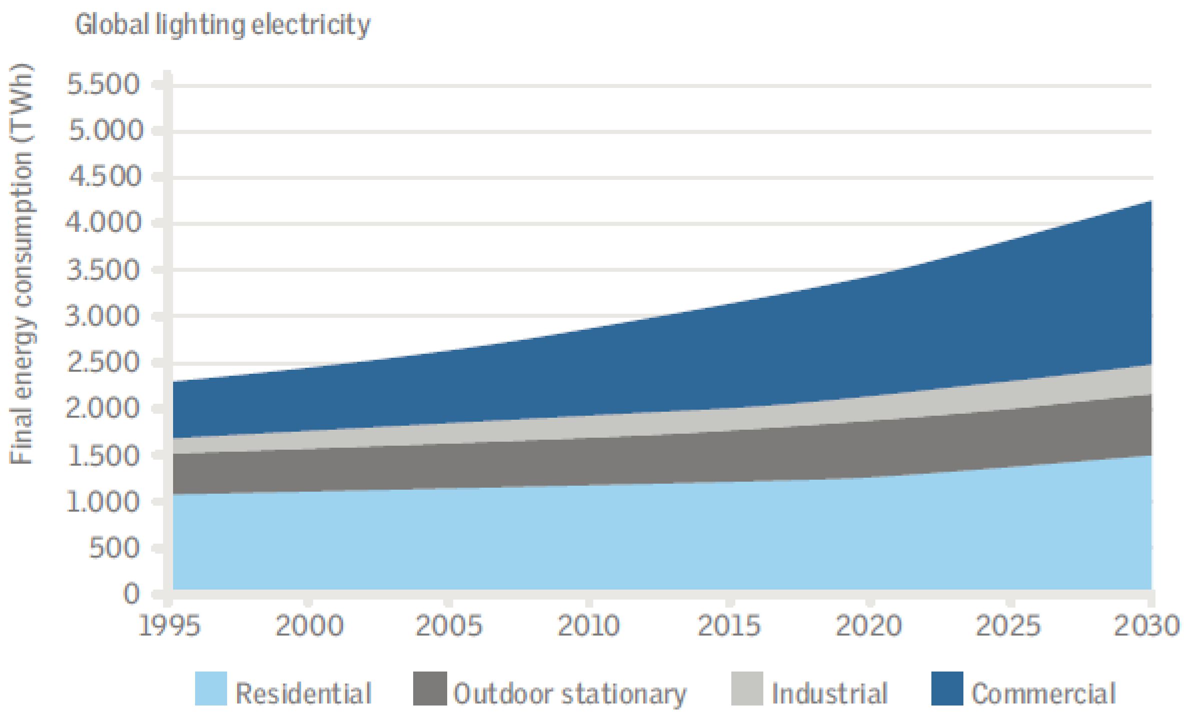


Fig 2.7 Global electricity consumption for lighting
Source: (Daylight, Energy, 2014)

2.3.3 Environmental benefits

Increasing use of natural resources, such as daylight and air, in our buildings, through constructive use of windows in the facades and roofs, can influence our dependency on fossil fuels as well as reduce combustion of greenhouse gases. Lighting is one of the largest consumers of electricity and one of the biggest causes of energy-related greenhouse gas emissions. The amount of electricity consumed by lighting is almost the same as that produced from all gasfired generation and about 15% more than that produced by either hydro or nuclear power. Indoor illumination of tertiary-sector buildings uses the largest proportion of lighting electrical energy, comprising as much as the residential and industrial sectors combined. On average, lighting accounts for 34% of tertiary-sector electricity consumption. (IEA, 2006).

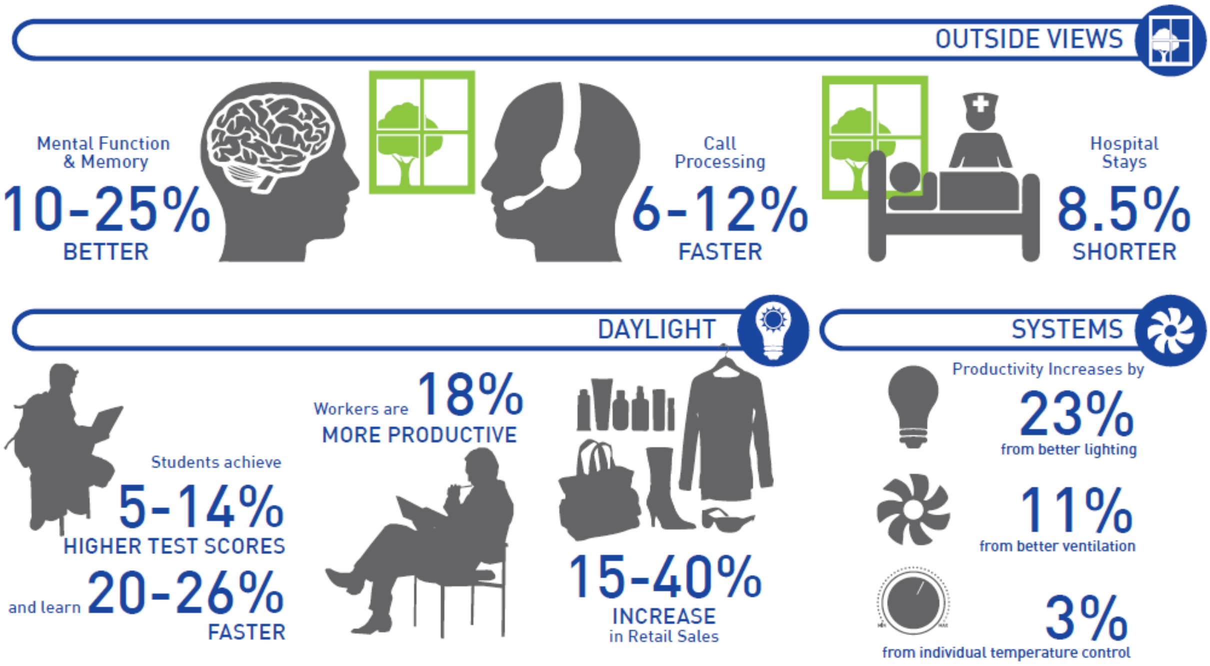


figure 2-8 benefits of daylight and views in different sectors

Source: (Sok, 2017)

2.4 The components of daylight

Daylight in buildings is composed of a mix – direct sunlight, diffuse skylight, and light reflected from the ground and surrounding elements those are the main components of daylight:

• Direct sunlight is characterised by very high intensity and constant movement. The illuminance produced on the surface of the earth may exceed100 000 lux. The brightness of direct sunlight varies by season, time of day, location and sky conditions. In a sunny climate, thoughtful architectural design is required, with careful management of allowance, diffusing, shading and reflecting.

• Skylight is characterised by sunlight scattered by the atmosphere and clouds, resulting in soft, diffuse light. The illuminance level produced by an overcast sky may reach 10 000 lux in the winter and as high as around30 000 lux on a bright overcast day in the summer. In a cloudy climate, the diffuse sky is often the main source of useful daylight.

• Reflected light is characterised by light (sunlight and skylight) that is reflected from the ground: terrain, trees, vegetation, neighbouring buildings etc. The surface reflectance of the surroundings will influence the total amount of reflected light reaching the building facade. In some dense building situations, the light reflected from the ground and surroundings can be a major contributory part of daylight provisions indoors (Daylight, Energy,2014 , p.14-15).

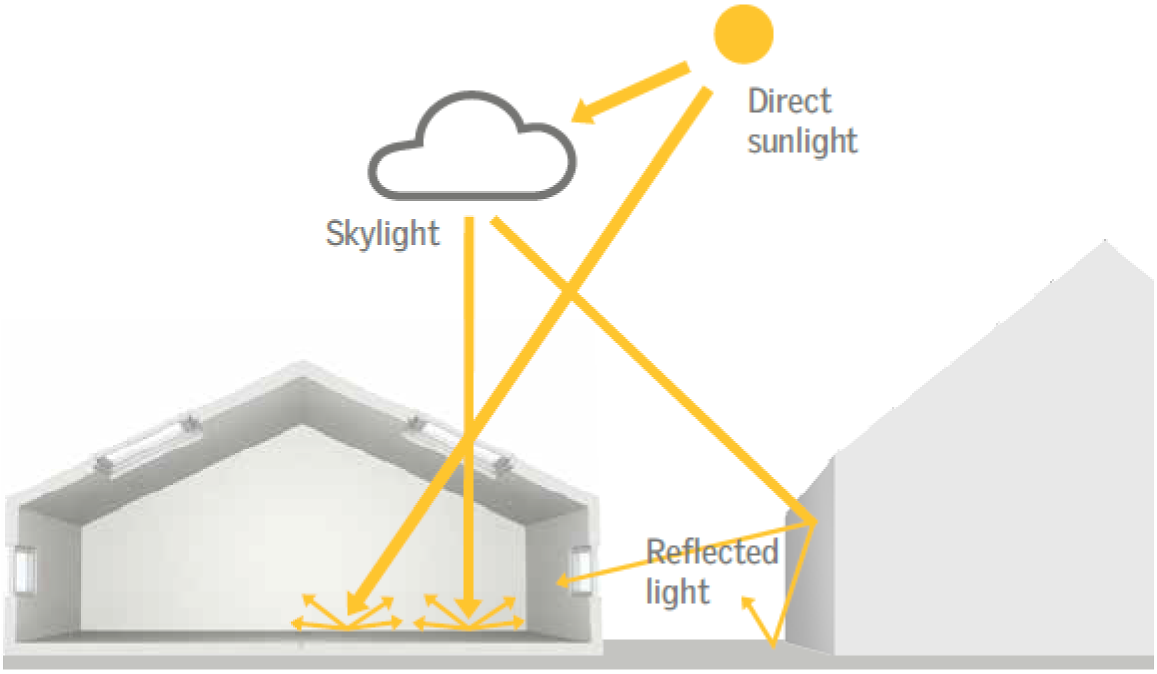


Fig 2-9 The components of daylight
Source: (Daylight, Energy, 2014)

2.5 Parameters influencing daylighting performance

2.5.1 Climate

The prevailing climatic conditions of a building site define the overall preconditions for the daylighting design in terms of sunlight availability, visual comfort, thermal comfort and energy performance (Daylight, Energy,2014 , p.32).

2.5.2 Latitude

The latitude of a building site determines the solar altitude for a given time of day and year. The summer and winter solar altitude properties for a specific location are important design inputs for the control of direct solar radiation. Latitude will also determine the length of daytime and solar availability at different seasons of the year. Maximum and minimum solar elevation will depend on the latitude of the site; on moving away from the equator towards north or south, the difference between summer and winter becomes greater as latitudes increase. The highest peak of global illuminance is during the summer (for the northern hemisphere), when the sun is at its highest level, and about two and a half times greater than the lowest peak during the winter, when the sun is at its lowest level (Daylight, Energy,2014 , p.34).

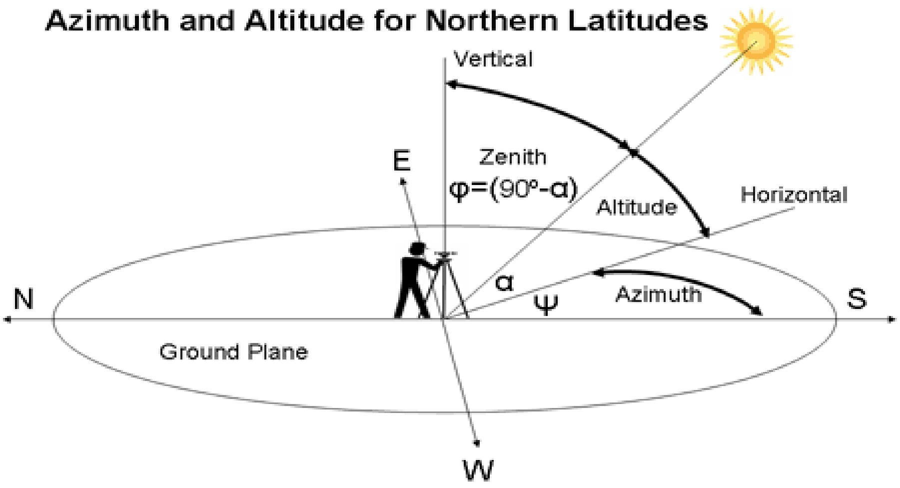


Fig 2-10 Azimuth and altitude for northern latitudes
Source: (علوي واخرون, 2013)

2.5.3 Orientation of buildings

Orientation is the arrangement or directionality of a façade or other element with regard to the azimuth angle. The optimum orientation is thus related to the building use, the geographical area and the climate (Vogiatzi , p.9).
The amount of sunlight received by a building depends on both the building's shape and orientation.

The importance of right orientation is insurance the maximum availability of useful natural light to the interior. So architects must be considered building orientation at the outset, when the architect is planning the location of the building on the site.

The principles of orientation are different for different climates. For example In the tropics where the sun is generally very bright and hot the preferable orientation is away from the sun and in the direction of prevailing breezes. In temperate zones buildings should be designed for two distinct climates, tropic in summer and sub-arctic in winter To meet both conditions (Yip , 1972 , p.76).
The several simple diagrams of building shapes shown in Fig, 3-6 will exploit sunlight to the maximum when they are properly oriented.

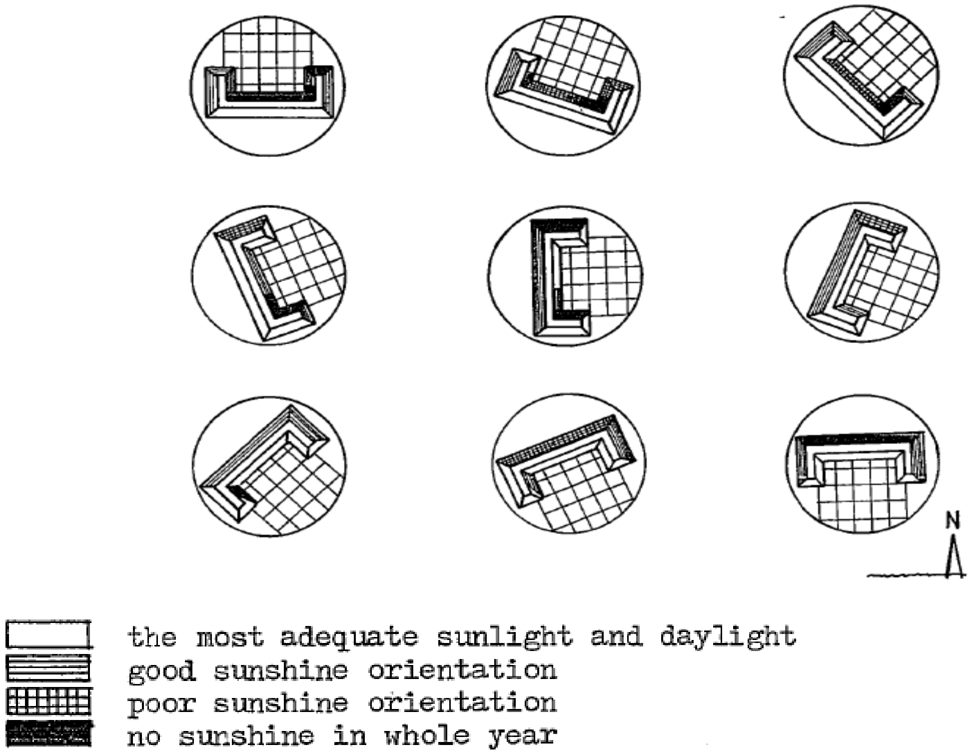


Fig 2-11 The conditions of sunshine of a U-shape building which faces to the various directions.

Source: (Yip , 1972)

Owing to the different climates and various sites, and variations. of individual tastes or requirements, it is difficult to present a standard of orientation for natural lighting, But diagrams of appropriate orientations for various rooms in different building types are proposed in the following figures. (Yip , 1972 , p.80)

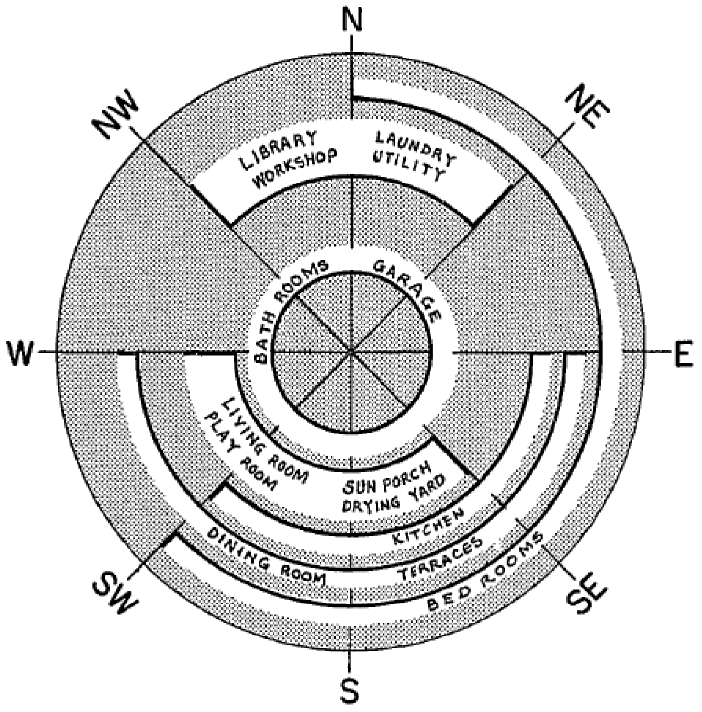


Fig 2-12 Orientations for the rooms of residence
Source: (Yip , 1972)

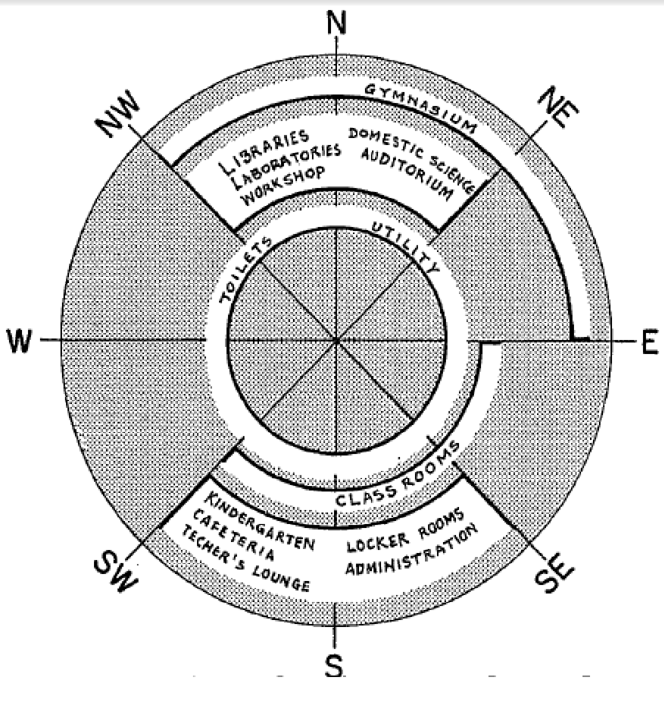


Fig 2-13 orientations for rooms of school
Source: (Yip, 1972)

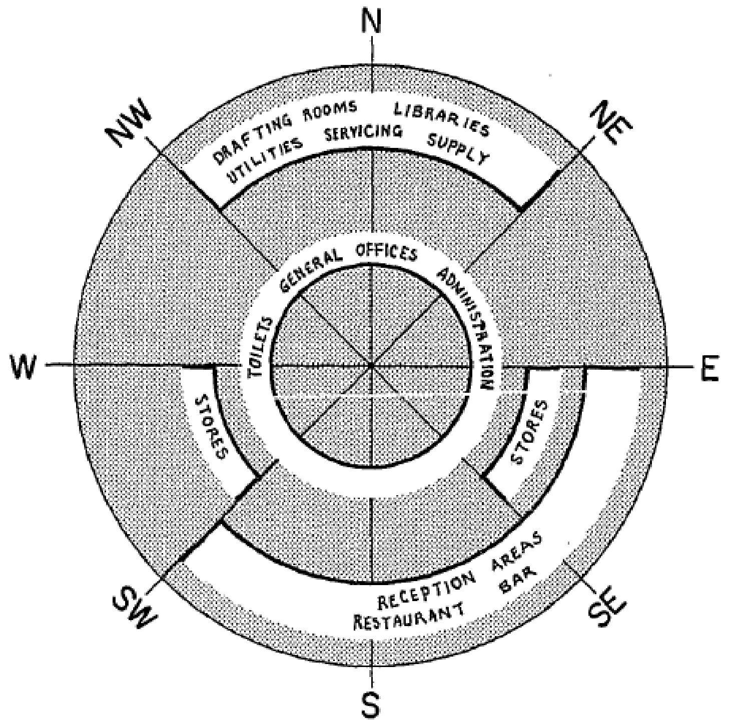


Fig 2-14 orientation for rooms of offices and stores
Source: (Yip, 1972)

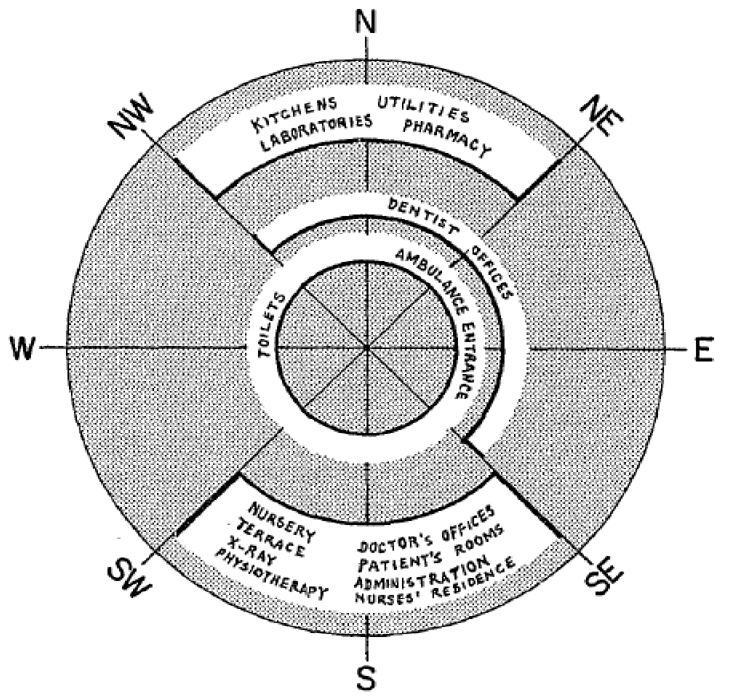


Fig 2-15 orientations for the rooms of hospitals
Source: (Yip, 1972)

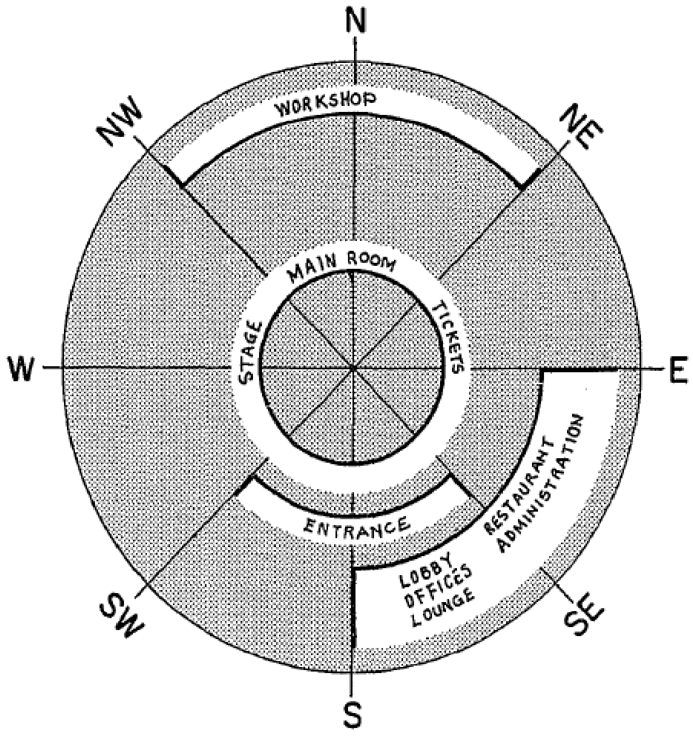


Fig 2-16 Orientations for rooms of church and auditoriums
Source: (Yip, 1972)

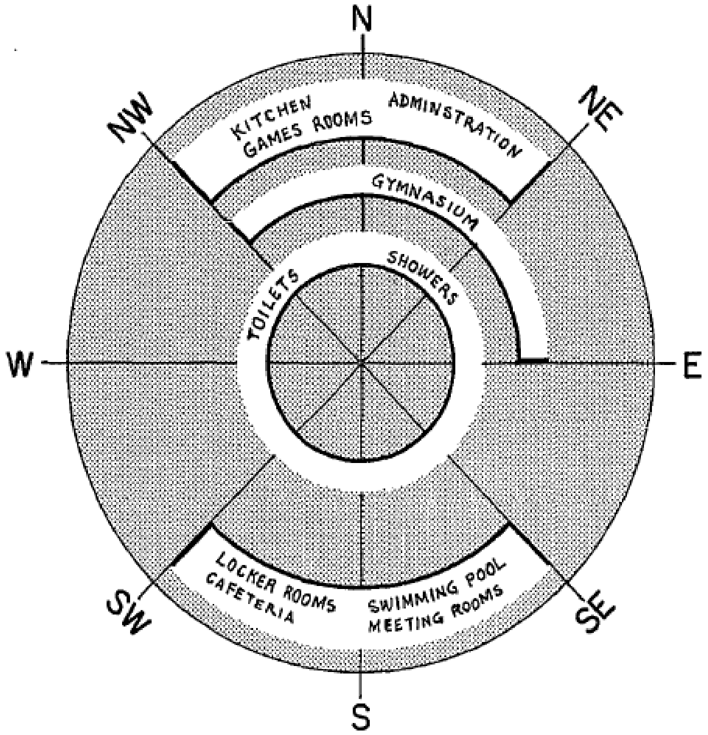


Fig 2-17 Orientations for rooms of athletic buildings and community centers
Source: (Yip, 1972)

2.5.4 Obstructions and reflections on site

The obstruction angle is defined in the Swedish standard (SS 91 42 01). It is the angle between the horizontal line from the center of the window to the opposite

building, and the line between the center of the window and the highest building point. Thus, the smaller obstruction angle, means more daylight penetration into a room (Vogiatzi , p.15).
External reflections and obstructions from surrounding elements on the building site (buildings, vegetation, ground surface etc.) will influence the amount of daylight reaching the interior of a building (Daylight, Energy,2014 , p.36).
and Their distance from the window and their reflectivity affects daylighting onto the façade (Leder et al., 2006) . Roof windows and skylights are generally less affected by obstructions from sand and have more generous views to the sky than facade windows (Daylight, Energy,2014 , p.36) as illustrated in Figures (2.18) and (2. 19).

Figure 2-18 Components of view – roof window situation.
Source: (Daylight, Energy, 2014)

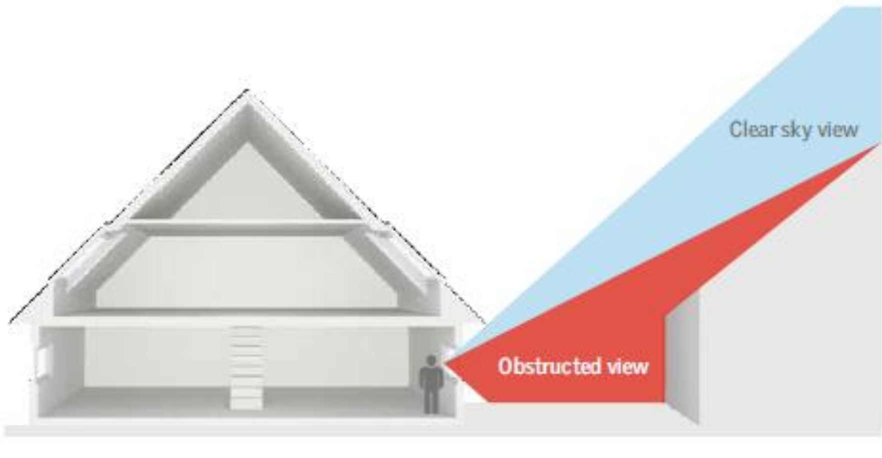


Figure 2-19 Components of view – facade window situation.
Source: (Daylight, Energy, 2014)

External obstructions always limit the areas in a room which have direct access to skylight. The line of demarcation between the areas of the room which receive direct skylight and those which do not is called the no-sky line. The no-sky line in a room is obtained by projecting the edge of an external obstruction through the head, as shown in Fig. 2-20, or sides as shown in Fig.2-21, of the window to the reference plane in the interior. when obstructing building facing a parallel window the no-sky line will be a straight line parallel to the window and to the building opposite the window as shown in fig 2-20.

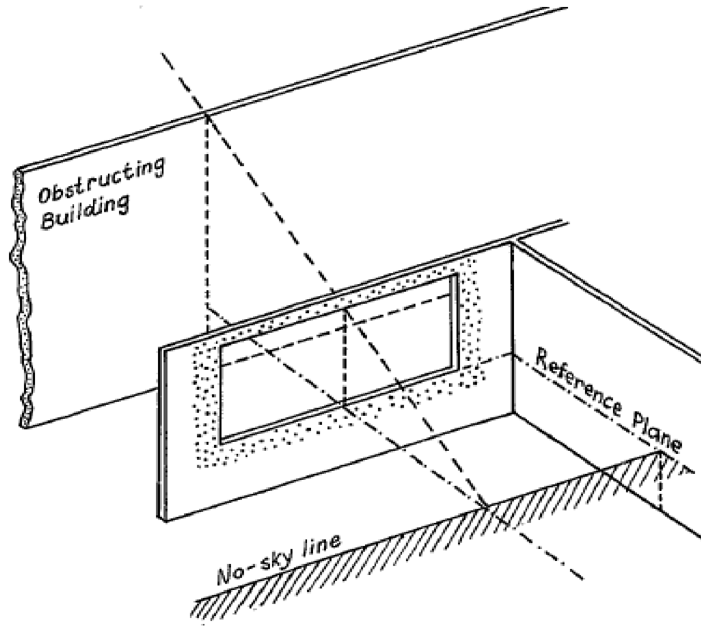


Fig 2-20 No-sky line for obstructing building parallel to window.
Source: (Yip, 1972)

and when obstructing building at right-angles will limit skylight to only one side of the building. The penetration of direct skylight at the back of a room is generally not seriously affected (Yip , 1972 , p.93-94) .

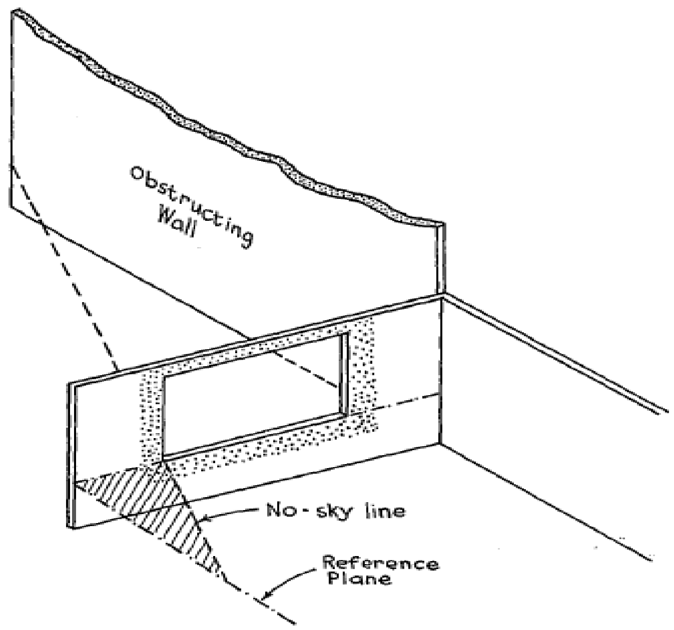


Fig 2-21 No-sky line for an obstructing wall perpendicular to the Window wall.
Source: (Yip, 1972)

2.5.5 Building design:-

2.5.5.1 Geometry

The geometry of a building influences its capacity to deliver adequate levels of daylight to the interior. When the building is deep, daylighting solely by facade windows has its limitations(Daylight, Energy,2014 , p.38) .

2.5.5.2 Material properties

The colour and reflectance of room surfaces are part of the lighting system. Dark surfaces reflect less light than bright surfaces, and the result is likely to be an unsatisfactory luminous environment in which there is little indirect or reflected light. Bright vertical surfaces inside the room are generally preferred to dark ones, but shading devices used to control sunlight should use darker materials in order to limit the risk of glare (Daylight, Energy,2014 , p.42).

2.6Visual Comfort

Visual comfort is the main determinant of lighting requirements. Good lighting will provide a suitable intensity and direction of illumination on the task area, appropriate colour rendering. the absence of discomfort, in addition a satisfying variety in lighting quality and intensity from place to place and over time (Daylighting in Buildings , 1994).

Visual comfort depends on :-

1- amount of light inside task area :
   The amount of light that are needed for a particular visual task will depend on the character of the task and the visual environment where it is performed (Daylight, Energy,2014 , p.18).

Amount of light	Task character
100 lux	for interiors where visual tasks is movement and casual seeing without perception of detail.
300 lux	for interiors where visual tasks are moderately easy.
500 lux	for interiors where visual tasks are moderately difficult and colour judgment may be required, e.g. general offices, kitchens
1 000 lux	for interiors where visual tasks are very difficult, requiring small details to be perceived.

Table 2.2 amount of light that match with some character of task
Source: Institution of Building Services Engineers (CIBSE, 2006)

2- type and amount of glare inside task area.
   It is important to introduce some form of glare in achieving the necessary level of illumination and controlling daylight from window. Glare is defined as " a condition of vision in which there is discomfort or a reduction in the ability to see significant objects. or both, due to an unsuitable distribution or range of brightness or to either simutaneous or sucessive, extreme contrasts in the field of view"

the luminance variations of around 10:1 are suitable for daylighting design. The sensation of glare can occur when luminance variations exceed 20:1 to 40:1. Glare from daylight may be caused by several potential sources such as the sun, bright sky and clouds, and surfaces reflecting the sun.
There are three main types of glare:
• Disability glare – the effect of scattered light in the eye whereby visibility and visual performance are reduced. This occurs when glare sources of high luminance (e.g. sun or specular reflection of the sun) are in the field of view.
•Discomfort glare
This form of glare is more common in building interiors and causes direct discomfort, Discomfort glare is frequently present in bright surroundings. It can also result when the work is placed in a bad position relative to a window. In both case the glare results in discomfort but does not affect the ability of the worker to perform his duties.
• Reflections or veiling glare – reflections on display screens or other task materials (e.g. paper) reduce the contrast between background and foreground for the visual task and thus reduce readability. Reflections occur when bright light sources (e.g. windows) are in the reflected field of view of the screen (Daylight, Energy,2014 ,p.17).
The following suggestions will assist in the control of glare:
a. Grade the contrast from the extreme brightness of the window to the much lower brightness of the room. Shadows and dark colours (Munsell values less than 7) should be avoided on the window wall; because If the walls are dark in colour the sky will appear to be very Glaring. So use light colures and where possible the wall should be lit from another source the glare will be greatly reduced . The framing members of the windows themselves should be designed with particular emphasis on these points.
b. Build low sills to allow more light to fall on the floor and to subsequently be reflected, softening the shadows on the window wall and ceiling. They also allow more of the light reflected from the ground to strike the ceiling at the back of the room (Yip , 1972 , p.69).
c-To reduce the occurrence of glare, shading devices should be employed. Figure 1.5 below shows a situation where glare is controlled by external solar shading (awning blind). Shading devices such as Venetian blinds, awnings, vertical blinds and roller blinds are suitable for this Purpose, but the specific material characteristics should be taken into consideration. (Daylight, Energy,2014 ,p.17).

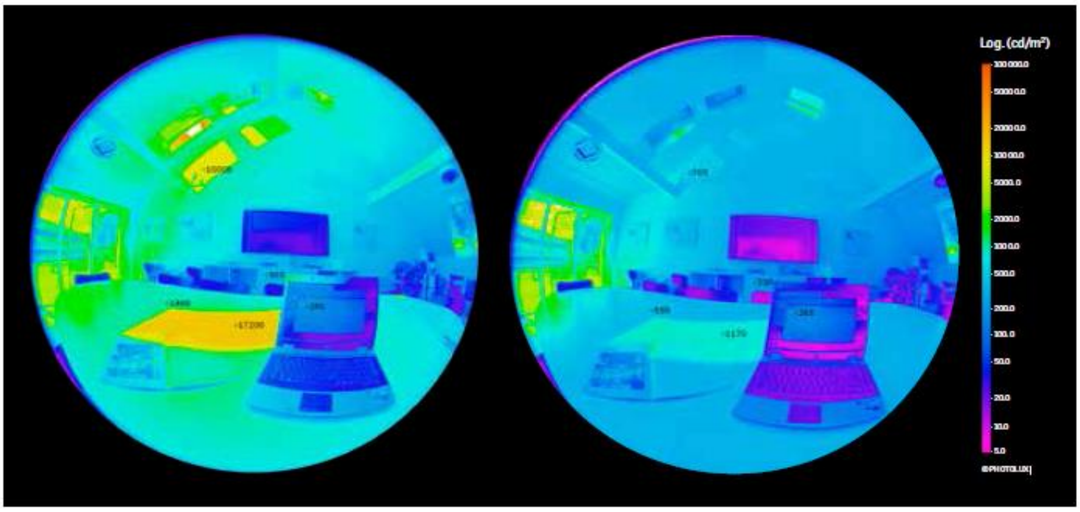


Figure 2-22 Luminance map of a task area showing sun patches causing glare. Luminance map of task area showing glare control with external solar shading

Source: (Daylight, Energy, 2014)

3- Visual rest availability: because our eyes have been developed for frequent changes in distance adaptation, for objects far away. the eyestrain is caused by continuous adaptation to the close tasks imposed by civi1ization. The strain is relieved by looking at distant objects from time to time, even if it be only for a few seconds. This relaxation is usually achieved by looking out of the window (Yip , 1972 , p.66).

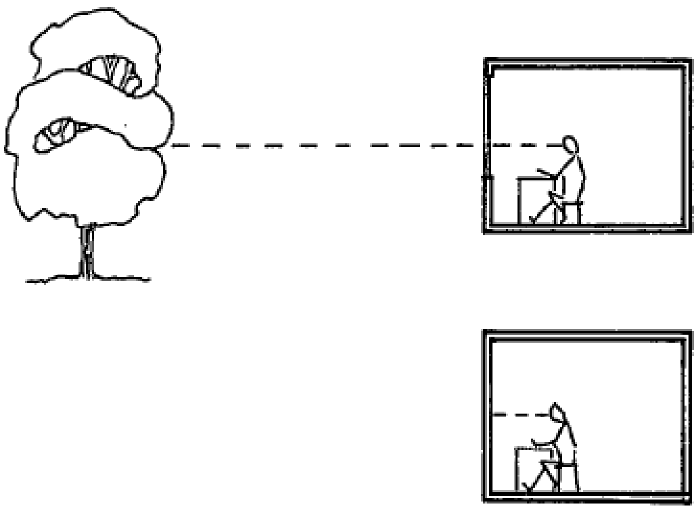


Fig 2-23 the importance of a distance view
Source: (Yip, 1972)

2.7 shading devices

One of the biggest challenges face architects in daylidgting design is heat comes with natural light which cause thermal discomfort inside spaces. Shading devices are successful tools to reduce heat gains during summer and promote heat gain during winter.

There are two types of shading devices:-

1- **External shading devices**

The best way to control the heat gain before it enters the building by external means,(Phillips,2004,p31)so Exterior shading devices are the most effective in reducing heat gains (daylighting in buildings,1994,p10).
such as:-

- Light shelves:

The light shelf**,** a flat or curved element placed at the window opening above eye level, redirects incoming light onto the ceiling and simultaneously provides shading for the area of the room close to the window (daylighting in buildings,1994,p10). It may be external or internal (Al-Shurafa,2016, p24), but it is most efficient when it is external, Interior shelves have not been found to be as effective - they obstruct daylight entering the room while providing little compensating benefit(daylighting in buildings,1994,p10).
The light shelf working mechanism depends on reflecting the light to the ceiling then to the working plane. The variables influencing its performance are reflectance factor, width, height, ceiling height and shape. (Al-Shurafa,2016, p24)

Figure 2-24 Sun ray guided by light shelf in winter and summer time
Source: (Ruck *et al.*, 2000)

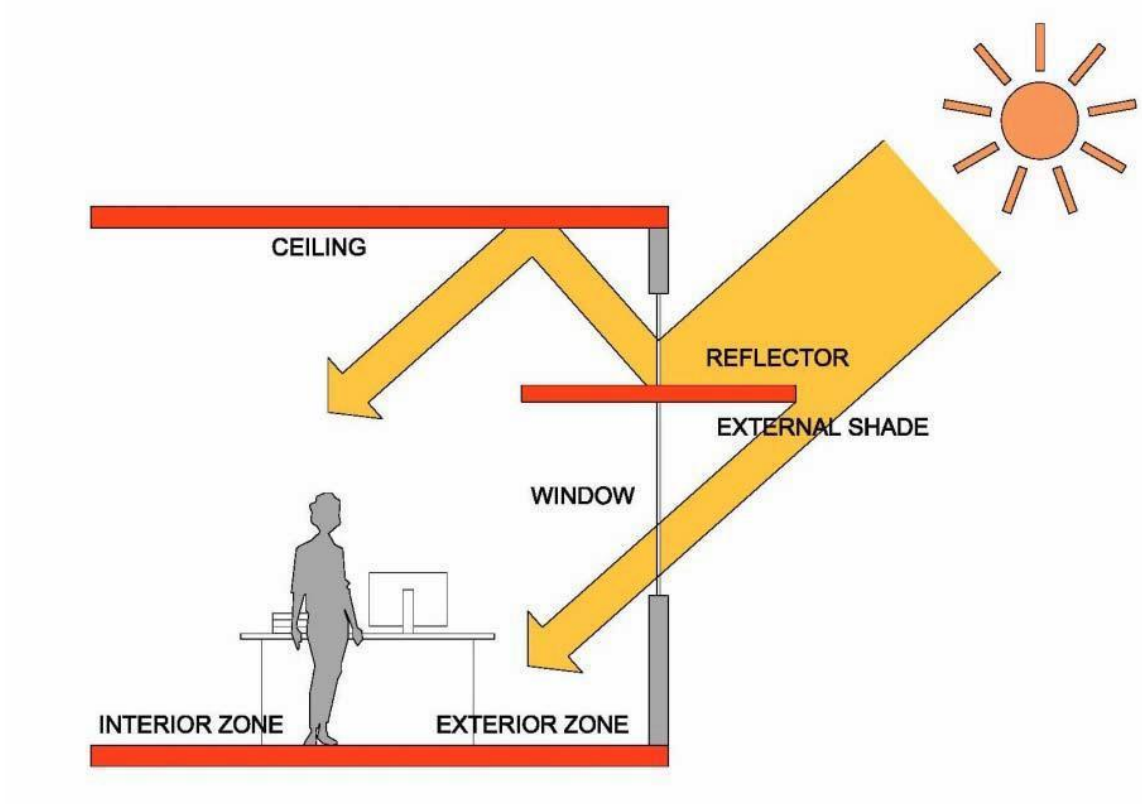


figure 2-25light shelf mechanism
Source:(www.superhomes.org.uk)

-louvres

Louvres are composed of multiple horizontal, vertical, or sloping slats with different shapes and surface finishes (Al-Shurafa,2016, p24). Louvers can be angled to redirect sunlight or diffuse light in the same manner (daylighting in buildings,1994,p10) also help to control excessive sun rays, reflecting daylight to the ceiling. (Al-Shurafa,2016, p24) . They are more responsive than light shelves (daylighting in buildings,1994,p10). Louvers may be partially or completely obstruct the sun's rays and view but if completely retractable, cause no obstruction to daylight on overcast days.

Variables affecting louvre daylight performance include width, distance between louvers, orientation and ceiling height (Al-Shurafa,2016, p24).

figure 2-26 louvers

Source: (www.pinterest.com)

- External environment
trees can be used to screen the sun in summer and filter light in winter, and planting can sometimes solve the problem of reflected light from neighbouring structures or ground finishes(daylighting in buildings,1994,p11).

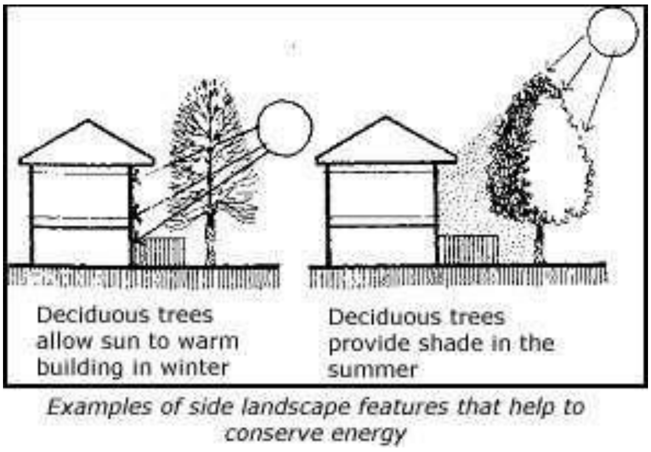


figure 2-27 the effects of external environment on dayligting
Source: (www.slidshare.net)

2- Internal shading devices.

-Curtains:

it is the most commonly used shading device. mostly used in residential buildings. it is used to reduce the solar gain when pulled across the opening (whilst at night they can keep out the cold). (Phillips,2004,p32)

figure 2-28 Curtain

Source: (www.amazon.in)

- Venetian blind

venetian blind composed of multiple slats. they can be made from metal or plastic, wood or bamboo also can be used. Suspended by tapes. all slats in unison can be rotated through nearly 180 degrees. slat width can be between 16 and 120 mm.

The advantages of venetian blind are: adjustability (can be raised when not required for sun control, to permit maximum daylight entry), durability (can be survive for many year), offering excellent glare control, the tilt of the slats can be varied to enable the top of the blind to reflect light up to the ceiling of a room, whilst the lower slats control the sunlight by reflecting it away from the building (Phillips,2004,p32).

figure 2-29Venetian blind

Source: (www.pinterest.com)

- **Prismatic panels**

Prismatic panels are thin, planar and saw tooth devices made of clear acrylic that are used in temperate climates to redirect or refract daylight. These can be used as shading and daylighting devices as they can refract direct sunlight while transmitting diffuse skylight and redirecting the light to the rear part. They can be fixed or sun-tracking, and can be applied in any direction.

The design of prismatic panels depends on solar angles, sawtooth dimension, depth and the angle of the panels. Prismatic panels can improve the uniformity and redirect light to the rear part, thus increasing the illuminance level in the rear of the space. The panels can be used under clear and overcast sky conditions (Al-Shurafa,2016, p25).

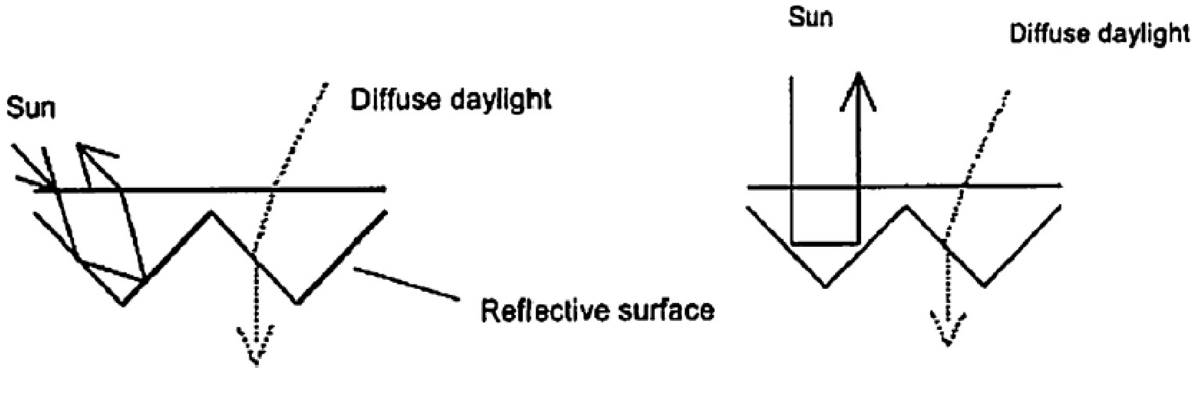


figure 2-30 Prismatic panels
Source: (Ruck et al., 2000)

CHAPTER THREE

DAYLIGHTING IN HOSPITALS

3.1 Introduction

In hospital buildings, where patients seek medical treatment and staff provides continuous support, creating a healing environment with appropriate physical aspects is an imperative to hospital design. Nevertheless, the restoration of health and well being is not merely a matter of physical science. The aspects of healing environment in hospital design are primarily important and relevant within the context of sustainability in healthcare facilities. The term 'Healing Architecture' is adopted to invoke a sense of a continuous process; in creating an environment physically healthy and psychologically appropriate. A healing environment with appropriate physical aspects (noise control, air quality, thermal comfort, lighting, communication, colour, texture, privacy and view to nature) would indirectly contribute to patients' outcome such as shorter length of stay, reduced stress, increased patients satisfaction and others. There are two important aspects that lead to sustainability in hospital design: The importance of physical aspects to achieve a healing environment and the impact of the physical aspects (i.e. daylighting) on health outcomes (S. ARIPIN, 2007, p.173).

For creating a healing environment is necessary to achieve the optimum level of comfort and care physically, socially and symbolically. For this the luminous environment plays an important role and an integral part of the hospital's healing environment and it is one of the crucial physical aspects to be considered in the healing environment (S. ARIPIN, 2007, p.174).

In hospitals daylighting can ensure better health outcomes to patients, staff and visitors physically, mentally and psychologically, which lead to improve staff performance and productivity (S. ARIPIN, 2007,p.174) moreover Adopting and implementing good daylighting will obviate the need for artificial lighting, subsequently lead for energy conservation, contributing to sustainability (S. ARIPIN, 2007, p.175).

3.2 benefits of daylighting in hospitals

1-Access to daylight enables patients to be discharged from hospital sooner than patients without daylight access.

-A study by Choi et al. published in 2012, found that;
'A significant relationship appears to exist between indoor daylight environments and a patient's average length of stay (ALOS) in a hospital. 25% of the comparison sets showed that, in the brighter orientations, as in rooms located in the SE area, the ALOS by patients was shorter than that in the NW area by 16%-41%. Further, no dataset showed a shorter patient ALOS in the NW area than in the SE.'
(Strong, Phil,2012).

- In the 1984 Science article "View through a Window may Influence Recovery from Surgery," Roger Ulrich, reported that patients in rooms that had windows and proper daylighting recovered 8.5 percent faster and took fewer analgesics than did those patients whose view was a brick wall (Wymelenberg, 2014).
2- Daylighting has an effect on the postoperative delirium rates in hospital units. A literature review of the effects of natural light on building occupants undertaken by Edwards and Torcellini states;
'Improving the mental well-being of patients improves their recovery rates. Recent studies show that daylit post-surgical facilities improve this mental well-being. Intensive Care Unit (ICU) areas in hospitals can be very stressful for patients and workers). Some patients can develop "post-operative delirium" in a stressful environment, which affects the intellectual ability of the patient. Many factors affect the development of the delirium: age, alcoholism, drug abuse, sex, preoperative anxiety, sleep deprivation, and perceptual distortion). Daylight helps reduce the stress associated with this environment'.

Wilson conducted a study to see whether windows had an effect on the postoperative delirium rates in hospital units. He found that;
' the windowless ICU had twice as many patients developing post-operative delirium and depression. Windows provided a psychological escape that decreased the stress level for patients. This environment provides a necessary mental balance for patients and reduces the tendency toward brief psychotic episodes. Windows are important in the medical field because they can reduce the stress and depression in patient units.' (Strong, Phil,2012).

3- Exposure to bright light affects the natural clock of patients and employees in hospitals. In certain illnesses, the biological regulatory system (circadian rhythms) plays an important role in maintaining the well-being of the individual. Alzheimer's is one such disease. Alzheimer's patients who are exposed to bright lights during the day have improved circadian rhythms and are less prone to depression .These improved circadian rhythms reduce the time demands of the caregivers in Alzheimer’s units. Windows provide patients with a view of light and weather changes that provide familiarity and help establish a time of year (L. Edwards , P. Torcellini,2002,p33).

4-daylighting helps the users to obtain the proper visual sharpness in hospital where many difficult visual task has been done like reading a thermometer accurately and to see abnormalities in colour of skin, lips finger-nails, wounds, pus and aIl other symptoms in terms of which the most elementary clinical procedures are taught and practiced (Yip, 1972, p127).

5-Daylighting reduces requirement for pain relief medication during hospitalization period.

Research has demonstrated a clear link between daylight/sunlight and a reduced requirement for pain relief medication in hospitals. The use of analgesic medication can result in side-effects and for this reason any strategy which reduces the requirement for pain-relief medication is desirable.

A study published in the Journal of Psychosomatic Medicine8 in 1995 concluded;

‘Consecutive patients undergoing elective spinal surgery who were assigned postoperatively to rooms on either the bright or dim side of the hospital unit. The patients staying on the bright side received 46% more natural sunlight and required 22% less opioid equivalent analgesic medications during their hospitalization. The patients staying on the bright side also experienced a 21% reduction in analgesic medication cost compared with patients on the dim side.’ (Strong, Phil,2012).

6- The long-term patient who must spend many weary days, weeks or even months in a hospital, craves the cheerful play of daylight and a view of the sky.

7- Sunlight –nature’s disinfectan

-Daylight is germicidal to pathogenic bacteria floating in the air or settling out in the dust which very important in hospitals (Yip, 1972, p128).

-Experiments undertaken in the USA and the UK between 1941 and 1944 demonstrated the extraordinary and remarkable effectiveness of daylight in killing the bacteria streptococci32. The blue light in skylight was found to be particularly potent. The trials also examined the bactericidal effects of artificial light, which was found to have little value as a disinfecting agent.

Even diffuse daylight passing through two layers of glass from a north window was found to be highly effective in killing haemolytic streptococci within 13 days, with the same strain surviving in the dark, at room temperature, for 195 days. (Strong, Phil,2012).

8-Healing in hospital settings aided by daylighting

-A patient room providing good outdoor views and daylighting can increase patient wellbeing: a psychological state resulting in reduced stress and anxiety, lower blood pressure, improved post-operative recovery, reduced need for pain medication and shorter hospital stays (.

- In a hospital study, views of nature were associated with reduced stress and fewer health-related complaints among employees. (Strong, Phil,2012).
- doctors and nursing staff displaying lower levels of stress and higher performance in daylit spaces and with views from windows (Strong, Phil,2012).
9- Daylight has important role in treatment of bone illnesses such as rickets,bone frailty, hip fractures.
- The relationship between hypovitaminosis D and bone frailty, especially hip fractures, among older people has been demonstrated in numerous studies .This problem has been shown to be particularly acute at the end of the winter season when days are shorter and exposure to sunlight is minimal and when people have had exposure to little sunlight for months. (Boubekri,2008,p68)
10- Daylight have an important role in the prevention and treatment of obesity and heart disease.
Obesity is reaching epidemic proportions in many developed countries. Considerable research evidence links obesity to depressive illness. Morbidly obese individuals seldom leave home and it is self-evident that their exposure to daylight and sunlight is likely to be severely restricted. Sunlight is essential for the production of Vitamin D. Experiments have shown that obesity is associated with Vitamin D deficiency with the human body accumulating fat as Vitamin D levels fall. The strong causal link between depression and inadequate access to daylight and sunlight has been demonstrated repeatedly –more research is required, but access to adequate levels of daylight and sunlight may prove to be useful in the treatment of obesity.
Sunlight and/or daylight may also have an important role to play in the prevention and treatment of heart disease. In his book The Light Revolution, Health, Architecture and the Sun, Hobday speculates that;
'Sunlight may prevent heart attacks in a similar manner to antidepressants by alleviating depressive symptoms ……..Regardless of the exact mechanisms involved the fact that being in a sunlit ward may have health benefits is a significant finding, which has profound implications not the least of which is the patients' survival from life-threatening conditions'. (Strong, Phil,2012)

3.3 Requirement of the Hospital Lighting

The diversity of the healthcare environment makes lighting a complex challenge. in summary healthcare lighting must take into account the needs of the following:-

1-**Patients:** The physical environment in which a patient receives care affects patient outcomes, patient satisfaction and safety of patients (Mehrotra, Basukala, Devarakonda,2015, p55) . thus appropriate lighting design is essential to provide an environment that will aid the recovery of patient . the correct ambience can affect mood and perception as well as enabling critical chemical reactions in the body. the design of daylighting also need to take into account infection control (healthcare lighting application guid , p3).

2-**Staff:** lighting must enable the performance of visual tasks by hospital staff such as examination and observation (healthcare lighting application guid , p3). A well designed lighting environment can enhance the wellbeing of staff and can also aid recruitment and the retention of staff as well as improving their morale (Mehrotra, Basukala, Devarakonda,2015, p55).
3- **the caretakers of patients:** Their needs differ from those of hospital staff and professionals as caretakers may try to sleep during the night rather than try to stay awake (Mehrotra, Basukala, Devarakonda,2015, p55).

4- **Visitors**: lighting must contribute to an overall ambience of comfort, safety and reassurance for visitors. it can also help to encourage positive feelings from their visit (healthcare lighting application guid , p3).

3.4 Window openings in hospital

Windows and daylight give a building a variety and interest that can rarely be achieved in any other way moreover the presence of windows at work would be related to improved mood and work performance (Joseph, 2006, p7). In surveys most of people prefer windows and daylighting in buildings.
There are three main benefits for windows in hospitals:
• Contact with the outside world, especially a view out.

View out is particularly important for people in hospitals (staff and visitors as well as patients). It reduces feelings of isolation and claustrophobia. It provides contact with the outside world and can add interest to the environment, particularly if things are happening outdoors. A view can also help people, particularly visitors, find their way around the hospital. This contact with the outside may help patients recover more quickly, studies shown that patients in a ward that had a view of trees recovered more quickly than those with a view of a brick wall. (Dalke, eta ,2004, p39-40). In a hospital study, views of nature were associated with reduced stress and fewer health-related complaints among employees. (Prof. DTG Strong eta, 2012, p4)

To provide an ideal view in hospitals :-
-Firstly: the most satisfying views should include three layers: the immediate foreground, buildings or trees opposite, and some view of the sky. This will vary with the eye level of the occupants. For example, in wards, it is important that the window-sill is low enough to allow a view out to recumbent patients and especially to children if they are likely to use the space.
-Secondly: the ideal viewing zone may vary with external obstruction; where tall

Buildings are nearby, for example in courtyards, a higher window head is preferred to allow occupants some view of the sky and to let more daylight come in.

-thirdly: Windows should be large enough to provide a reasonable view. Window areas below 20% of the external wall are unlikely to give a satisfactory view. Above 30% area, however, people are largely satisfied.

There is important point here which is privacy. Privacy is an important issue in many hospital interiors. for example in wards or consulting rooms, in this case it is better to provide adjustable blinds or curtains rather than diffusing glazing. (Dalke, eta ,2004, p41)

• Light from the sky

Light from the sky is particularly important in hospitals. It gives excellent colour rendering, making many clinical tasks easier. It can also give significant energy savings by displacing the need for electric lighting. The diurnal variation in daylight can help patients (particularly those who are in hospital for a long time) maintain their body clocks. Daylight is also constantly changing as the sun moves round the sky and as clouds form and move about. This short-term variation gives variety and interest. A lack of windows gives a constant environment, which is potentially boring and depressing. (Dalke, eta ,2004, p 40)

• Sunlight, which is seen as therapeutic and invigorating.

Access to sunlight will depend on window orientation and on overshadowing by obstructions. In general, spaces lit solely by windows facing within 45 degrees of due north will be perceived as poorly sunlit. Windows within 90 degrees of due north are also likely to give little sun if there are significant obstructions to the south. (Dalke, eta ,2004, p41).

-to get all these benefits from windows the ratio of window area to floor area must be l/5 the floor area.(Brown,1893, p19).

3.5 Examples

3.5.1 Wansbeck Hospital

- building's location**:** Wansbeck Hospital on the outskirts of Ashington in Northumberland.

Architect**:** Powell Moya Partnership.

Lighting Design : Cundall Johnston & Partners.

About building**:** the building was completed in 1993, the second National Health Service low-energy hospital following the building of ABK's St Marys Hospital on the Isle of Wight.

Daylighing in building**:** the building was designed to achieve a target of a60 per cent reduction in the use of energy compared to a traditional nucleus plan hospital. To assist with the development and introduction of the natural lighting and ventilation systems needed to achieve this target.

The roof lighting design which uses a walk-through duct at high level, to provide good natural light into the wards provides natural light to the rear of the deep wards. Coupled with the side windows this means that electric light is rarely required even on overcast days. To eliminate glare, vertical baffles are provided to intercept the patient's view of the roof lights.

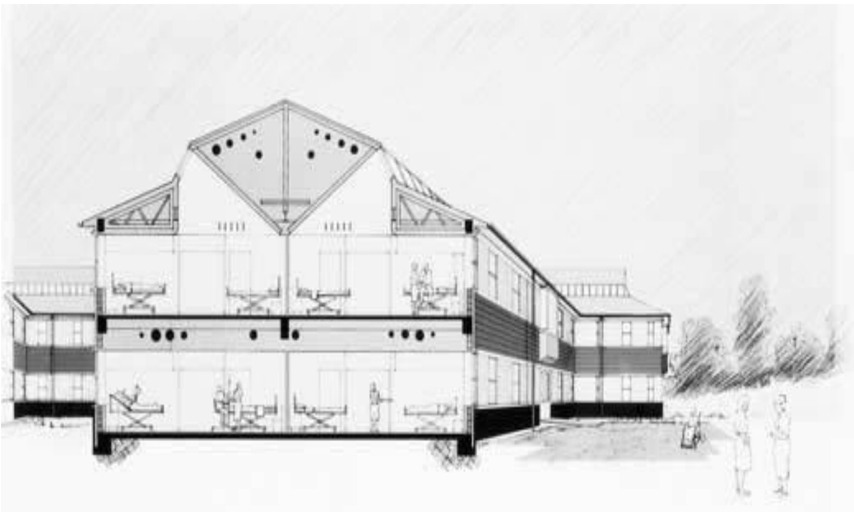


figure 3-1Sectional perspective through wards
Source: (Phillips, 2000)

figure 3-2 Typical ward, illustrating the natural and artificial lighting systems
Source: (Phillips, 2000)

figure 3-3 Dining Room
Source: (Phillips, 2000)

3.5.2 St Mary's Hospital

building's location**:** Isle of Wight
Architect**:** Ahrends, Burton & Koralek (ABK)
Lighting Design : Cundall Johnston & Partners.
About building**:** is the principal hospital for the island, offering 191 bed spaces, new outpatient's, children's and old people's departments, laboratories, workshops and operating theatres, as well as a social centre for the village. The plan is organized on the nucleus principle, a system based on a cruciform plan, with legs containing the patients' areas and a central station for nurses. The legs can be planned in a variety of ways to accommodate small or large wards according to need.
Daylighing in building**:** the natural light is provided into wards by roof light and side windows so all patient areas have access to good natural light and views to

the excellent landscaping of the outside courtyards. The patient's restaurant area has good natural light from side windows.

figure 3-4 View of ward to show the natural lighting system
Source: (Phillips, 2000)

figure 3-5 View from the window to the outside court
Source: (Phillips, 2000)

figure 3-6 Patient's restaurant
Source: (Phillips, 2000)

3.5.3 Finsbury Health Centre
building's location**:** London
Architect: Lubetkin
About building: the centre was designed in 1938, survives to still function today in the manner it was designed. Avanti Architects have undertaken conservation

and repair work in the1990s with a view to ensuring that its purposes are well-served into the twenty-first century.
Dayligthing in building: the foyer of centre is lit by natural light during the day using a wall of glass bricks, All the offices and consulting rooms located in the side wings are daylit by glass wall. The access corridors are lit during the day by side windows, giving very adequate daylight.

the centre was designed to be avery energy efficient building, thus electric lighting would have only been used at night.

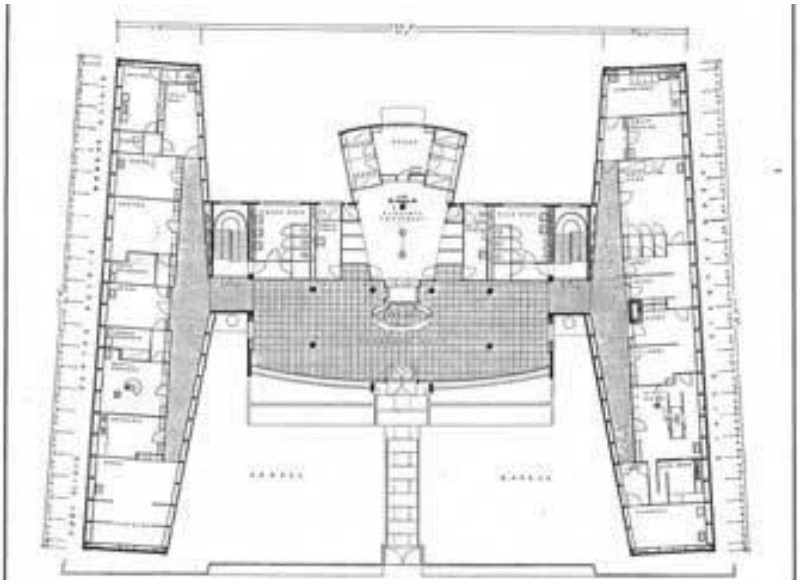


Figure 3-7 Ground floor plans for Finsbury Health Centre - London
Source: (Phillips, 2000)

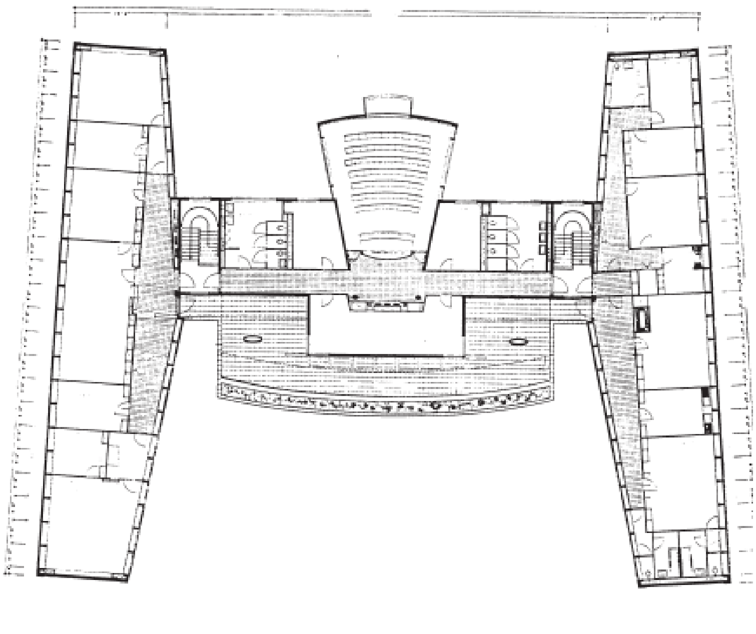


Figure 3-8 first floor plans for Finsbury Health Centre - London
Source: (Phillips, 2000)

Figure 3-9 The foyer (1999) of Finsbury Health Centre - London
Source: (Phillips, 2000)

3.5.4 Infante D. Juan Manuel Health Centre, Spain

building's location**:** The Health Centre 'Infante D. Juan Manuel' is located in the town of Murcia in the south-east of Spain

Architect: Tomas Menor Perez.

About building: the health centerlatitude is 37°59'N. (Mean daily global radiation 4850Wh/m2.. Mean daily sunlight duration 8hrs.) Daylight is not significantly obstructed by neighbouring 6-storey apartment buildings. The two-storey building has a floor area of 1,800m2 and is planned for a maximum occupancy of 300 persons. The client was the Instituto Nacional de la Salud. Construction was completed in mid-1993 .

Dayliging in building: The health centre consists of three parallel bays with pitched roofs. Treatment, consulting and service rooms are distributed along the north and south faces, with the main stairway and the waiting spaces in a two-storey day-lit central bay on the east-west axis. The south elevation has large windows (set in a Trombe wall), the north has smaller ones, while east and west facades are almost windowless. The windows on the south facade are shaded from summer sun by a 3.5m loggia.

With the exception of one or two small bathrooms, all perimeter rooms are side-lit. There are small external light shelves on these windows. Two of the three south-facing roof slopes are pierced by large rooflights which admit daylight and winter sunlight to the white-painted roofspace. This light is directed down into the upper atrium, and thence through lightwells and glass block flooring to the waiting areas, conference room and physiotherapy room on the ground floor. Awnings within the roof-space reduce sunlight penetration during the summer.

The combined effect of the natural heating, cooling and lighting strategies was expected to result in energy savings of 70% over those of a conventional building in the same area.

fig 3-10 Infante D. Juan Manuel Health Centre’s exterior views
Source: (The European Commission, 1994)

fig 3-11 Infante D. Juan Manuel Health Centre’s interior views
Source: (The European Commission, 1994)

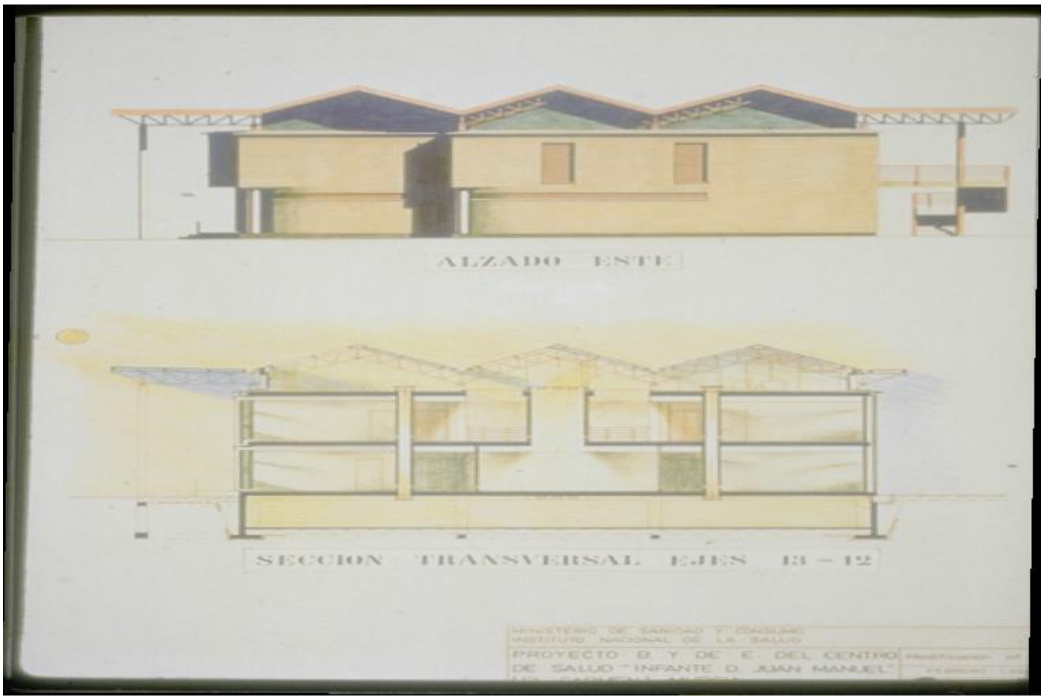


fig 3-12 Infante D. Juan Manuel Health Centre’s section
Source: (The European Commission, 1994)

3.6 Previous studies

3.6.1 Diab, Abu Qadourah and Hammad's study / 2017.

-Title of research: Daylight Quality in Healthcare Design, Daylight Measurements Results and Discussion, Case Study: Jordan University Hospital
-place of studying: Amman – Jordan.
- this research was applied in Jordan University Hospital (JUH). a multi-method approach used in this study, lab test and on-site measurements were conducted to investigate, analyse, and evaluate the daylight conditions in patient rooms in pediatric wards at JUH.
on-site measurements The lux meter used to measure the internal illuminance levels in the patient room also CAD (computer aided design) software was used to model the patient room configurations.
- D-plot analysis graphic was used as a tool to present the result. Comparative analyses were conducted for the field measurements of the current situation, and the recommended values.
- From the analysis of all data The study found that :-
1- the indoor daylight performance in terms of illuminance, luminance level, and daylight factor in east patients' rooms are higher than the recommended values by CIBSE in the area nearest to glass window at the morning and less the recommended values in the depth of the room at afternoon. This means that the patients in the east facing rooms exposed to visual discomfort like glare.
2- According to experimental tests, the day light control strategy which consists of the vertical louver, horizontal louver with reflected surface and sky light diffuse is successful. This strategy solves the problem and gives optimized indoor daylight performance in terms of illuminance which reaches the recommended values by CIBSE. This strategy can be applicable in east patients' rooms to avoid the excessive glare and to provide an effective visual comfort environment for
patients and staffs.
- the researchers recommend for making another research in this filed in Jordan.

3.6.2 Ju-Yoon Lee1, a, Kyoo-Dong Song's study/2007

-Title of research: The Daylighting Effects in Hospital for Healing Patients
-place of studying: Seoul - Korea**.**
-this research was applied in H-hospital in Haengdang-dong, Seongdong-gu, Seoul, and the K-hospital in Cheongnangni-dong, Dongdaemoon-gu, Seoul. in H-hospital The main building is with twenty-one stories above ground and two below, and the wards are placed between 6th and 21st floor. the research in every ward
between 6th and 15th floor except three departments in 6th floor. while in K-hospital there is just one big building has ten stories above ground and two below. The wards are between 5th and 9th floor.
This study was conducted to identify the effect of the daylight on the treatment

period of patients and medical outcomes in hospitals. Two major variables were the direction of the wards and the hospitalization period of various kinds of patients. To evaluate the visual environment in patient rooms, illuminance and luminance distributions were calculated through the computer simulation. Then statistical tests were applied in order to verify if the natural light reduced the hospitalization period of patients.

- The summaries of this study are as follow;

1- According to the result of analysis of the period of the hospitalization based on direction of south and north both H-hospital and K-hospital, the patients in the southern wards tend to stay shorter than in the northern, by 19.84%, 8.52% respectively.

2- The amount of daylight coming inside the hospital affects the period of the hospitalization of patients and it gives positive effect in shortening the period of the hospitalization of patients.

3.6.3 Choi ,Beltran's study / 2004

-Title of research: study of the relationship between penitent's recovery and indoor daylight environment of penitent's rooms in healthcare facilities.

-Place of study: Soul in South Korea and Texas in U.S.A.

- this study examines how daylight affects penitent's hospitalization times in two healthcare facilities (st.joseph hospital in (Bryan , Texas , USA) and yonsei medical center (Soul , South Korea)).this study uses on-site observations and measurements for illuminance level and daylight conditions of penitent's room. the data of peitent's hospitalization times were obtained from st.joseph hospital in (Bryan , Texas , USA) and yonsei medical center (Soul , South Korea) . the collected data were categorized according to their ward's department. hospitalization time was compared within wards based on their orientation, location and diseases.

Other aspects considered in this study were : solar position , weather properties, daylight level and other physical environment properites of two site locations (Bryan , Texas and Soul , South Korea) statistical analysis , weather conditions and miscellaneous properties of each facility were investigated.

-Results show that penitents in a room with higher daylight levels had shorter stays than those in rooms with lower daylight level. in case of st.joseph hospital, north-facing rooms had higher daylight factors than south-facing rooms thus penitents of north-facing rooms hospitalization room times were 12.5% shorter than those who were in the south – facing penitent room. in case of Yonsei medical center . daylight factors are higher in south-east facing penitent's room than in north-west facing rooms. penitent hospitalized in the south-east facing rooms of oncology and internal wards left hospital 4.5% and 8% earlier (respectively) than in the norh-west facing rooms.

3.6.4 Alzubaidi1, Roaf, Banfill, Talib, Al-Ansari's study / 2013

-Title of research: Survey of Hospitals Lighting: Daylight and Staff Preferences.

-Place of study: Doha, Qatar.

-face to face interviews were conducted to explore the staff satisfaction with hospital lighting in Hamad General Hospital (HGH) the central healthcare facility in Doha, Qatar. The questionnaire was aimed at hospital professionals who visit the patient on a daily basis. one hundred and thirty four participants volunteered to participate were asked twenty eight questions, but for the purpose of this study we will present their response on four questions that show their preference and experience with daylighting at patient rooms. The results of survey were as fallowing:

- seventy nine percent of the staff believes that daylight in patient's room helped them do their work more easily, including treating and diagnosing patient health and monitoring their recovery.

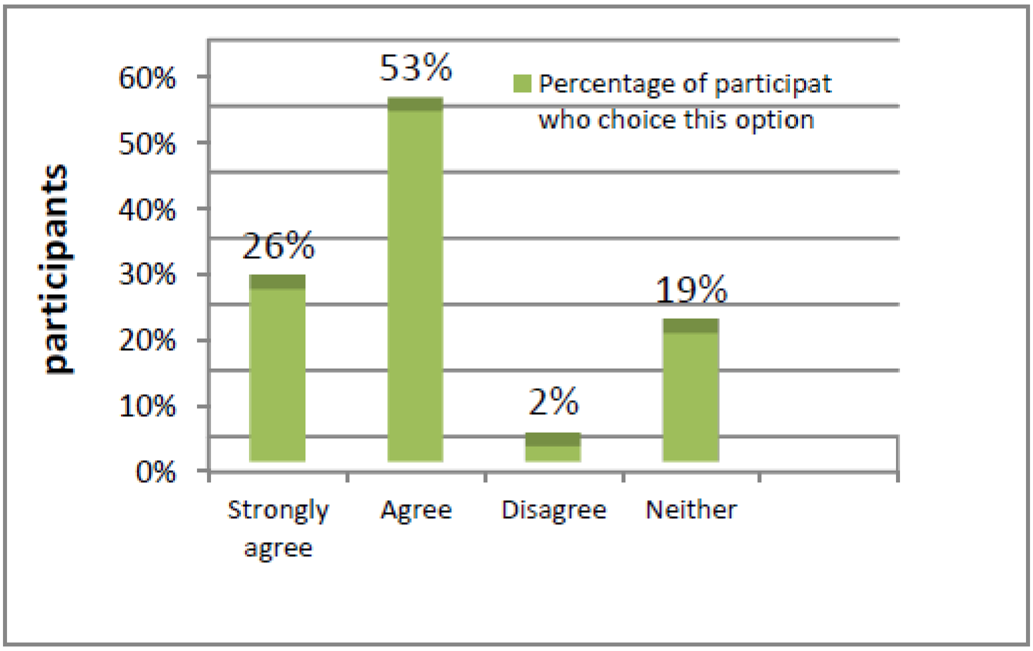


figure 3-13Treat Patient in room with Daylight
Source: (Alzubaidi1, Roaf, Banfill, Talib, Al-Ansari, 2013)

-seventy one percent of the staff think daylight plays an important role in recognizing changes in patient skin color. The daylight features of providing brighter light source during the day and having a more balanced colored spectrum than other light sources contribute to it being a suitable source to be used in patient rooms.

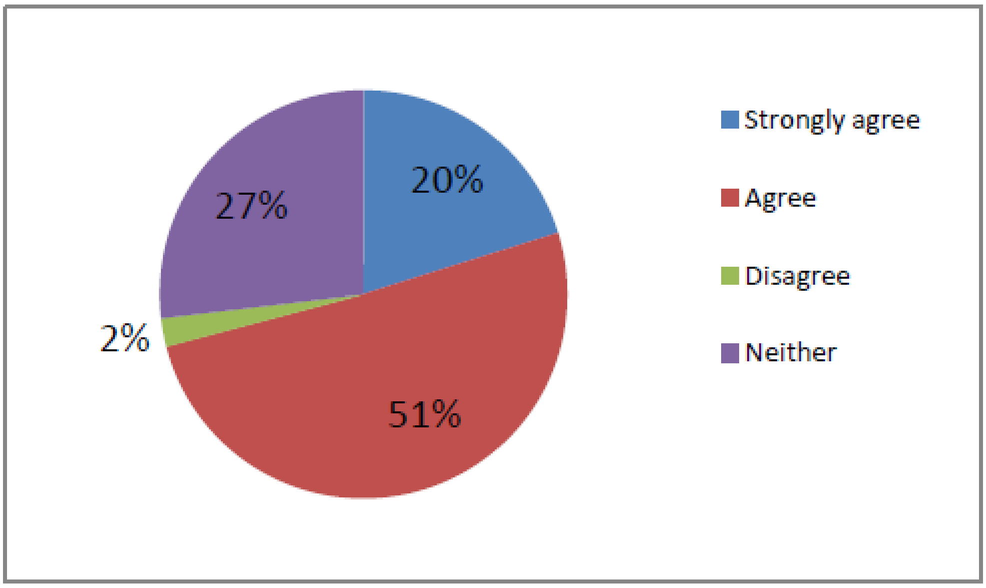


figure 3-14 Daylight helps identify patient skin colour
Source: (Alzubaidi1, Roaf, Banfill, Talib, Al-Ansari, 2013)

-ninety two percent of the staff agreed with daylight makes patient feel comfortable.

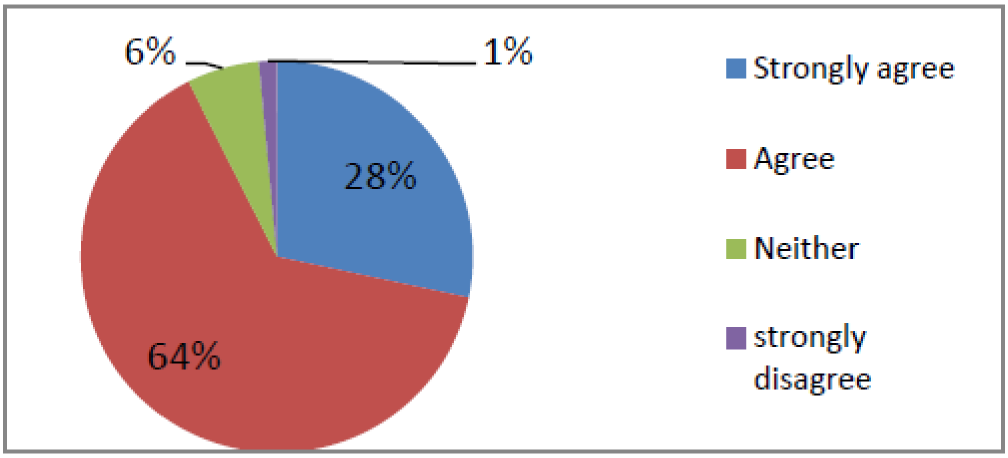


figure 3-15 Daylight makes Patient Feel Comfortable
Source: (Alzubaidi1, Roaf, Banfill, Talib, Al-Ansari, 2013)

-eighty two percent of the hospital staff see daylight as an element that can help speed up the recovery process for patients and hence reduce the length of stay in the hospital.

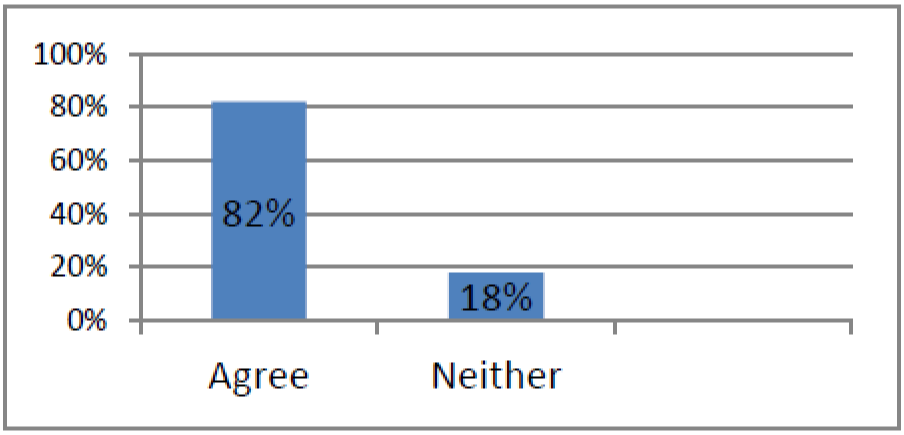


figure 3-16 Daylight makes Patient Recover Faster
Source: (Alzubaidi1, Roaf, Banfill, Talib, Al-Ansari, 2013)

CHAPTER FOUR

METHODOLOGY

4-1 Background

4-1-1The case location

Fig 4-1 Al-moalem medical city
Source: (www.google.com)

The study case was Almoalem medical city. it was built in , it’s located in Khartoum buri. with a geographical coordinates of(31°10'00"N) latitude and (34°26'00"E) longitude and UTC / GMT +2 time zone.

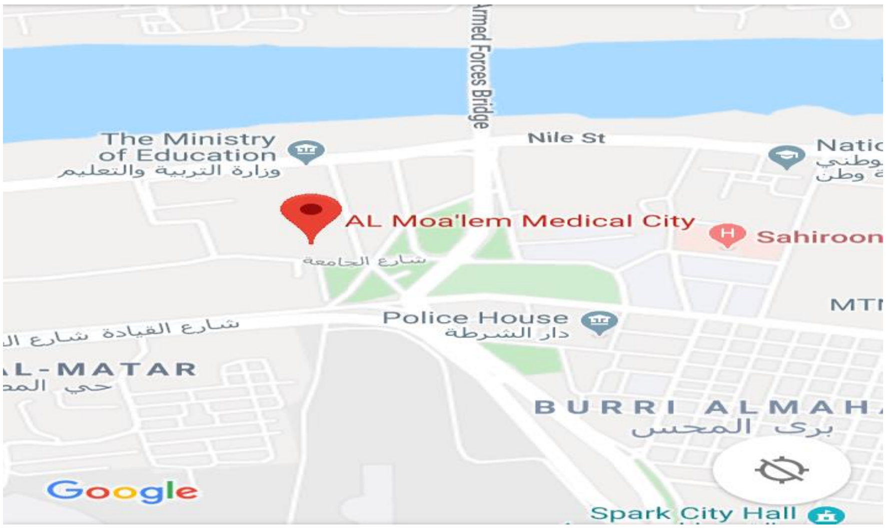


Fig 4-2 Al-moalem medical city location
Source: (www.google.com)

4-1-2 Climate

Almoalem medical city characterized with very long sunshine and daylight hours because it locates geographically in hot dry climate area.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Sunlight Hours/ Day	10:36	11:04	10:23	10:42	10:00	09:48	08:23	08:36	09:18	10:17	10:48	10:30	10:01
Average Daylight Hours & Minutes/ Day	11:18	11:36	12:01	12:28	12:50	13:01	12:56	12:37	12:11	11:45	11:22	11:12	12:00
Sunny & (Cloudy) Daylight Hours (%)	95 (5)	96 (4)	87 (13)	87 (13)	79 (21)	76 (24)	65 (35)	69 (31)	77 (23)	88 (12)	96 (4)	95 (5)	84 (16)
Sun altitude at solar noon on the 21st day (°).	54.4	63.7	74.6	86.3	85.3	82.2	84.9	86.4	75	63.4	54.3	51	71.9

fig 4-3 Khartoum sunshine and daylight
Source (www.khrtoum.climatemps.com)

Figure (4-3) shows the average sunshine and daylight hours in Khartoum city. It is noticed that hours of sunshine in Khartoum range between 8:23 hours for each day in July and 11:04 hours for each day in February. with annual average of sunshine 10:01hours per day.and 12:00 hours per day as annual average of daylight hours.

the longest day of the year in Khartoum is 12:55 long and the shortest day is 11:04 long. and it is sunny 83.6% of daylight hours the remaining 14.6% of daylight hours are likely cloudy or with shade, haze or low sun intensity.

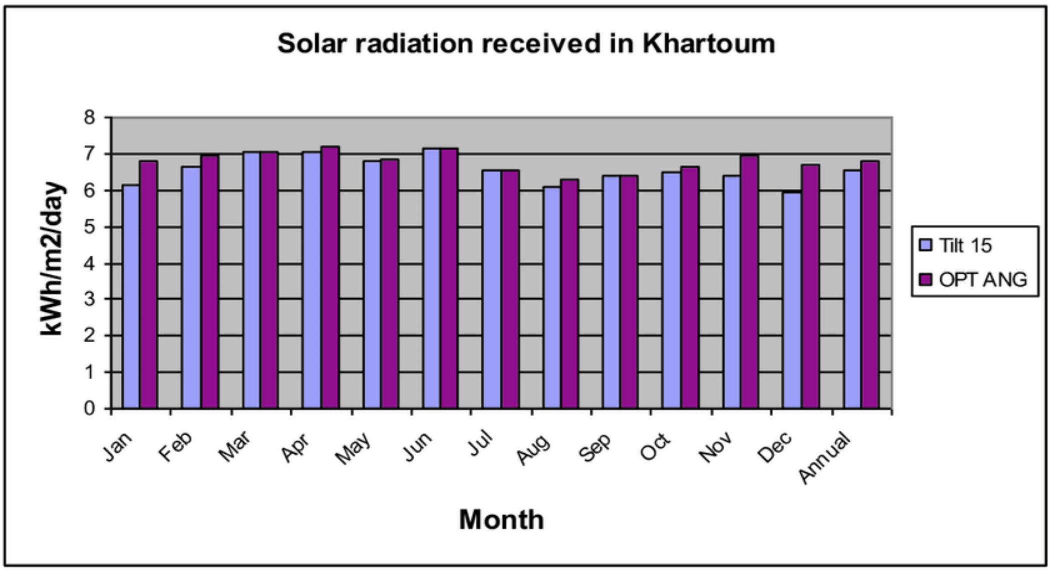


fig 4-4 Solar radiation received in Khartoum
Source (www. researchergate.com)

4-1-3The Case Description

Almoalem medical city compose medical building and three servicing buildings (mosque – medical waste – electric main rooms+ toilets).the medical building was the field of study compose of four floor :-

- ground floor includes main building (dental clinic – laboratory – pharmacy – main reception – waiting areas – x-ray room – ultrasound room - C.T. room – emergency ward) and servicing buildings which includes (kitchen- store – workshop – central sterilization – medical gas system – oxygen generation-electrical room)

-First floor includes (oncology department – maternity department – endoscopy department- I.C.U room – operation rooms – staff rest rooms).
-Second floor includes (wards – rooms – administrative offices –conference hall- doctors lounges – C.C.U).
- Third floor includes patient rooms.

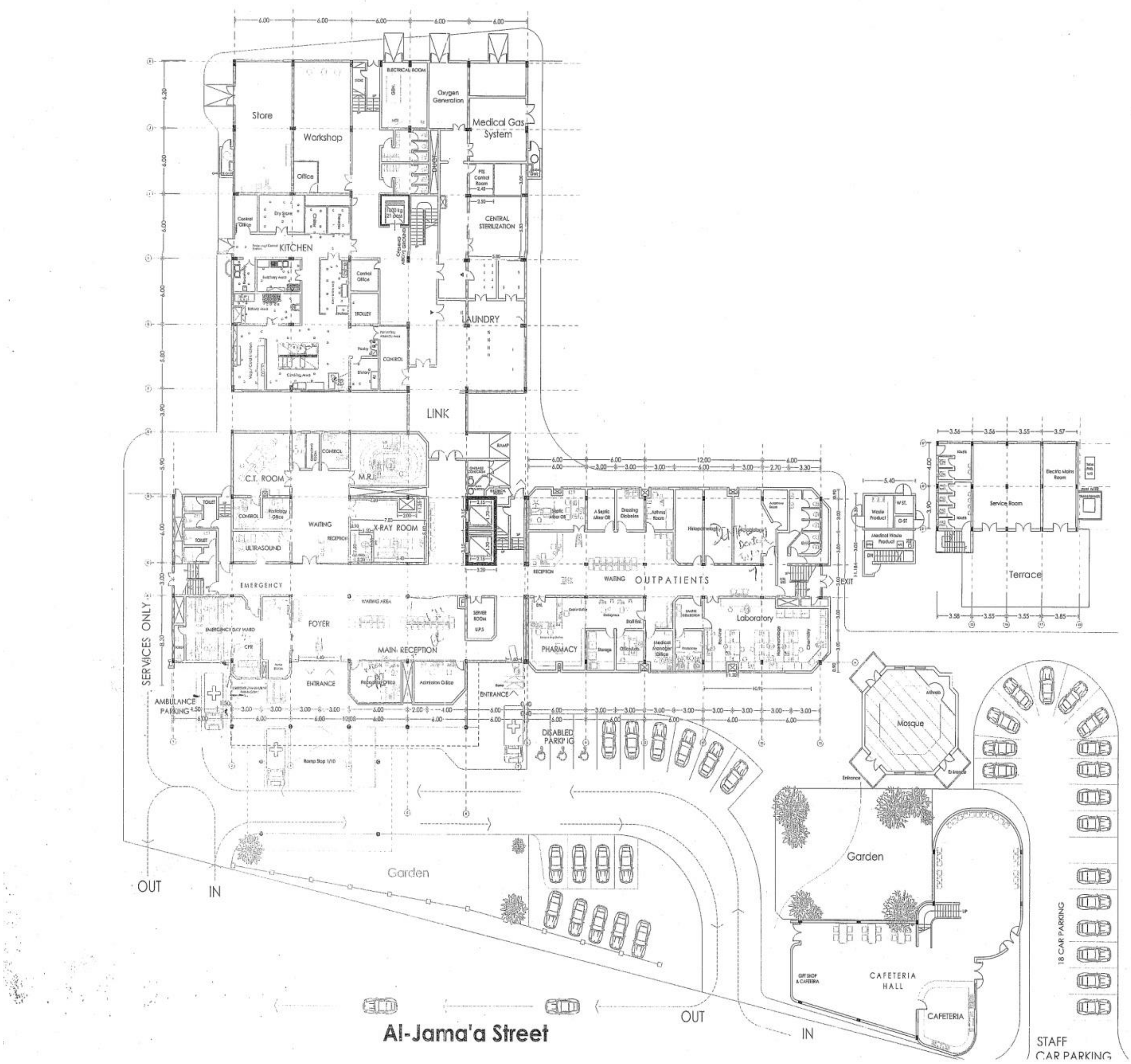


Fig 4-5 Al-moalem hospital’s ground floor plan
Source: (Al-moalem medical city administration)

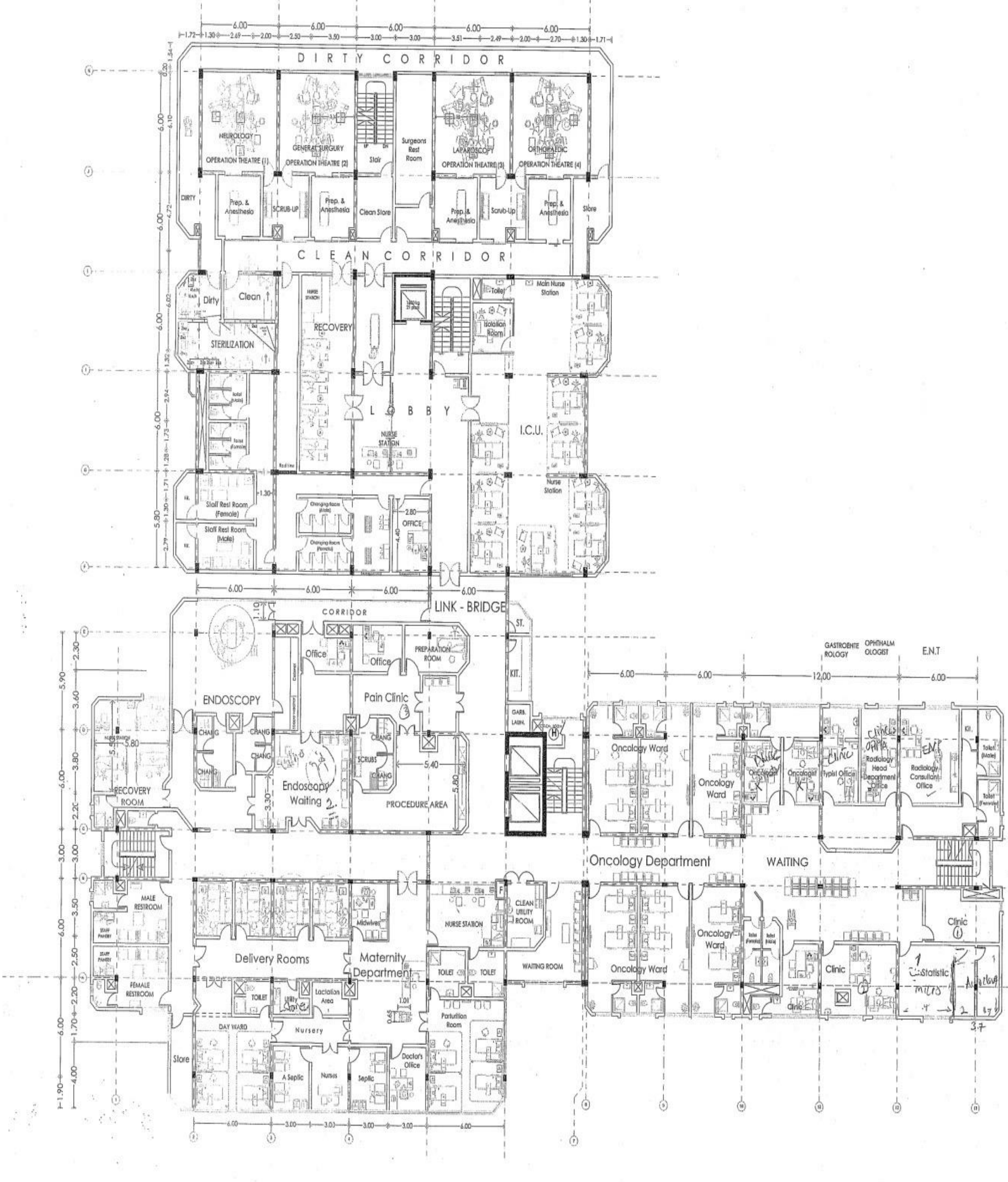


Fig 4-6 Al-moalem hospital's first floor plan
Source: (Al-moalem medical city administration)

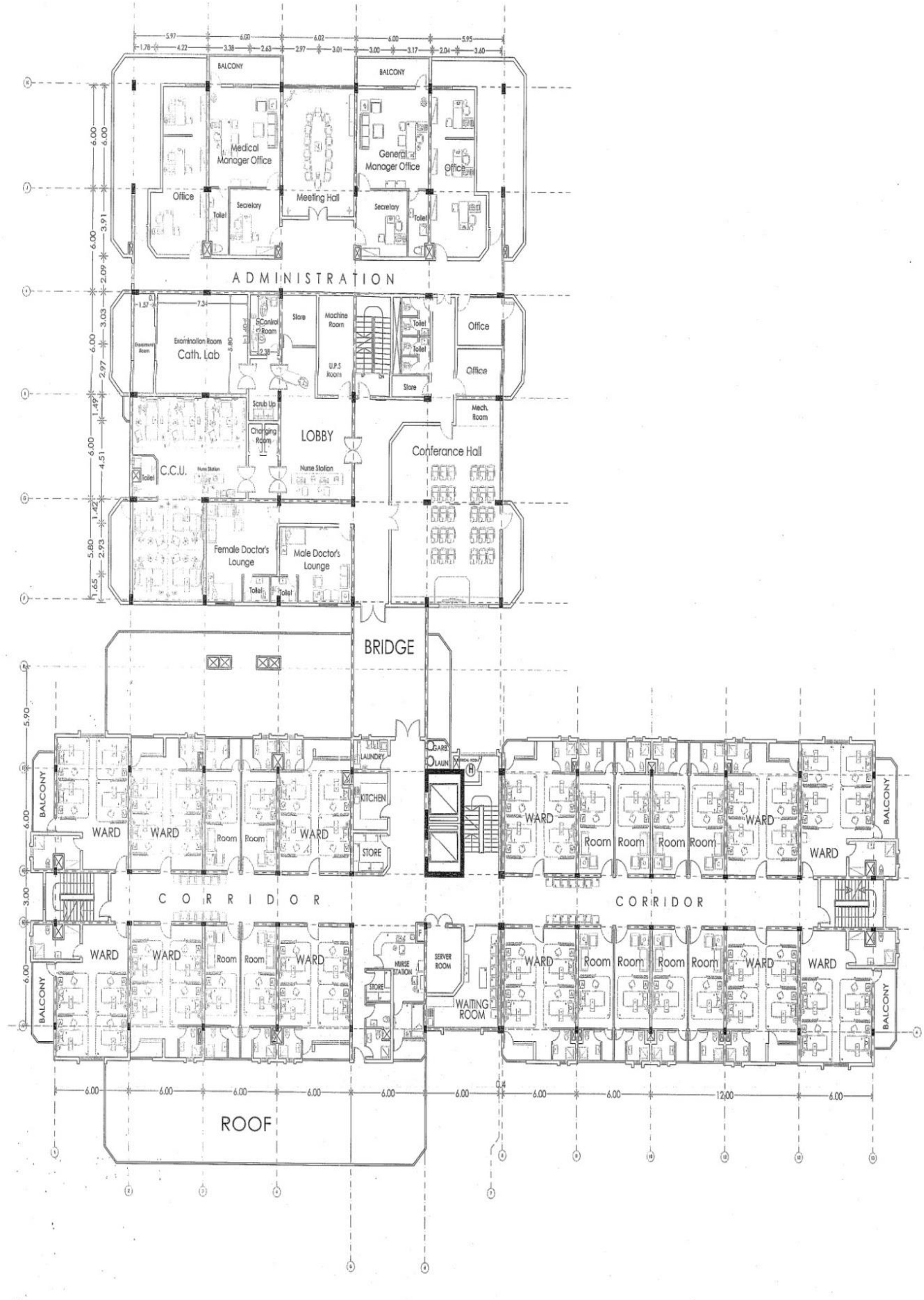


Fig 4-7 Al-moalem hospital's second floor plan
Source: (Al-moalem medical city administration)

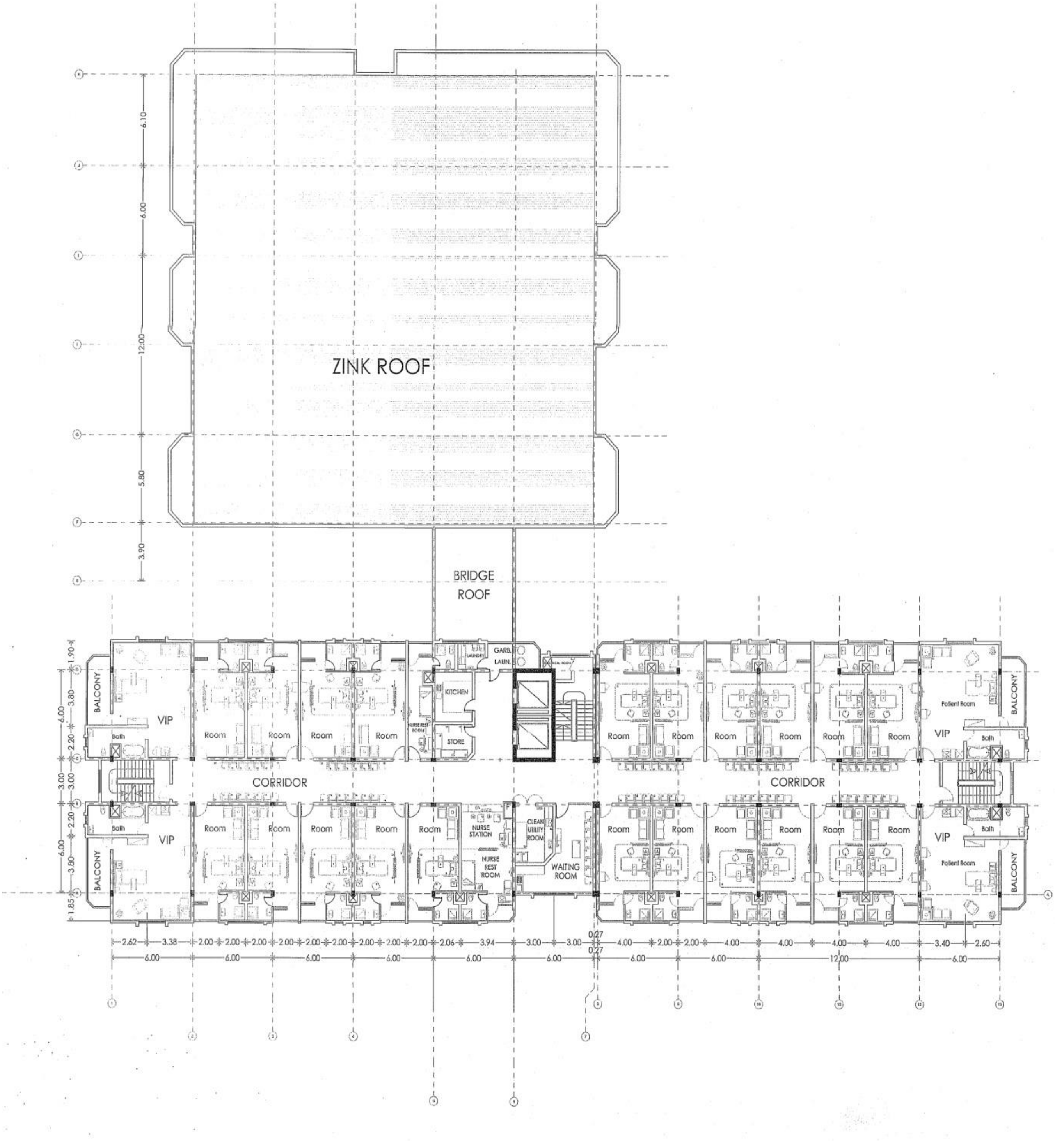


Fig 4-8 Al-moalem hospital's third floor plan
Source: (Al-moalem medical city administration)

4-2 Methodology

the methodology was followed in this study depended on analysis of daylighting levels in each space in hospital by the following steps.

Step 1: Measuring interior daylighting level

The interior daylighting level in spaces was measured by taking readings of daylighting level in random points which specified in each space, These readings were taken by luxmeter.

Step2:calculating the arithmetic mean of interior daylight readings & comparing it with standard value

The following formula was used to calculate the arithmetic mean :

$$\overline{X} = \Sigma x_i / n$$

$x_i = i^{th}$ variable

n = number of variables in the data set

- CIBSE standard(chartered institution of building services engineers) will be used for comparing.

conclusions

Step3: Calculating (DF) daylighting factor& comparing it with standard value

The following formula was used to calculate the real daylighting factor

$$DF = 0.1 \times p$$

DF = daylighting factor
p = Percentage of glazing area to floor area
- CIBSE standard (chartered institution of building services engineers) will be used for comparing.

⇩

Step4 :daylighting parameter analysis

in this step daylighting parameters (orientation , window openings, obstructions , materials reflectivity) will be analyzed and evaluated according to standards.

⇩

fig(4-9)research methodology

4-2-1 Analysis of daylight levels

-The study was in winter on 19th November from 10 am -12 pm.

-Readings were taken when the artificial light shutting down.

- Daylight levels Measurement tool used was luxmeter.

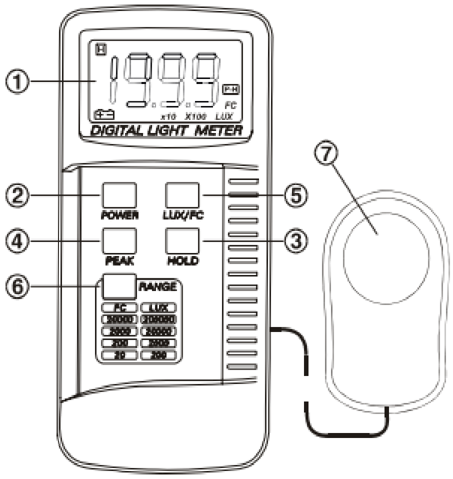
luxmeter is used for checking the level of luminance , or the light falling on a surface.

fig 4-10 daylight level measurement tool (luxmeter)

Source: (www.pce-instruments.com)

parts of luxmeter are:

1- LCD display which display reading of luminance level.



2- power switch : turns the luminance meter ON/ off.

3- Data- hold switch.

4- Data-peak switch: to clear the peak recording mode.

fig 4-11 daylight level measurement tool (luxmeter)

Source: (www.pce-instruments.com)

5- LUX / FC unite switch : to choose LUX / FC unite.

6- Range switch: to choose the range of luminance level reading which start from 0 up to 200,000 LUX or 0 up to 20,000 FC.

7- Photo detector.

1- Main reception:-

Fig 4-12 Al-moalem hospital's main reception
Source: (taken by researcher)

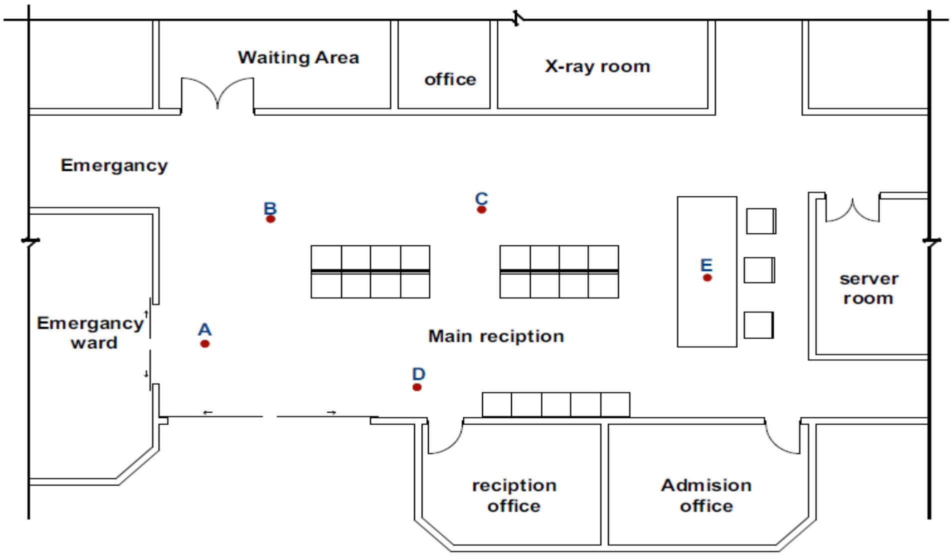


Fig 4-13 Reading points of Al-moalem hospital's main reception
Source: (the researcher)

location	Reading points	Measured lux merter readings
General reading	A	22
	B	22
	C	4
	D	12

Enquiry desk	-	12
Arithmetic mean		16
Standard reading		300

Table 4-1 measured and standard lux meter readings for main reception
Source: (the researcher)

location	Area(m2)		P(glazing area to floor area)	Calculated DF(0.1×p)	Standard DF
	glazing area	floor area			
main reception	13.2	93.6	14	1.4	2

Table 4-2calculated DF and measured DF for main reception
Source: (the researcher)

Space name	orientation	WFR	obstructions	reflectance	
reception	North	14%	√	wall	20%
				floor	30%
				ceiling	63%

table 4-3 daylighting parameters analysis for main reception
Source: (the researcher)

- Result:-

The result showed that the arithmetic mean of measured readings and calculated DF are lower than standard reading which means this space is too dim as shown in figure 4-12 and table 4-1, in addition to the distribution of lighting is unregulated - in some points almost no light such as point C - as shown in table 4-1.

- Conclusion:-

The orientation of main reception is northern orientation which is suitable for daylighting but there are two rooms blocked this direction as illustrated in figure 4 -12, and it has very large area in addition to there is no neutral light access despite of there is only one door size 6.00*2.20m northern orientation ,but there is a large awning in front of this door which obstruct natural light enter the space and WFR is lower than standard. Moreover the material reflectance for walls and floor are 20%(wooden brown) ,30% (gray marble) respectively. All these factors decrease the amount of daylight enter the space.

2- Medical manger office :-

Fig 4-14 Al-moalem hospital’s medical manger office
Source: (taken by researcher)

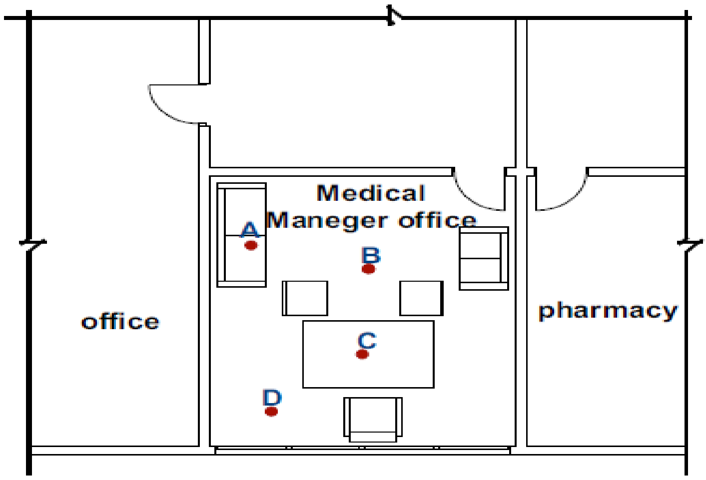


Fig 4-15 Reading points of Al-moalem hospital’s medical manger office
Source: (the researcher)

location	Reading points	Measured lux merter readings
General reading	A	0
	B	0
	C	1

	D	5
Arithmetic mean		16
Standard reading		200

Table 4-4 measured lux meter and standard readings for medical manger office
Source: (the researcher)

location	Area(m2)		P(glazing area to floor area)	Calculated DF(0.1×p)	Standard DF
	glazing area	floor area			
medical manger office	1.5	11.7	12	1.2	3

Table 4-5calculated DF and standard DF for medical manger office
Source: (the researcher)

Space name	orientation	WFR	obstructions	Reflectance	
medical manger office	North	12%	×	wall	66%
				floor	53.4%
				ceiling	70%

Good
Poor

table 4-6 daylighting parameters analysis for medical manger office
Source: (the researcher)

- Result:-

The result showed that the arithmetic mean of measured readings is lower than standard reading which means this space is too dim, almost there is no light in this space- as readings shown in table 4-4 .

- Conclusion:-

The orientation of space is southern orientation which is suitable for daylighting availability, but there are no windows in the space at all, there is glazed area in southern wall size 0.50*3.00m which give lower WFR, in spite of there are no obstructions and the space materials has a high reflectivity (wall 66% (medium blue), floor 53% (cram), and ceiling is 70% (white)).

Ward:-

Fig 4 -16 Al-moalem hospital's wards
Source: (taken by researcher)

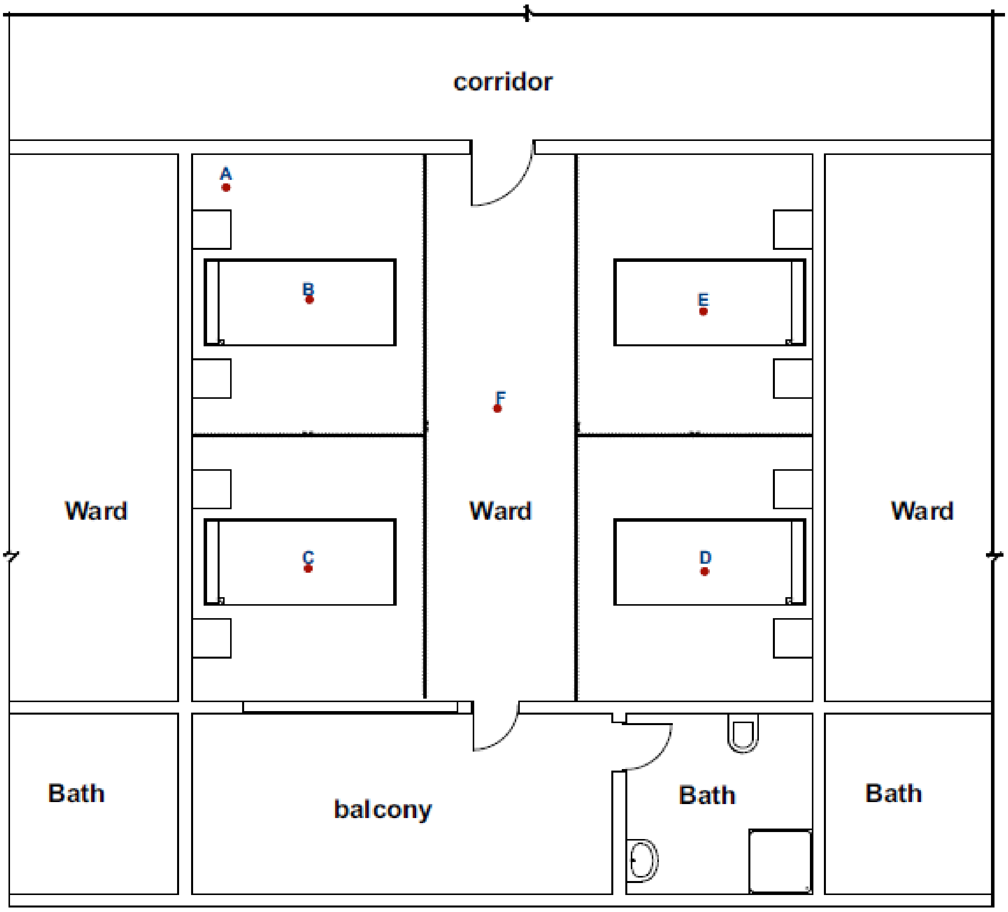


Fig 4 -17 Reading points of Al-moalem hospital's wards
Source: (the researcher)

location	Reading points	Measured lux merter readings
General reading	A	51
	B	74
	C	182
	D	181
	E	86
	F	51
Arithmetic mean		104
Standard reading		100

table 4 -7 measured lux meter and standard readings for ward
Source: (the researcher)

location	Area(m2)		P(glazing area to floor area)	Calculated DF(0.1×p)	Standard DF
	glazing area	floor area			
Ward	4.40	36	12	1.2	3

Table 4-8calculated DF and standard DF for ward
Source: (the researcher)

Space name	orientation	WFR	obstructions	reflectance	
ward	South	12%	×	wall	66%
				floor	95%
				ceiling	-

Good

Poor

table 4-9 daylighting parameters analysis for ward
Source: (the researcher)

- Result:-
The space is bright (it can be considered according to standard).

- Conclusion:-
The ward is deep somewhat which lead to unregulated distribution for daylighting. In addition to WFR is lower than standard. But the orientation of ward is south orientation which is suitable orientation. Moreover the materials reflectivity is high and there are no obstructions restrain daylight. as shown in table (4-9).

4-Clinic:-

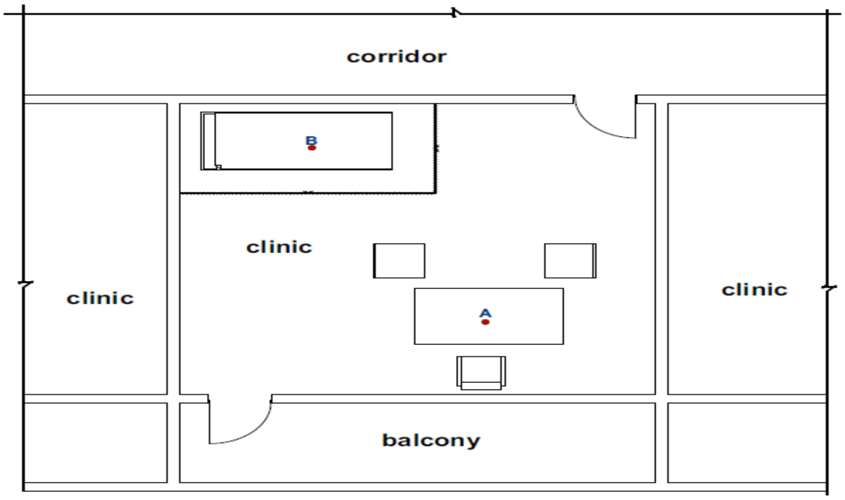


Fig 4-18 Reading points of Al-moalem hospital's clinic
Source: (the researcher)

location	Reading points	Measured lux merter readings
Working plane	A	28
Enquiry desk	B	2
Arithmetic mean		15
Standard reading		500

table 4-10 measured luxmeter and standard reading for clinic
Source: (the researcher)

location	Area(m2)		P(glazing area to floor area)	Calculated DF(0.1×p)	Standard DF
	glazing area	floor area			
Clinic	1.10	11.4	9	0.9	3

Table 4-11calculated DF and standard DF for clinic
Source: (the researcher)

Space name	orientation	WFR	obstruction	reflectance	
clinic	South	9%	×	wall	-
				floor	95%
				celleing	70%

Good

Poor

table 4-12 daylighting parameters analysis for clinic
Source: (the researcher)

- Result:-
The result showed that the arithmetic mean of measured readings is lower than standard reading which means this space is too dim, in addition to the distribution of lighting is unregulated - in some points almost no light such as point B - as shown in table 4-10 .
- Conclusion:-
The orientation of clinic is southern orientation which is suitable for daylighting availability, but there are no windows in the space at all, there is glazed area in southern door its WFR is lower than standard so enters a little amount of daylight. Although there are no obstructions and it has a high materials reflectivity as shown in table (4-12).

5-corridors:-

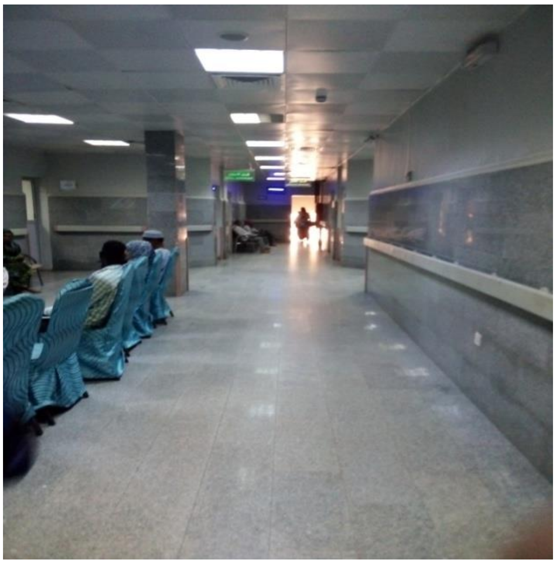


Fig 4-18 Al-moalem hospital's corridor
Source: (taken by researcher)

location	Reading points	Measured lux merter readings
General reading	A	0
	B	0
	C	0
	D	0
Arithmetic mean		0
Standard reading		200

Table 4-13 measured lux meter and standard reading for corridor
Source: (the researcher)

location	Area(m2)		P(glazing area to floor area)	Calculated DF(0.1×p)	Standard DF
	glazing area	floor area			
Corridor	0	90	0	0	1

Table 4-14 calculated DF and standard DF for corridor
Source: (the researcher)

Space name	orientation	WFR	obstructions	reflectance	
corridor	-	0%	√	wall	30%
				floor	30%
				ceiling	70%

Good

Poor

table 4-15daylighting parameters analysis for corridor
Source: (the researcher)

- Result:-

The result showed that the arithmetic mean of measured readings is (0) which means there is no daylight in this space at all, as shown in figure 4-18 and table 4-13.

- Conclusion:-

The corridor is blocked by many spaces from all directions so there is no access for daylight (WFR is 0%) , also the material reflectance is 30% (gray marble) for walls and floor does not help lighting process.

6-Room:-

Fig 4-20 Al-moalem hospital's rooms
Source: (taken by researcher)

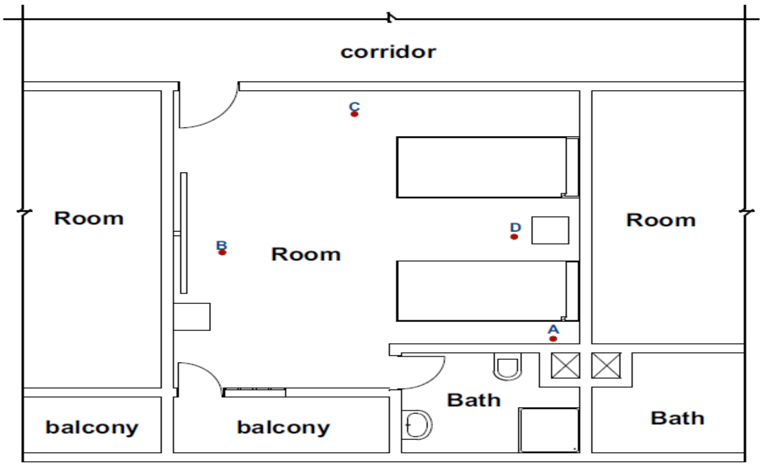


Fig 4-21 Reading points of Al-moalem hospital's rooms
Source: (the researcher)

location	Reading points	Measured lux merter readings
General reading	A	93
	B	93
	C	52
	D	9
Arithmetic mean		62
Standard reading		100

table 4-16 measured lux meter and standard reading for room
Source: (the researcher)

location	Area(m2)		P(glazing area to floor area)	Calculated DF(0.1×p)	Standard DF
	glazing area	floor area			
Room	3.16	24	13	1.3	3

Table 4-17calculated DF and standard DF for room
Source: (the researcher)

Space name	orientation	WFR	obstructions	reflectance	
room	South	13%	√	wall	63%
				floor	95%
				ceiling	70%

Good

Poor

table 4-18 daylighting parameters analysis for room
Source: (the researcher)

- Result:-

The result showed that the arithmetic mean of measured readings and calculated DF are lower than standard reading which means this space is dim, in addition to the distribution of lighting is unregulated - in some points almost no light such as point D - as shown in table 4-16.

- Conclusion:-

The orientation of room is southern orientation which is suitable for daylighting availability, and it has a high material reflectivity as shown in table 4-18 all these factors increase the amount of daylight inside the room but there is a balcony in south direction obstruct the light, moreover the WFR is lower than standard.

7-VIP room:-

Fig 4-22 Al-moalem hospital's VIP rooms
Source: (taken by researcher)

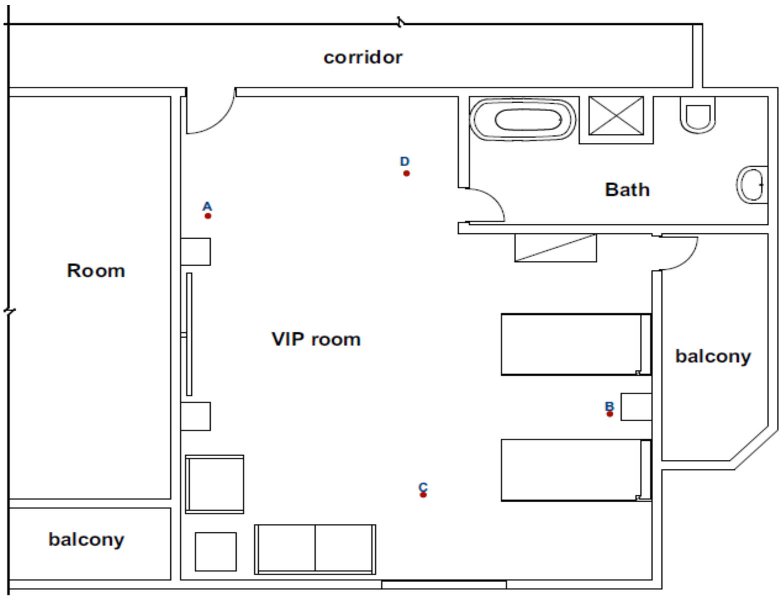


Fig 4-23 Reading points of Al-moalem hospital'sVIP rooms
Source: (the researcher)

location	Reading points	Measured lux merter readings
	B	72
	C	130
	D	62
Arithmetic mean		85
Standard reading `		100

table 4-19 measured lux meter and standard reading and (DF) for VIP room
Source: (the researcher)

location	Area(m2)		P(glazing area to floor area)	Calculated DF(0.1×p)	Standard DF
	glazing area	floor area			
VIP Room	3.16	47.1	6	0.6	3

Table 4-20 calculated DF and standard DF for VIP room
Source: (the researcher)

Space name	orientation	WFR	obstructions	reflectance	
VIP room	South	6%	×	wall	63%
				floor	95%
				ceiling	70%

Good (green)

Poor (yellow)

table 4-21 daylighting parameters analysis for VIP room
Source: (the researcher)

- Result:-

The result showed that the arithmetic mean of measured readings and calculated DF are lower than standard reading which means this space is dim, in addition to the distribution of lighting is regulated as shown in table 4-19.

- Conclusion:-

The orientation of room is southern orientation which is suitable for daylighting availability, moreover it has a high material reflectivity as shown in table 4-21 and there is no obstructions but the WFR is lower than standard.

8-Stair:-

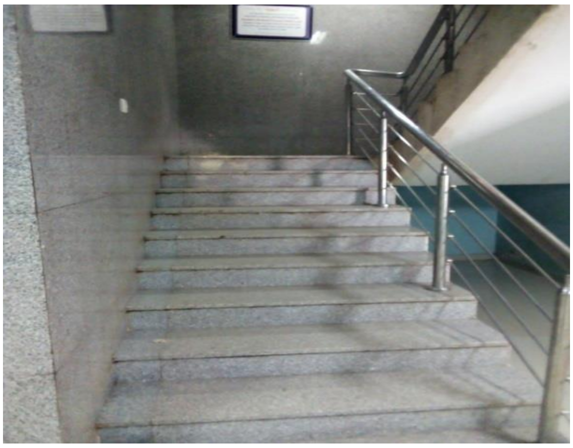


Fig 4-24 Al-moalem hospital's stair
Source: (taken by researcher)

location	Reading points	Measured lux merter readings
steps	A	12
	B	17
	C	5
landing	D	2
Arithmetic mean		9
Standard reading		150

table 4-22 measured lux meter and standard readings for stair
Source: (the researcher)

location	Area(m2)		P(glazing area to floor area)	Calculated DF(0.1×p)	Standard DF
	glazing area	floor area			
Stair	0	12.6	0	0	1

Table 4-23calculated DF and standard DF for stair
Source: (the researcher)

Space name	orientation	WFR	obstructions	reflectance	
stair	-	0%	√	wall	30%
				floor	30%
				Ceiling	30%

Good

Poor

table 4-24 daylighting parameters analysis for stair
Source: (the researcher)

- Result:-

The result showed that the arithmetic mean of measured readings is (0) which means there is no daylight in this space at all, as shown in figure 4-24 and table 4-22.

- Conclusion:-

The stair is blocked by many spaces from all directions so there is no access for daylight, also the material reflectivity is low and WFR is 0%all these factors make the space is too dim.

4-2-2 Comparison of Almoaleam measured readings with standard readings (Lighting guide 02: lighting for healthcare premises LG2 (2008)). CIBES's illumination recommendations have been aligned with European standards of lighting and the SLL code for lightning which acknowledge the importance of non-visual effects of light on health and wellbeing and they give the priority to daylight and complemented by electric lighting.

Building component	orientation	Measured Lux Meter Readings	Standard Lux Meter Readings	Notes
Main reception (floor)	south	16	300	Too dim
Main reception (enquiry desk)	-	12	500	Too dim
Medical maneger office	south	0	200	Too dim
ward	north	104	100	Bright
Clinic (work plane)	south	15	500	Too dim
Corridor	-	0	200	Too dim
Room	south	62	100	dim
VIP room	south	85	100	dim
Stair	-	9	150	Too dim

table 4-25 Comparison of measured lux meter readings with standard lux meter readings

Source: (the researcher)

4-2-3 Comparison of Almoaleam Calculated DF with standard DF

Building component	orientation	Calculated DF	Standard DF
Main reception	south	1.4	2
Medical maneger office	south	1.2	1
ward	north	1.2	3
Clinic	south	0.9	3
Corridor	-	0.0	1
Room	south	1.3	3
VIP room	south	0.6	3
Stair	-	0.0	1

table 4-26 Comparison of calculated DF with standard DF for Almloalem hospital
Source: (the researcher)

4-2-3 Graphical Representation

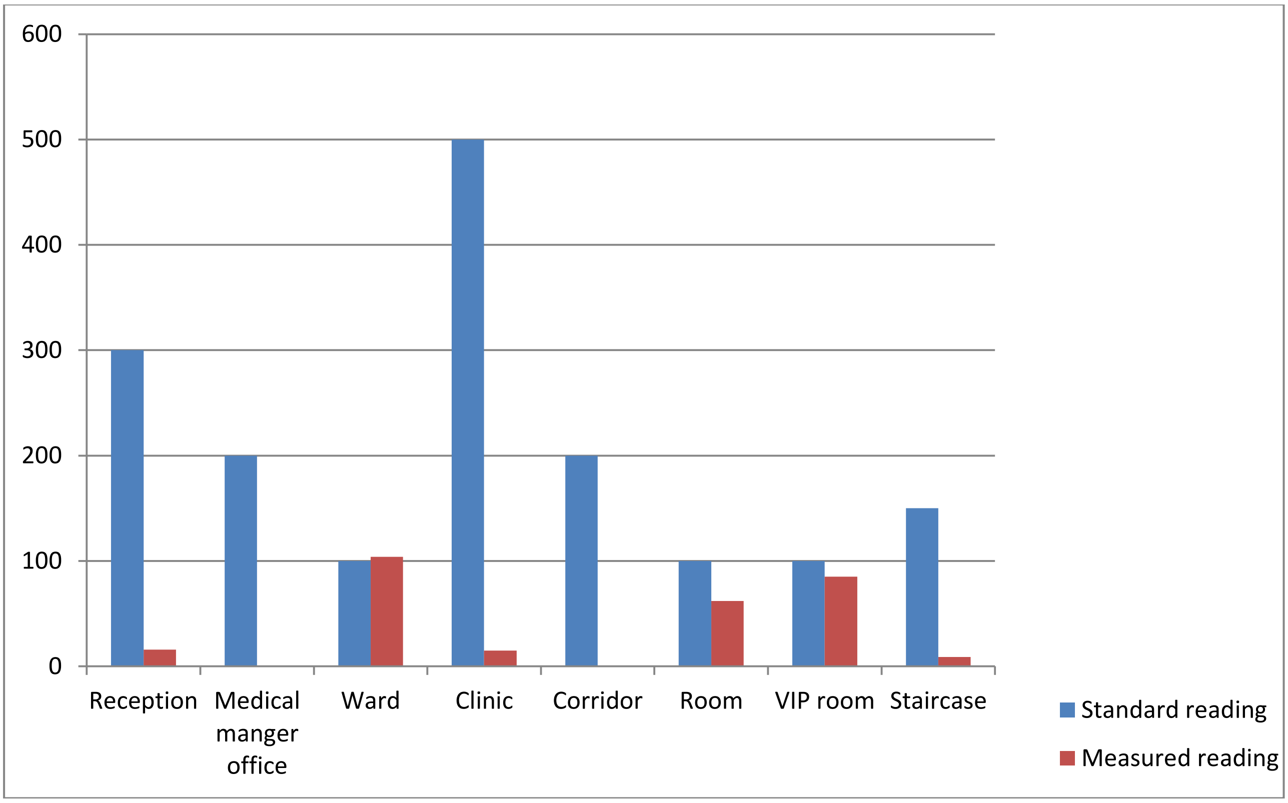


fig 4-25 Comparison between measured readings and standard readings for hospital component
source: (the researcher)

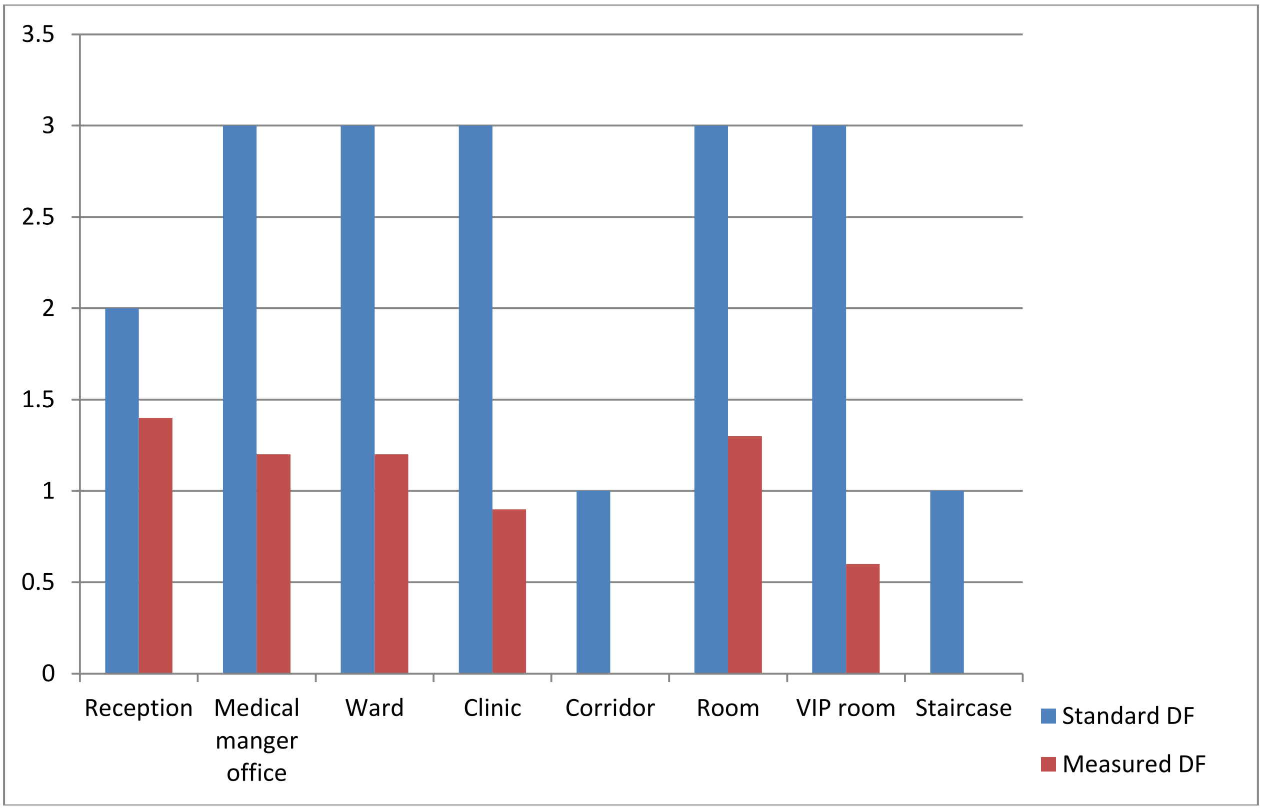


Fig 4-26 Comparison between measured DF and standard DF for hospital component
Source: (the researcher)

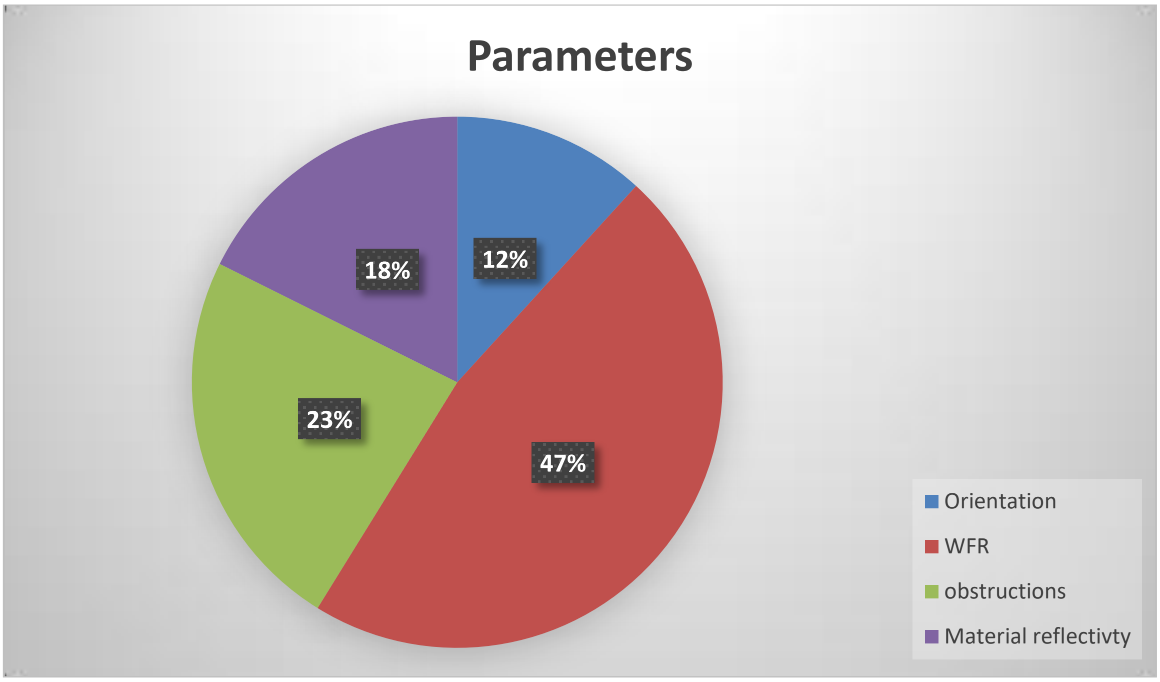


Fig 4-27 Problems percentage in Parameters of daylighting in hospital component
Source: (the researcher)

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5-1 Introduction

Daylighting performance becomes one of the most important factors in assessment of building environment quality because it affects directly occupants health, mood , performance and productivity in addition to it's environmental and economical effects.

In hospitals as curing buildings the importance of daylighting performance evaluation higher than other buildings, daylighting performance plays important role in patient curing by providing vitamin D , regulates many physiological activities that responds to a circadian rhythm such as hormone levels (e.g. melatonin, serotonin, cortisol), timing and structure of sleep, body temperature, cardiovascular functions etc ,also shortening patient's average length of stay (ALOS) in a hospital….etc. moreover psychological effects so this study focused on the parameters effects on daylighting performance and it's effects on daylighting levels inside spaces.

5-2Conclusions

The research evaluated daylighting performance in Almoalem medical city according to factors effects on daylighting performance which are:

- Climate:

Almoaleam hospital located in Khartoum which has one of longest annual average of daylight hour (12:00 hour per day).

- Orientation:

For hospital's orientation, Almoalem medical city has suitable orientation in general (south and north orientation). but it has space's design and orientation problem inside the hospital ,for example penitent's rooms are put in very good location for daylighting (north and south faces) but they are put in bad orientation (east and west orientation) for daylight in addition to the only face(north or south face) that can enter the sunlight is locked by bathroom which obscured a big amount of light could enter the space. even the penitent's bed is put behind this bathroom (the darkest area in the room).the same problems in VIP rooms and wards which consider the most spaces need daylight.

- Obstructions and reflections:

There are no external obstructions in Almoalem medical city but most of finshing materials medium and dark colors which means low materials reflection which lead to decrease daylighting performance.

- Building design:

Externally: The building design is very simple design. There are no projected elements to obstruct daylighting enter the building.

Internally: Al-moalem medical city was not designed as medical city firstly but it converted later on to be medical city so there is a big problems related to hospitals design such as there is no access for daylighting in many spaces such as clinics – offices -corridors – stairs, because are blocked by many buildings.

- daylight levels and daylight factors are lower than the standards of CIBSE .which means lower indoor air quality, lower biological and psychological well-being for patients, lower performance for staff, more cooling and electricity cost.

5-3Recommendations

According to presented results and conclusions the following recommendations are suggested to improve performance of daylighting in hospitals :

- The orientation of building should be considered because it has significant effect on illuminance levels.
- The Arrangement of space's furniture and component must be considered to get more benefits from daylight specially in wards and penitent's rooms. for example the penitent's beds have to be but in brighter area inside rooms.
- The reflectance values of spaces and windows surfaces must be considere Because it is effective factor in increasing the illuminance levels in spaces, despite the good design of the spaces

- Colour in the entrance should be bright, light, fresh and natural.

- Dark, dull and cold colours should be avoided as they will make an entrance seem inhospitable and austere

- Using shading devices on windows to avoid glare and decrease heat gain inside spaces.
- design the windows and glazed areas in suitable size to provide

The proper level of daylighting inside space and permit penitents to see outside view simultaneously.

Space	Suggested window area (M2)
Reception	18.70
Medical manger office	2.34
Ward	7.20
Clinic	2.28
corridor	18.00
Room	4.80
VIP room	9.40
Staircase	2.52

Table (5-1) Suggested window area for hospital component

- Daylighting design and availability should be more considered in design process.

- daylighting availability and design legalizations should be more clarified and considered in list of building’s organization.

- This study is to encourage the consideration to daylight quality in the health care buildings and recommends making another research in this filed in sudan.

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