

**PARAMETRIC DESIGN OF TESSELLATED  
GEOMETRIC KINETIC FAÇADE FOR  
DAYLIGHTING AND GLARE CONTROL IN A  
HIGH-RISE HOSPITAL BUILDING IN AMMAN,  
JORDAN**

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**2025**

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JORDAN**

**by**

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**Thesis submitted in fulfilment of the requirements  
for the degree of  
Doctor of Philosophy**

**January 2025**

## ACKNOWLEDGEMENT

I would like to express our gratitude to Allah for giving us opportunity and help us endlessly in finishing this thesis.

I would like to express my deepest thanks to my supervisor Dr. Nooriati Talb and co-advisor Dr. Christopher Heng Yii Sern for their excellent guidance, caring, patience, and bits of advice.

A special thanks to my husband Dr. Mohannad and my children Laith and Zeina for their support, encouragement to continue Doctoral's in architecture faculty at Universiti Sains Malaysia University.

A special thanks to family, mom, dad, Mohannad's dad and Mohannad's mom, for encouragement and support.

Also, a special thanks to Ms. Jana Hajjaj and Mr. Mohammad Asem.

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## LIST OF SYMBOLS

$\theta$  Solar zenith angle

## LIST OF ABBREVIATIONS

ASE	Annual Sunlight Exposure
CLT	Curtain Light Transmittance
DA	Daylight Autonomy
DF	Daylighting Factor
DGI	Daylight Glare Index
DGP	Daylight Glare Probability
DV	Dependent Variable
EC	Expand & contract
Fo	Folding
GA	Glare Autonomy
GI	Glare Index
HDR	High Dynamic Range
IGP	Islamic geometric designs
IRC	Internally Reflected Component
Isc	solar constant
IV	Independent Variable
LEED	Leadership in Energy and Environmental Design
LGR	Limiting Glare Rating
MV	Mediating Variable
NURBS	Non-Uniform Rational B-Splines
SAD	Seasonal Affective Disorder
sDA	Spatial Daylight Autonomy
SMA	Shape Memory Alloys
UDI	Useful Daylight Illuminance
UGR	Unified Glare Rating
USGBC	US Green Building Council

## LIST OF APPENDICES

Appendix A	Building Design
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**REKA BENTUK PARAMETRIK FAKAD KINETIK GEOMETRI TESELASI  
UNTUK PENCAHAYAAN DAN KAWALAN SILAU DI BANGUNAN  
HOSPITAL BERTINGKAT DI AMMAN, JORDAN**

**ABSTRAK**

Baru-baru ini, fasad kinetik telah menjadi pilihan yang popular bagi bangunan untuk memenuhi keperluan yang semakin kompleks dan pelbagai berkaitan dengan keselesaan pengguna. Reka bentuk bangunan hospital mengambil isu cahaya siang dan silau dengan sangat serius. Keupayaan fasad kinetik untuk bertindak balas dan menyesuaikan diri dengan perubahan dalam persekitaran sekeliling adalah definisi yang diberikan kepada mereka dalam kajian ini. Tujuan kajian ini adalah untuk mengoptimumkan reka bentuk fasad Hospital Al-Abdali, yang terletak di Amman, untuk meningkatkan kualiti cahaya siang dan mengatasi masalah silau. Ini menambah pengetahuan berharga ke dalam literatur mengenai fasad kinetik, cahaya siang, dan silau dalam konteks Jordanian kerana isu silau yang dikurangkan sambil meningkatkan cahaya siang. Kajian ini terdiri daripada dua komponen: soal selidik dan simulasi. Untuk fasad kinetik, reka bentuk parametrik dicipta untuk meningkatkan prestasi silau dan cahaya siang. Menggunakan plugin Grasshopper dan Ladybug untuk perisian Rhino, simulasi cahaya siang parametrik dilakukan untuk menyiasat potensi reka bentuk parametrik dalam meningkatkan prestasi cahaya siang dan silau. Fasad Tenggara dan Barat Daya bangunan mempunyai tiga reka bentuk parametrik fasad kinetik kawalan cahaya yang berbeza diterapkan kepadanya. Reka bentuk 1 menggunakan siri transformasi geometri untuk

mencipta corak dengan susunan seragam bentuk rhombus dan segi lapan. Reka bentuk 2 adalah versi yang dikemaskini yang memanjangkan tepi segi lapan. Reka bentuk 3 adalah iterasi lanjutan dengan bentuk bintang. Dalam bahagian soal selidik, soalan tentang kepuasan pesakit dengan kes asas hospital diajukan untuk menilai keadaan cahaya siang semasa dalam reka bentuk fasad Hospital Abdali. Untuk meningkatkan tahap pencahayaan dan keseragaman cahaya di ruang, skrip cahaya siang setiap jam dicadangkan. Untuk menunjukkan silau (zon cahaya siang, kurang cahaya, dan terlalu banyak cahaya), nilai iluminasi jam yang dianalisis ditukar ke format peratus. Reka bentuk tiga mempunyai prestasi yang lebih baik berbanding dengan rekaan lain mengikut keberkesanan reka bentuk parametrik dan pengoptimuman dalam mencapai matlamat prestasi. Iluminasi cahaya siang dalam reka bentuk tiga adalah antara 300-3000 lux. Pendedahan Cahaya Matahari Tahunan (ASE), Autonomi Cahaya Siang Ruang (sDA) dan Iluminasi Cahaya Siang Berguna (UDI) adalah 10%, 76.57% dan 60.2%, masing-masing. Autonomi Silau (GA) berkisar antara 61.64-89.76% dan kebarangkalian Silau Tidak Selesa (DGP) kebanyakannya  $<0.35$ , yang bersesuaian dengan silau yang tidak dapat dikesan. Reka bentuk 3 menggunakan geometri adaptif yang mengoptimumkan pengedaran cahaya siang dan mengurangkan silau sepanjang tahun dengan memenuhi atau melebihi standard kunci LEEDv4. Penemuan ini berpotensi mempunyai kesan yang menguntungkan untuk cadangan yang dibuat pada masa hadapan mengenai kaedah reka bentuk hijau dalam bangunan hospital.

**PARAMETRIC DESIGN OF TESSELLATED GEOMETRIC KINETIC  
FAÇADE FOR DAYLIGHTING AND GLARE CONTROL IN A HIGH-RISE  
HOSPITAL BUILDING IN AMMAN, JORDAN**

**ABSTRACT**

Recently, kinetic facade has become a popular choice for building increasing complex and varied needs associated with user comfort. Hospital building design takes daylight and glare issue very seriously. The capacity of kinetic facades to react and adjust to changes in the surrounding environment is the definition given to them in this study. The intention of this research was to optimize the façade designs of Al-Abdali Hospital, located in Amman, to improve daylighting quality and overcome glare issue. It adds valuable knowledge to literature on kinetic façades, daylighting, and glare within the Jordanian context due to mitigated glare issues while improving daylighting. Two components comprise the research: questionnaire and simulation. For Kinetic facades, parametric design is created to improve glare and daylighting performance. Using the Grasshopper and Ladybug plugins for Rhino software, parametric daylight simulation was carried out to investigate the potential of parametric design in improving daylight performance and glare. The South East and South West façade louvers of the building have three distinct light control kinetic façade parametric designs applied to it. Design 1 used a series of geometric transformations to create a pattern with a uniform array of rhombus and octagon shapes. Design 2 is an updated version extending the edges of the octagon. Design 3 is an advanced iteration with a star shape. In the questionnaire section,

questions on patient satisfaction with the hospital's basic case are asked to assess current daylight conditions in the facade design of Abdali Hospital. To improve the degree of illumination and homogeneity of light in space, an hourly daylight script is suggested. In order to display glare (daylit, underlit, and overlit zones), the illuminance values of the analyzed hours were transformed to a percentage format. Design three has a better performance compare to other designs in accordance to effectiveness of parametric design and optimization in achieving performance goals. The daylighting illuminance in design three was between 300-3000 lux. Annual Sunlight Exposure (ASE), Spatial Daylight Autonomy (sDA) and Useful Daylight Illuminance (UDI) were 10%, 76.57% and 60.2%, respectively. The Glare Autonomy (GA) was ranging between 61.64-89.76% and Discomfort Glare likelihood (DGP) was mostly  $<0.35$ , corresponding to imperceptible glare. Design 3 employs adaptive geometry which optimizes daylight distribution and reduces glare throughout the year by meeting or exceeding key LEEDv4 standards. The findings potentially have advantageous repercussions for suggestions made in the future regarding green design methods in hospital buildings.

# CHAPTER 1

## INTRODUCTION

### 1.1 Background

The weather and climatic patterns that both living things and man-made structures have historically relied on are being disrupted by the current phase of global warming (Hassan, 2016). Buildings and global warming interaction is a growing source of worry since they have a complicated relationship, especially when it comes to natural light and the issue of excessive brightness (Alnaser et al., 2022).

The traditional design process is significantly impacted by adaptation, which is the continual reaction to condition changes on the outside. Architects are always refining their methods in an effort to realize the notion of designing places that can adapt to the demands of the users (Kolarevic & Parlac, 2015). During the earliest design phases, it is critical to examine how changes in the external environment relate to the comfort and requirements of interior users (Yi, 2016). Architects now have the chance to experiment with unique geometric designs and replicate human behavior, which was previously difficult due to the ongoing breakthroughs in technology and the creation of innovative computer programs (El Sheikh, 2011 & El-Dabaa, 2016).

The use of effective methods and cutting-edge equipment in buildings may have led architects to assume that the problems of daylighting and glare in architecture have been solved. Thus, engineers and other experts could have believed that regardless of the design, they would be able to successfully implement suggestions into the building systems (Kovalchuk & Shcherbakova, 2024).

According to the Köppen climatic map (Figure 1.1), Jordan has a desert hot and dry climate (Kottek et al., 2006). With between 9 and 12 hours of sunlight each day, architects and designers use better opportunities to utilize this voluminous natural light to improve artificial daylighting in buildings. Several factors need to be taken into account in order to deal with such an environment efficiently. These include minimizing wide open facades (Gut and Ackerknecht, 1993), including flexible features that can respond to temperature disparities between hot and cold seasons, and enhancing shade to decrease direct solar radiation during the summer (El-Dabaa, 2016).

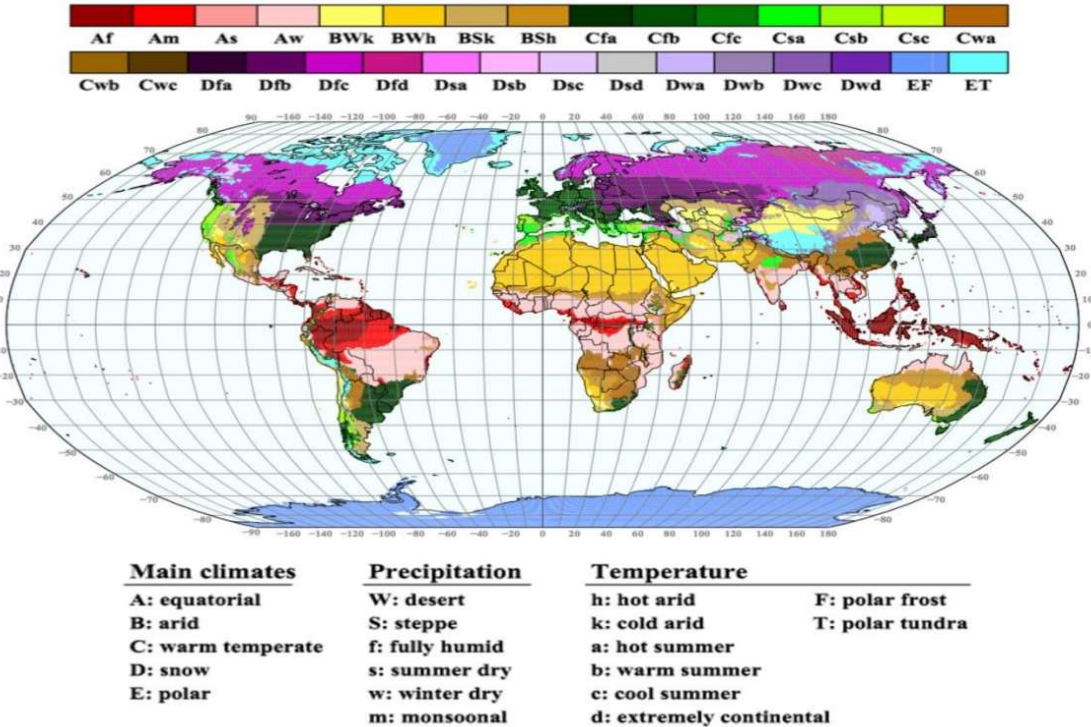


Figure 1.1 Köppen's climate map

Source: Kottek et al. (2006)

It is usual to think of a building's façade as a physical barrier separating the interior from the external. As a multifunctional part of a structure, it provides a broader role (Tzempelikos et al., 2007; Sharaidin, 2014). According to Sharaidin (2014), the façade of historic buildings often consists of permanent parts that cannot adapt to changing climatic circumstances or tenant demands. Although traditional blinds and louvers have affected the evolution of facades, they frequently fail to successfully fulfill evolving requirements. Therefore, there is a need for creative design approaches that can adapt to human preferences as well as environmental factors. Kinetic architecture is capable of satisfying this criterion (Razaz, 2010).

Kinetic façade systems have the capacity to dynamically alter their form in reaction to outside weather conditions, lighting requirements, and sun angles by utilizing sensors and actuators. In addition to improving occupant comfort, this adaptable flexibility helps the building blend with its surroundings (Le-Thanh et al., 2021; Chen & Chen, 2013). Dynamic, kinetic, adaptable, and responsive building façade technologies have gained popularity (Sharaidin, 2014). In addition, Sharaidin claimed (2012) that these systems have the ability to adjust and react to shifting ambient circumstances while improving artificial daylighting, glare management, and user comfort.

As Sherif et al. (2012b) noted, controlling sun penetration is essential in arid settings. Access to sunshine is crucial, but it can also result in glare due to excessive solar heat uptake and uneven light distribution. Shading devices can be used to adjust artificial lighting and reduce glare in interior environments to solve this problem. But as Sherif et al. (2012b) pointed out, a common issue in the Middle East is the poor design of solar screens. This problem also pertains to Jordan's widespread architectural style of excessive

use of glass hospital structures. In order to lessen the need for artificial lighting, it is vital to limit daylight penetration through well-designed facades, which will lower the intensity of sunlight and minimize glare (El-Dabaa, 2016).

Systems that are used to shade daylight might be static or dynamic (Bayar, 2020). Dynamic systems have the benefit of adjusting to the exterior environment and managing the quantity of sunlight entering a space dependent on the movement and location of the sun. As a result, architects are now considering using kinetic facades, facades with moving parts, to address this problem (El Sheikh, 2011).

There is an increasing need in contemporary architecture for performance-based solutions that put user's comfort first. To do this, it is necessary to simulate how people behave and react to various environmental changes. By using dynamic facades, designers are investigating how to incorporate facades into performance-based designs. The primary purpose of facades, which serve as the physical barrier between the inner space and the outside world, is to safeguard the internal space. Facades must be adaptable to these conditions given the ongoing changes in the outside climate. By physically moving its components, kinetic facades may adapt to these shifting environmental factors (Mejia, 2010). It is commonly known that facade design affects the internal atmosphere (Carlucci et al., 2015; Chen & Chen, 2013).

Healthcare facilities are one setting where adjusting the amount of daylight may improve user's experience. Hospitals has a significant impact on people's health and the environment (Hassooni & Kamoona, 2023). Hospitals are structures of particular relevance in any community that require special consideration in their construction

(Alsawaf & Albadry, 2022). The most significant buildings with various levels of complexity are hospitals. Among them are advancements in medicine, such as the field of medical sciences, and technology, including tools and methods utilized in operating rooms, critical care units, and spaces designed for continuous occupancy, such as bedrooms (Babbu, 2016). Kinetic facades can be configured to maintain constant lighting levels and minimize glare during business hours. This makes it possible to create a cosy atmosphere (El Sheikh, 2011).

The purpose of the study is to look at how kinetic facades might optimize daylight in healthcare facilities. It entails modeling and analysis of the ideal louver arrangement to optimize daylight. The target audience for this thesis comprises practicing architects, students studying architecture, academic scholars studying building technology and architecture, as well as researchers in the disciplines of sustainability and energy conservation. It is especially pertinent for architectural designers who use cutting-edge technology in environmental research.

## **1.2 Problem Statement**

The design and construction of healthcare facilities in Jordan, particularly in densely populated urban areas, present significant challenges in achieving optimal daylighting conditions. Excessive daylight and glare are common issues in healthcare facilities, potentially compromising to visual discomfort, making it difficult for staff to perform their tasks efficiently and negatively impacting the overall patient experience (Akinbami, 2024). While natural light is crucial for enhancing the psychological and physiological health of occupants, its management in hospital settings is complex and

must be balanced to avoid negative effects (Hosseini et al., 2019). Similar to this, Legrand (2022) emphasized the value of task-focused lighting in healthcare facilities, emphasizing its ability to improve patient and occupant comfort while maintaining staff alertness. Excessive natural light and brightness and glare

Al-Abdali Hospital, located in the heart of Amman, Jordan, is selected as the case study for this research due to its unique architectural challenges and its status as one of the most modern healthcare facilities in the country. Unlike many other hospitals in Jordan, Al-Abdali Hospital is a high-rise structure situated in a densely built urban area, where the proximity of other buildings severely impacts the distribution of natural light. This makes it an ideal case for examining the effectiveness of daylighting strategies in healthcare facilities in Jordan.

The choice of Al-Abdali Hospital is further justified by its reliance on large glass façades, which, while natural light, have led to significant issues with glare and thermal discomfort. Figure 1.2 shows the excessive use of glass in architectural design of Al-Abdali Hospital. These glass sections intended to maximize natural light and created areas of intense brightness and glare, which are not suitable for the hospital environment and neglect the climatic conditions of Jordan (El-Dabaa, 2016). These challenges are representative of broader issues faced by modern healthcare facilities in similar climatic and urban contexts, making this case study relevant for understanding the effectiveness of current daylighting practices and exploring innovative solutions.

In high-rise structures, like Al-Abdali Hospital, there is a risk of summer overheating and temperature changes in the vicinity (Lotfabadi, 2015). These

environmental factors, coupled with the dense urban setting, contribute to the potential for both insufficient daylight and excessive glare, which can negatively affect the internal environment of the hospital. Addressing the lighting issues at Al-Abdali Hospital is critical to meeting the lighting standards required in healthcare facilities (CIBSE, 2022).



Figure 1.2 Larger glass sections Al-Abdali Hospital

**Source:** Wikipedia contributors (2023)

Traditional interventions such as stone cladding, architectural shading, and landscaping have been the primary methods for adapting Jordanian buildings to the local climate. However, these techniques are inadequate for high-rise structures like Al-Abdali

Hospital (Elgendy, 2020). To address the dual challenges of providing sufficient natural light while minimizing glare and overheating, more advanced solutions are necessary.

Throughout its operating hours, hospitals experience constant difficulties. There is rising discontent with the hospital environment, which includes aspects like comfort, lighting, indoor air quality (IAQ), temperature, humidity, and noise, according to several research on healthcare design. Simply replacing natural daylight with electric illumination might not be enough because natural daylight has unique and complex features, such as shifting intensity throughout the day. Alzoubi & Rqibat (2015) and Diab et al. (2017) are the only studies in Jordan that particularly address architectural approaches to enhance interior daylight quality in hospitals.

Given the limitations of traditional fixed external shading systems, which cannot dynamically respond to changing sunlight conditions, a kinetic façade offers a superior solution for Al-Abdali Hospital (Hassan, 2016). Unlike fixed shading systems, which provide a static level of protection against sunlight, a kinetic façade can adjust in real-time to varying light levels throughout the day (Konstantoglou & Tsangrassoulis, 2016). This dynamic adaptability allows the façade to optimize natural light intake while minimizing glare and reducing the risk of overheating.

Furthermore, integrating modern digital generative systems, such as parametric design and optimization algorithms, with simulation tools can enhance the design process. This integration allows architects to explore a wider range of design options and create a kinetic façade that not only addresses the hospital's daylighting and glare issues but also

improves energy efficiency and enhances the overall aesthetic and functional performance of the building.

### **1.3 Research Questions and Research Objectives**

The problem statement underscores the need to explore the following questions:

- 1 What are the current daylight conditions in the facade design of Abdali Hospital in Amman, Jordan?
- 2 What are the multiple optimal light control kinetic façade parametric designs to be developed?
- 3 What is the effectiveness of parametric design and optimization for managing daylight and reducing glare in high-rise hospitals in hot climates?

Thus, the main goal of this thesis is to explore parametric design systems, and algorithms to analyze various kinetic facade characteristics in Abdali Hospital case study to improve daylight quantity and quality, decrease glare and lessen the adverse effects of hard external circumstances, notably in the Jordanian desert. Thus, there are several objectives that must be met in order to reach this aim, including:

- 1 To investigate current daylight conditions in the facade design of Abdali Hospital, Amman, Jordan
- 2 To develop multiple optimal light control kinetic façade parametric designs
- 3 To examine the effectiveness of parametric design and optimization as a solution for optimizing daylighting and reducing glare in the hospital

### **1.4 Scope and Limitation**

This research has taken Al-Abdali Hospital in the center of Amman, Jordan, as a case study because of its very particular architectural challenges and status as one of the most up-to-date healthcare facilities within the country. Unlike most of the other hospitals in Jordan, Al-Abdali Hospital is a high-rise building located in a highly built-up urban area; hence, the proximity of the adjacent buildings alters the potential distribution of natural light drastically. This makes it an ideal case study for assessing daylighting strategies in Jordanian health facilities. Given the limitations of traditional fixed external shading systems, which cannot dynamically respond to changing sunlight conditions, a kinetic façade offers a much better solution at Al-Abdali Hospital. Base Case building analysis was performed in respect to the variables: daylight, glare, wind rose, radiation rose, and sun path. The building was identified to be overlit, excessive glare, and high radiation in both its south-east and south-west directions.

This study attempts to create kinetic façades for healthcare facilities using parametric optimization techniques, using daylighting, and glare as the main performance requirements. In order to enhance natural light distribution while lowering radiation and glare, the thesis investigated the integration of simulation tools, parametric design systems, and optimization algorithms throughout the early design stages. The hospital building in Amman, Jordan, which has a south-facing orientation, was the subject of the case study (Figure 1.3).

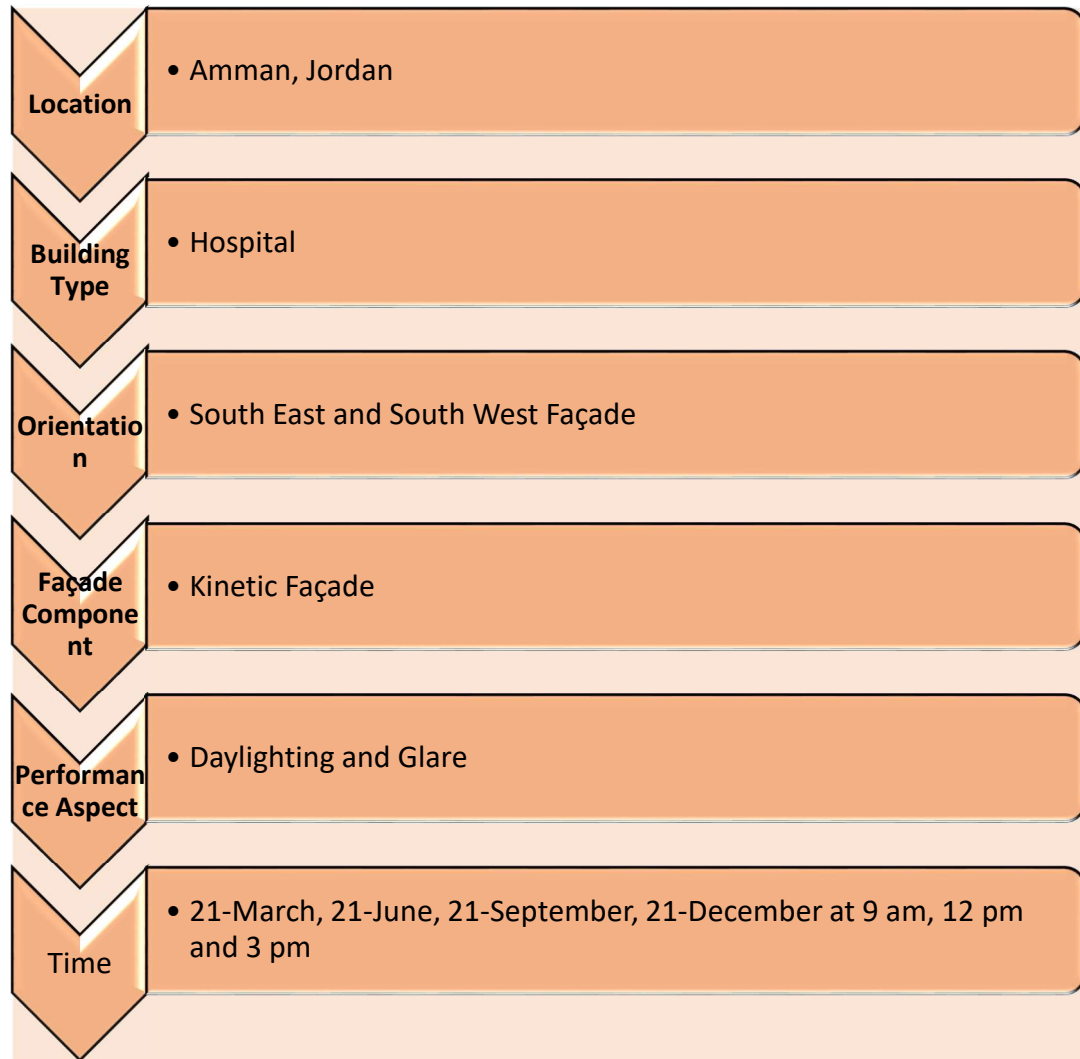


Figure 1.3 Research Scope

The studied area is situated on an upper floor (floor 25<sup>th</sup>), with no reflection of indirect light from the surrounding environment or lower level. Testing the impact of interior materials and kinetic louvers on light dispersion in space was not the goal of this study. The hourly simulation was changed to three crucial hours (9 am, 12 pm and 15 pm) and four crucial days (21-Mar, 21-Jun, 21-Sep and 21-Dec).

The specific times of 9 am, 12 pm, and 3 pm are chosen to capture glare at different points of the day where 9 am represents early morning conditions, providing data on low-angle sunlight and potential issues with morning glare, 12 pm (Noon) represents midday conditions with the sun at its highest point, critical for assessing peak daylighting and glare conditions and 3 pm represents late afternoon conditions, useful for studying potential glare as the sun begins to set.

These dates, corresponding to the equinoxes (March 21 and September 21) and solstices (June 21 and December 21), were chosen to simulate and study daylighting and glare because they represent key points in the solar calendar. March 21 and September 21 (Equinoxes): On these dates, day and night are of equal length, and the sun is directly over the equator. These dates are crucial for understanding how daylight is distributed in the space during periods of balanced light. June 21 (Summer Solstice): This is the longest day of the year, with the highest solar elevation. It allows the study of maximum daylighting and potential glare issues during peak sunlight. December 21 (Winter Solstice): This is the shortest day of the year, with the lowest solar elevation. This helps in understanding the challenges of daylighting when natural light is minimal.

## **1.5 Research Framework**

The research begins by searching for definitions, characteristics, principles and classifications for kinetic façade, daylighting and glare through published researches available in literature review. In addition, a brief information about Al-Abdali hospital as a case study. The second stage is a quantitative approach using 2 methods. The first part is a questionnaire and second part is an analysis of parametric designs. Both parts are used

collect data about the current situation of the hospital. In the third part, simulation of more than one design through Rhino plug-ins is done. Finally, the researcher discusses the results and writes down conclusion and recommendations for future (Figure 1.4).

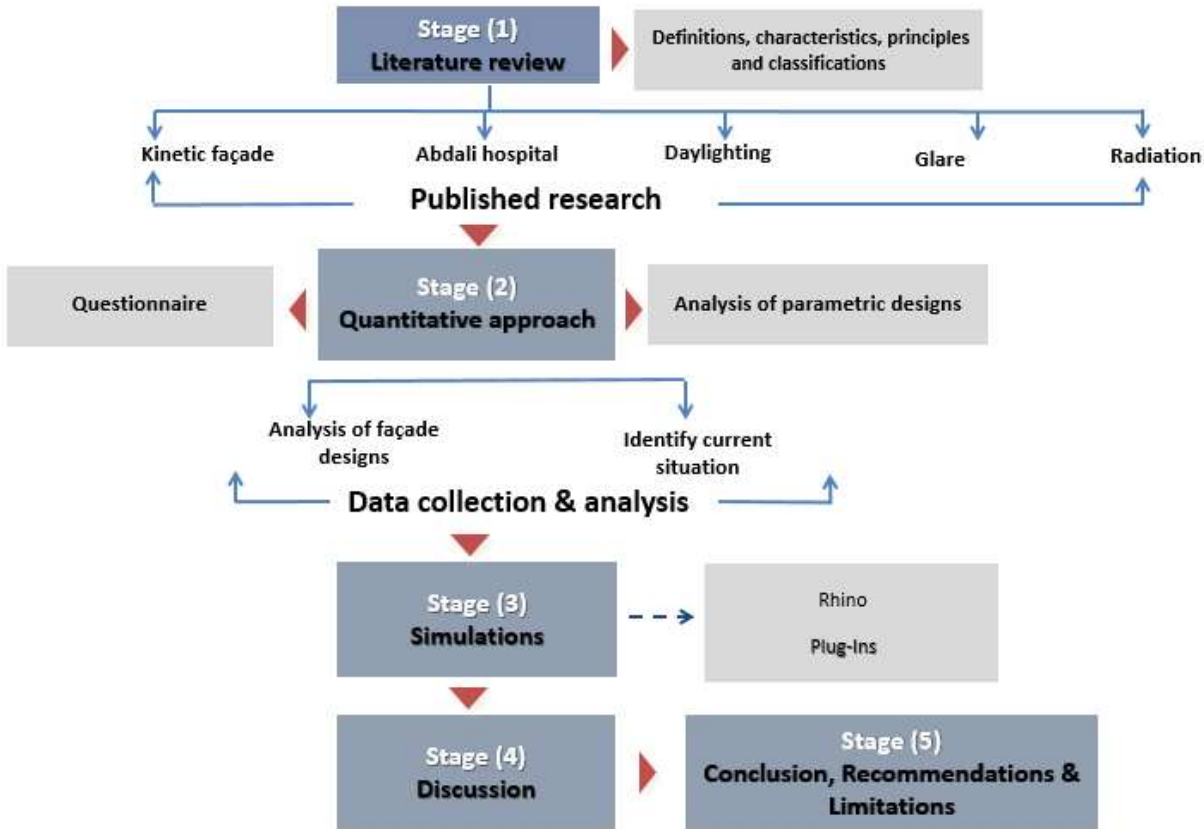


Figure 1.4 Work flowchart

**1.6 Significance of Research**

With a particular focus on constructing a kinetic façade system at Abdali Hospital, this case study addresses the integration of sustainable design concepts into healthcare buildings and has significant scientific importance. This work adds important knowledge to the body of literature on kinetic facades, daylighting, and glare in the context of Jordan

by resolving glare-related difficulties while also improving daylighting. It closes knowledge gaps in research projects and gives architects and designers useful information. Additionally, the simulations and theoretical designs in the thesis offer a workable strategy for maximizing daylighting in buildings, inspiring academics to look into daylighting and glare simulation tools and enhance the precision of daylighting models using cutting-edge simulation techniques. Finally, using state-of-the-art computer simulation techniques, the study's findings provide suggestions and guidelines for the creation of kinetic facades in medical buildings. These findings could potentially have advantageous repercussions for suggestions made in the future regarding green design methods. This will give architects a blueprint for putting the ideal pattern on the southern front of an Amman healthcare facility. To help researchers build more complex facades, the logical phases of the simulation process was described. By carefully analyzing lighting principles and dynamic facades, the research offers an overview of performance-based architecture. In the end, the study presents a parametric tool that combines daylight design with dynamic facades.

### **1.7 The Novelty of the Study**

This case study on integrating sustainable design principles into healthcare facilities, specifically through the construction of a kinetic façade system at Abdali Hospital, offers significant scientific value in several key areas.

It addresses critical issues related to glare and daylighting, contributing to the evolving body of research on dynamic façades. By focusing on a real-world application in Jordan, it adds valuable insights into how dynamic façade systems can be tailored to

local environmental and cultural contexts, thereby enriching the global discourse on sustainable building design.

It identifies and fills knowledge gaps in existing research by exploring the integration of kinetic façades in healthcare settings. It provides new information on how dynamic systems can mitigate glare and improve daylighting, which is crucial for enhancing the comfort and well-being of patients and staff in medical facilities.

The theoretical designs and simulations presented in the thesis offer practical approaches for optimizing daylighting in buildings. This practical perspective provides architects and designers with actionable strategies to improve lighting quality and reduce glare, thereby influencing the design of future healthcare facilities.

The use of state-of-the-art simulation tools in this study enhances the accuracy of daylighting models. By incorporating advanced simulation approaches, the research demonstrates how these tools can be employed to refine daylighting designs and address glare more effectively.

By examining dynamic façades and lighting concepts through a performance-based lens, the study underscores the importance of optimizing building designs to meet specific performance criteria. It contributes to a deeper understanding of how dynamic facades can enhance building performance and user comfort.

It introduces a parametric tool that combines dynamic façades with daylight design. This innovative tool facilitates the creation of intricate façade patterns and supports ongoing research into integrating dynamic systems with daylighting strategies.

It also offers a comprehensive overview of the simulation process, including logical steps and methodologies. This documentation assists researchers and practitioners

in developing more complex and effective façade designs by using detailed simulation data.

It advances the field by using state-of-the-art simulation tools and methodologies to optimize daylighting, improving the accuracy of daylighting models and providing a more reliable framework for future research.

## **1.8 Thesis Outline**

CHAPTER ONE: Introduction. It begun by giving an overview of the research by presenting the problem followed by the significance of the research. After that, the objectives and questions of this study is presented. The goals and limitations of the research are also shown. A flow chart of the research work was also presented.

CHAPTER TWO: Literature Review. It begun by giving an overview of the climate in Jordan and Amman in particular. Then, it contained a section about daylighting and its fundamentals. The study on kinetic façade fundamentals were also reviewed in this chapter. It also contains overview on Tessellation and parametric design in particular to Islamic patterns. A conceptual framework was prepared using the key information from the literature review. In addition, it gives the standard of LEED v4. The sections summed up with the research gaps.

CHAPTER THREE: Methodology. This chapter highlighted the sources of primary and secondary research, including the criteria for data collection, data analysis, and validation of the simulation tools of current research on the subject and ethical considerations.

CHAPTER FOUR: Results and discussion. In this chapter, the outcomes of the questionnaire that states the current situation of the hospital and simulation of daylighting illuminance, ASE, sDA, UDI, glare and annual glare are presented. In the discussion, all available options are discussed to sum up with the best kinetic façade design.

CHAPTER FIVE: Conclusion, Limitations and Recommendations. In this chapter, a summary of the main results is presented. In addition, advises for future work and the limitations of the study are written.

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Introduction**

Climate change is having a significant negative influence on Jordan's urban environment. As a result, making good use of sunshine in hospitals has emerged as a key tactic for enhancing artificial lighting and lowering radiation and glare. It started off by providing a general summary of the weather in Jordan, with a focus on Amman. The next part covered daylighting's foundations. In this chapter, the principles of the study on kinetic façades were also discussed. In particular, it offers an overview of parametric design and tessellation with regard to Islamic designs. Key details from the literature research were used to create a conceptual framework. It also provides the LEED v4 standard. The research gaps were used to summarize the parts. The flow chart is shown in Figure 2.1. Figure 2.1 shows the topics discussed in this chapter.

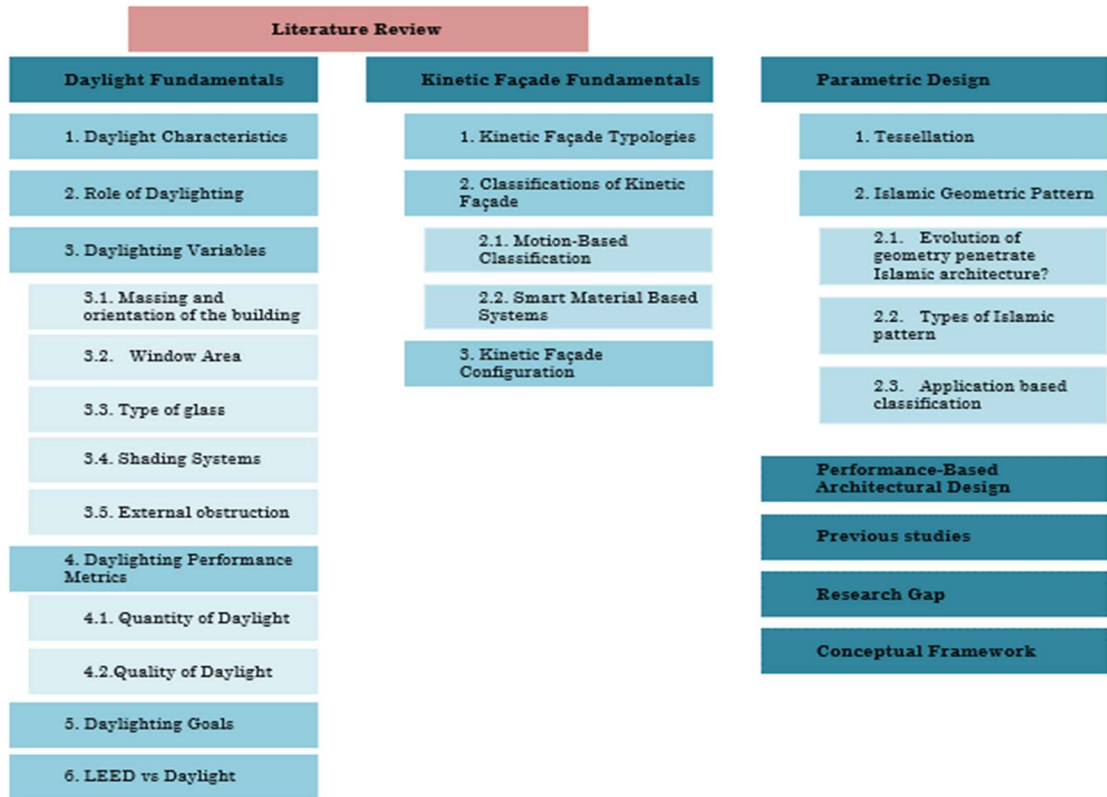


Figure 2.1 The flow chart of the literature review

## 2.2 Daylight Fundamentals

Diffused daylight and direct sun energy are combined in a balanced way to create daylight (Volla & Seinre, 2012). The use of daylight is a subject that is extensively studied across many different professions, with each one focused on a distinct element. A multidisciplinary team is necessary to successfully incorporate daylighting into building design, taking into account elements including building orientation, fenestrations, and lighting control systems (Ruck et al., 2000). Because daylight constantly fluctuates throughout the day and even from day to day, managing it can be difficult (Khoshroonejad, 2010).

As part of the continuous effort to create a more sustainable living environment, daylighting design is being used more frequently in modern buildings (Wong, 2017). Architecture has always included the notion of daylighting, which is harnessing natural light to brighten a building's interior (Edensor, 2017). However, as artificial lighting replaced natural lighting as the main source of illumination in the 1940s, its relevance started to fade (Sholanke et al., 2021). Buildings were able to have deeper floor layouts and fewer windows because electric lighting and mechanical ventilation were readily available, which decreased the need for windows to let in light and air (Lee et al., 2022). When the oil crisis hit in the 1970s, attention was once again drawn to energy-efficient construction methods, particularly the effective use of sunshine to replace electric lighting and lower cooling requirements (Alliance, 2019). Due to the introduction of green building technology and a rising emphasis on environmental sustainability, daylighting has recently attracted more attention.

Daylighting has several benefits for inhabitants from various angles. First of all, it improves the aesthetics and functionality of a medical facility (Alzoubi & Rqaibat, 2015; Diab et al., 2017) and aids in minimizing any potential side effects from continuous exposure to artificial lighting (SLL, 2011; Luca, 2020). Second, it significantly correlates with patients' increased performance and health (Michael & Heracleous, 2017). Last but not least, inadequate or insufficient sun exposure can cause fatigue, tension, irregular circadian rhythms, and Seasonal Affective Disorder (SAD) (Figueiro et al., 2011). Since human health and mental abilities are regulated by circadian cycles, which are in turn controlled by the length and intensity of daytime light exposure, there is a direct connection between daylighting and patients (Wirz-Justice et al., 2021). Additionally, to

improve visual comfort, other aspects such as sunshine distribution, glare, direct sunlight penetration, and access to views of the outside world should be taken into account (Safranek et al., 2020).

Individuals' well-being is greatly influenced by how indoor settings are designed, with light being a key component. By understanding the importance of light, architects may improve their interior designs (Dalke et al., 2006). Human demands, architectural concerns, and economic-environmental variables are the three main determinants of lighting quality in interior settings. The Society of Light and Lighting (SLL) Code (CIBSE, 2022) and BS EN 12464-1 provide support for the studies done by Hosseini et al. (2019) on the effects of appropriate lighting on health and well-being.

Human requirements include the capacity for vision, interaction with the environment, beauty, health, and comfort. To achieve the best perception, the illumination must be sufficient and of great quality. A 5% increase in brightness intensity results in increased human performance, according to research by Ming et al. (2011), which may be attributed to higher visual acuity, biological effects, and psychological benefits. In many contexts, human behavior, mood, efficiency, and effectiveness are greatly influenced by light's intensity, source type, color, direction, and dispersion. Most people agree that natural light is the most ideal and complete type of illumination (Jung & Arar, 2023). However, patients in hospitals sometimes don't have access to natural light and spend a lot of time in dark spaces. The lack of natural light in hospitals might make people more depressed and anxious (Morales-Bravo & Navarrete-Hernandez, 2022).

Furthermore, as artificial lighting is frequently less aesthetically attractive than natural illumination, its use in healthcare environments might be harmful to the retina

(Dalke et al., 2006). The consequences of poor illumination on patients' mental, cognitive, and physiological health are not limited to their visual system (Boyce, 2022). Eye fatigue, headaches, visual impairments, accidents brought on by poor vision or glare, and general discomfort can all be caused by prolonged exposure to artificial illumination (Ticleanu, 2021). Therefore, hospitals should work to include the best possible daylighting in order to suit the demands of their patients in terms of ergonomics, safety, and health.

The flow chart of the daylighting fundamental section is shown in Figure 2.2.

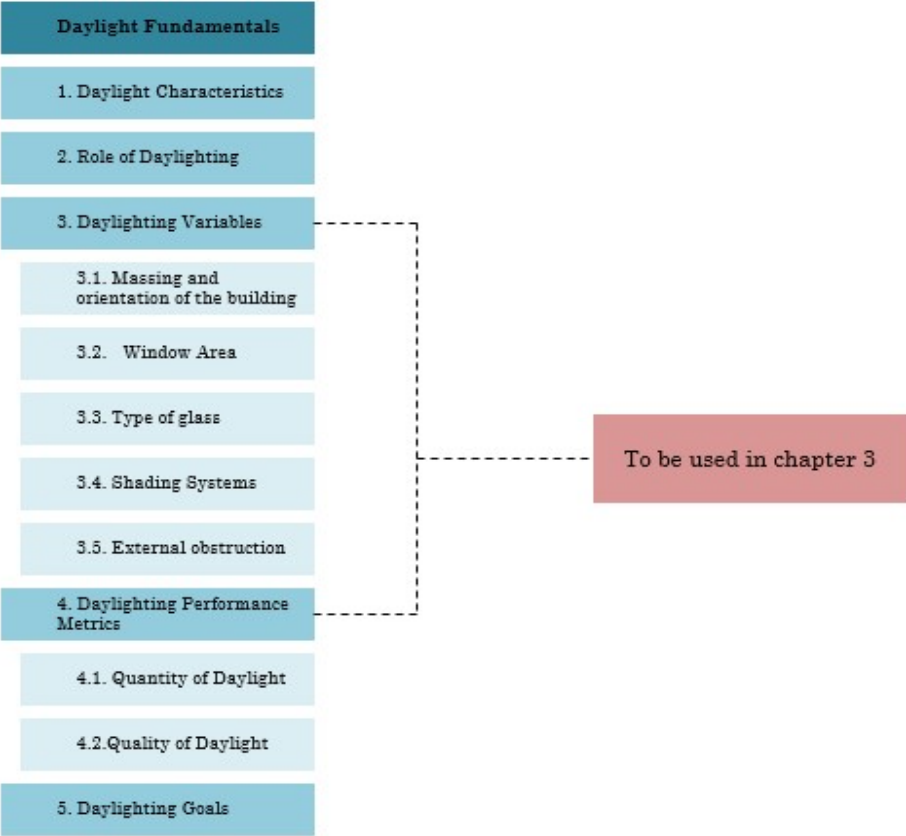


Figure 2.2 The flow chart of the daylighting fundamental

### 2.2.1. Daylight Characteristics

Our retinas include receptors that interact with electromagnetic waves known as light, which are subsequently conveyed to the brain (Fan et al., 2022). A healthy person may physiologically sense light waves in the color spectrum between 400 and 700 nm (Grzybowski & Kupidura-Majewski, 2019). Daylight is a type of solar energy radiation that plays a significant part in our everyday life and varies based on location, time of day, and season. Light rays can either be reflected or absorbed when they come into contact with objects or surfaces (Husein & Salim, 2020).

People used to depend on sunshine and spend a lot of time outside in the past. But in the present era, people typically spend most of their time indoors, where artificial light predominates. The predominant source of interior illumination was sunshine until the invention of artificial light in 1940 (Yin et al., 2018). Despite the advantages it has provided, the rising use of artificial light has increased power consumption and presented threats to human health and the environment. In order to use natural light as the main source of interior illumination, there is a revived desire in doing so. There is a growing interest in utilizing natural light as the primary source of interior illumination due to its benefits in enhancing energy efficiency, improving occupant well-being, and creating more sustainable and health-conscious building environments. This approach not only reduces reliance on artificial lighting but also leverages the psychological and physiological advantages of exposure to natural light. Daylight is an excellent alternative since it is a renewable natural resource and doesn't call for any technical changes.

### 2.2.2. Role of Daylighting for Human Health

Daylight plays a crucial role in two aspects: the utilization of space and the well-being of individuals. The use of space and the function of daylight are intimately related. As it improves the perception of key architectural components including shape, texture, and color, light is an essential component of architecture. By enhancing comfort and environmental management, it also helps places work properly (Khoshroonejad, 2010; Al-Dabaa, 2016).

In addition to providing a link to the outside world, natural daylighting design also significantly improves user health (Al-Dabaa, 2016). The dynamic lighting environment that daylight produces adds to the upbeat vibe. In other words, the natural variation and quality of daylight can contribute to a space feeling more vibrant, uplifting, and welcoming, thereby enhancing the mood and overall well-being of the occupants. Neglecting lighting strategies can have detrimental effects on visual comfort, which has a direct impact on productivity and human well-being in the healthcare industry (Akinbami, 2024). Daylight-filled areas are typically regarded as comfortable working environments (El Sheikh, 2011).

Natural light is essential for regulating the biological clock of humans, which controls the sleep-wake cycle. The neurological system can be disturbed by insufficient sun exposure, which can cause exhaustion and feelings of loneliness. In these circumstances, intensive light therapy may be employed as a treatment (El Sheikh, 2011). The fact that the photoreceptor cells in the eye and the brain have additional nerve connections showed that the eye affects the human biological clock in addition to being a