IMPACT OF GLAZED FACADES ON DAYLIGHT QUALITY IN THE CASE OF SELECTED OFFICE BUILDINGS IN ADDIS ABABA, ETHIOPIA.

Betelhem Alemu

A Thesis Submitted to the Department of Architecture
School of Civil Engineering and Architecture.

Presented in Partial Fulfillment of the Requirement Master of Science
In Environmental Architecture

Office of Graduate Studies
Adama Science and Technology University

June - 2024

Adama, Ethiop

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Declaration

I declare that this Master Thesis proposal entitled "**Impact of glazed facades on daylight quality in the case of selected office buildings in Addis Ababa, Ethiopia**'' is my own work and has not been submitted to any university for a similar purpose. The references used in this proposal are duly acknowledged through citation.

________________________	________________________	________________________
Name of student	Signature	Date

RECOMMENDATION

I/we, the advisor(s) of this thesis, hereby certify that I/we have read the revised version of the thesis entitled "**Impact of glazed facades on daylight quality in the case of selected office buildings in Addis Ababa, Ethiopia**" prepared under my guidance by **Betelhem Alemu** submitted in partial fulfillment of the requirements for the degree of Mater's of Science in Environmental Architecture. Therefore, I/we recommend the submission of revised version of the thesis to the department following the applicable procedures.

Yared Girma (PhD)	____________	________
Major Advisor/Supervisor	Signature	Date

APPROVAL PAGE

I/we, the advisors of the thesis entitled **"Impact of glazed facades on daylight quality in the case of selected office buildings in Addis Ababa, Ethiopia"** and developed by Betelhem Alemu**,** hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

___Yared Girma (PhD) __________ _________________ ______

Major Advisor/Supervisor Signature Date

___________________________ ________________________ ________________

Co-advisor/ Co-supervisor Signature Date

APPROVAL BOARD OF EXAMINERS

We, the undersigned, members of the Board of Examiners of the thesis by **Betelhem Alemu** have read and evaluated the thesis entitled " **Impact of glazed facades on daylight quality in the case of selected office buildings in Addis Ababa, Ethiopia**" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in **Environmental Architecture.**

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LIST OF ACRONYMS AND ABBREVIATIONS

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CCT	Correlated color temperature
DF	Daylight factor
ERC	Externally reflected Component
IRC	Internally reflected Component
IR	Infrared
MoE	Margin of Error
SC	Sky component
SHGC	Solar Heat Gain Coefficient
UV	Ultraviolet
VLT	Visible Light Transmittance
RHG	Relative Solar Heat Gain
CCT	Correlated Color Temperature

ABSTARCT

Natural light had a significant impact on our surroundings. Glazed facades, which use glass served as an effective light medium. However, glazed facade was a challenge for disturbing the quality of daylight in office buildings. Research evaluating the impact of glazed building facades on the daylight quality within office buildings in the context of Ethiopia was inadequate. The primary objective of the research, was to thoroughly assess how glazed facades affected the quality of daylight in specific office buildings. The study collected and analysed data using a combination of quantitative and qualitative methods, with the purpose of providing a comprehensive understanding of the relationship and impact of glass facades on daylight quality in office building. The quantitative component of the study involved measuring natural light levels in office spaces with window facades using light meters and sensors to obtain precise data. The findings of the study were expected to be revealed, and based on the findings, a solution was given to the problem. The current day lighting conditions of office buildings that utilizes glazed facades has been examined through the respondents' background which resulted discomfort due to the presence of over illumination and based on simulation analysis the effects of glazed facade on daylight quality has resulted in over illumination and glare. Based on the findings, the study proposed a model-based design for enhancing daylight quality in office buildings where the occupants can perform their day today activity.

Keywords: Daylight quality, Glare, Glazed facades, Office buildings,

CHAPTER ONE

INTRODUCTION

In recent years, Addis Ababa has experienced a surge in diverse construction styles, particularly with the city's growing status as a regional economic hub, leading to an increase in the construction of office buildings. This has been accompanied by a growing trend of utilizing glass facades in the structures. The motivation behind this research stems from the observation that, despite the proliferation of modern glazed office buildings, there is a lack of comprehensive exploration into the effectiveness of glazed facades in enhancing and keeping the quality of the visual comfort of occupants. The adoption of glazed facades in office buildings is a notable trend in Addis Ababa, reflecting a contemporary architectural style. However, there is a need to delve deeper into the impact of clear glazed facades on the quality of daylight within office buildings in this urban setting. Daylight plays a crucial role in office design, influencing the well-being of occupants, their productivity, and the overall energy efficiency of the buildings. Given the distinctive climate and construction practices in Addis Ababa, there are specific challenges and opportunities associated with optimizing the daylight quality in office buildings featuring glazed facades that warrant further investigation.

Therefore, this research aims to explore the impact of glazed facades on daylight quality in the case of office buildings in Addis Ababa, with a focus on understanding how the design element in which glass type , facade orientation building height and the surrounding, can influence the distribution and quality of natural light within the buildings.

1.1. Background of the study

For centuries, daylight was the only efficient source of light available. Architecture was dominated by the goal of spanning wide spaces and creating openings large enough to distribute daylight to building interiors. Natural light or daylight plays a crucial role in our sense of direction and influencing our environment. Glass empowers us to manage and influence light in a beneficial way and allows us to harness and control light, offering us an advantage (Ruck, 2000).

Glazed façades have become more common in new construction, providing access to light, solar radiation, and outside views. The use of glazed facades in developed countries has surged in recent years, particularly in office buildings. These curtain walls, made of glass panels, offer a modern and sleek appearance, while allowing natural light to enter the building, reducing the need for artificial lighting and creating a more pleasant and productive indoor environment (WURM, GLASS, 2007).

The quality of daylight can have a significant impact on the satisfaction and well-being of office occupants. Adequate natural light in the workplace has been linked to improved mood, productivity, and overall well-being. Exposure to natural light can help regulate circadian rhythms, leading to better health. In addition, access to natural light and views has been shown to reduce stress and increase satisfaction with the indoor environment, ultimately enhancing employee morale and job satisfaction. Furthermore, natural light can enhance the visual comfort of occupants, reducing eye strain and fatigue, which can lead to improved work performance and reduced absenteeism. Therefore, ensuring high-quality daylight in office buildings can contribute to a more positive and healthy work environment, ultimately enhancing the satisfaction and well-being of office occupants (Li, 2001).

In Ethiopia, where rapid urbanization and economic growth have led to a surge in construction and development (BUILD, 2015), the impact of glazed facades on daylight quality in office buildings are a pertinent issue. Addis Ababa is known for its unique climate, with high levels of solar radiation and a distinct seasonal variation in daylight hours. As such, the design and implementation of glazed facades in office buildings must be carefully considered to ensure optimal daylight quality. Gaps in the subject area of the impact of glazed facades on daylight quality in office buildings are shaped by the unique urban and climatic conditions. Therefore, careful consideration must be given to the design of these facades, with an emphasis on how they will affect internal visual comfort.

Therefore, this study aims to investigate the impact of glazed facades on daylight quality of office buildings in Addis Ababa, considering both the global perspective on the use of clear glazed facades and the specific regional and local context of the city.

1.2. Statements of the problem

Glazed façades can significantly influence the quality of daylight within a building. They allow more daylight to penetrate the interior spaces compared to opaque walls, but can also lead to uneven daylight distribution, creating bright and dark zones. The type and design of the glazing impact factors like glare control, color rendering, and daylight dynamics. While increased daylight availability is beneficial, excessive glazing can cause visual discomfort due to glare.

In Ethiopia, the use of glazed façades in buildings has been increasing, especially in the rapidly growing urban centers. This trend is driven by a desire for modern architectural aesthetics, as well as the potential benefits of natural daylight. However, the impact of these glazed façades on daylight quality within buildings needs to be carefully considered in the Ethiopian context. Ethiopia experiences a diverse climate, ranging from the hot and arid conditions in the eastern regions to the more temperate climates in the central and northern highlands. In this context, the increased daylight penetration provided by glazed façades can be both beneficial and challenging.

The use of glazed facades in office buildings in Addis Ababa provides multiple benefits. They maximize natural light, reduce energy consumption, enhance aesthetics, offer panoramic views, and help create a distinctive brand identity. Overall, glazed facades improve functionality, energy efficiency, and attractiveness of office buildings in the city, making them more desirable for occupants and visitors alike. However, the presence of glass facades in these urban areas has raised concerns about the quality of daylight, as they can cause issues such as glare, discomfort, and impairment for occupants, ultimately affecting their performance.

Despite the growing adoption of glazed facades in office buildings in Addis Ababa, there is a lack of comprehensive understanding of how these design elements influence daylight quality within the specific urban context. The problem arises from the need to balance the desire for ample natural light with the potential challenges related to glare and overall occupant comfort. To the level of my knowledge there are some local researches related with outdoor glare problem arise from the glazed buildings. This study stands out from previous research because it addresses important gaps that have not been thoroughly explored in existing studies. These gaps include a conceptual gap, which refers to a lack of understanding or clarity in a particular area of research; a population gap, which suggests that certain groups or demographics have been overlooked or underrepresented in previous studies.

The lack of comprehensive research and data on the effectiveness of glazed facades in office buildings in Addis Ababa is a significant challenge that exacerbates the existing issues. Without a thorough understanding of how these facades perform in the local context, it is difficult to maximize their benefits and address potential drawbacks. The absence of implementing design guidelines and strategies specifically geared towards optimizing daylight quality within office buildings with glazed facades further complicates the situation. This lack of guidance hinders architects and designers in creating spaces that effectively utilize natural light to enhance occupant comfort and well-being.

As a result, there is an urgent need to address this knowledge gap and create methods to optimize the impact of glazed facades on lighting quality in office buildings since it affects the occupants in advance. By conducting extensive research, collecting relevant data, and implementing tailored design solutions, it will be possible to confirm whether or not these facades improve overall occupant comfort within the city's unique urban context, as well as provide a better solution that will not only improve the performance of office buildings but also contribute to their users' well-being and productivity.

1.3. Research Objectives

1.3.1. General objective

To evaluate and provide solution on the impacts of glazed facades on daylight quality in the case of office buildings in Addis Ababa, Ethiopia.

1.3.2. Specific Objectives

1. To assess the current day lighting conditions within selected office buildings in Addis Ababa that utilizes glazed facades.
2. To measure the effects of glazed facade on daylight quality.
3. To propose model based solution that enhances daylight quality in office buildings.

1.4. Research questions

1. What are the current day lighting conditions within selected office buildings in Addis Ababa that utilize glazed facades?
2. How do glazed facades affect daylight quality in office buildings?
3. How can a model-based solution be developed to improve the quality of daylight in office buildings?

1.5. Significance of the study

The study's significance lies in its ability to offer valuable insights into the performance of glazed facades in enhancing the comfort, productivity, and energy efficiency of building occupants. By evaluating the actual illumination levels and distribution within these buildings, the research seeks to provide a comprehensive understanding of the impact of glazed facades on factors such as light intensity and distribution, thereby improving the visual comfort of the indoor environment. Furthermore, the proposed model-based solutions are expected to offer practical recommendations for optimizing natural lighting in office spaces with glazed facades, thereby contributing to sustainable building practices and occupant well-being. The study's findings have the potential to significantly impact the design and development of office buildings, providing architects and designers with actionable insights to create healthier and more sustainable indoor environments.

In addition, the study's significance extends to its contribution to the advancement of knowledge in daylighting design. By investigating the impact of glazed facades on daylight quality in office buildings, the research aims to expand the existing body of knowledge in this field, providing valuable insights for future research and development.

1.6. Scope of the study

1.6.1. Spatial scope

This study is limited to three selected office buildings in Addis Ababa, These are respectively Awash bank and insurance Sc. at kirkos sub-city (Mexico), Hagbes Building at Bole sub city (Bole), Meklit Building located Yeka sub-city (Megenagna-22). The selection of only three office buildings was a strategic decision made to ensure the study was representative, feasible, and allowed for a thorough and in-depth analysis of the impact of glazed facades on daylight quality within the context of Addis Ababa.

1.6.2. Thematic scope

The thematic scope for the research topic focuses on several key aspects. The study primarily aims to assess the quality of daylight within selected office buildings, particularly in areas illuminated by glazed facades. This includes considerations of light intensity, distribution, color rendering, and visual comfort. The research also examines the performance of glazed facades in providing daylight to interior spaces, facade orientation, and other design elements in optimizing daylight quality.

The study also considers the urban context of Addis Ababa, including local climatic factors and surrounding structures, to understand how these elements influence the performance of glazed facades in office buildings. Additionally, the study acknowledges the importance of occupant well-being and productivity, particularly in relation to the influence of daylight quality on visual comfort, mood, and work performance.

1.7. Operational Definitions

- **Daylight Quality**: Operationalized as the IL luminance levels (measured in lux) within the interior spaces of the selected office buildings, with specific thresholds for adequate day lighting.
- **Glare:** Excessive brightness in the visual filed and depending on the degree may produce discomfort or visual disability (Emmit and Gorse, 2010).
- **Glazed façade**: an architectural element characterized by large areas of transparent glass used as the primary cladding material on the exterior of a building, creating a visually open and light-filled environment (Littlefair, 2002).
- **Glazed Facade Performance**: Operationalized through measurable parameters such as visible light transmittance (VLT), solar heat gain coefficient (SHGC), and shading coefficient of the glazing material, as well as the distribution of daylight within the building's interior spaces.
- **Glare Sensitivity**: is a debilitating loss of visual acuity in bright lighting. (van den Berg et al., 2009)
- **IL luminance:** The amount of light flux falling on a surface area is measured in lumens per square foot or foot candles (Pohl, 2011)
- **Luminance:** The intensity per unit area of a surface as seen from a specific direction, measured in candela/surface area or foot-lamberts (fL) (Pohl, 2011).
- **Occupant Well-being**: Operationalized by assessing factors such as visual comfort, glare, and the potential for circadian rhythm regulation based on the quality and quantity of daylight within the interior spaces, potentially using standardized survey instruments or physiological measurements.
- **Urban Context**: Operationalized by considering specific urban and climatic factors such as the building's orientation, surrounding building heights, and the presence of shading elements in relation to the performance of glazed facades.

- **Visual comfort**: The criteria are based on the amount of light, the contrast balance, the color 'temperature,' and the presence or absence of glare in the visual field (Pohl, 2011).

1.8. Limitation of the study

The lack of reliable data from glass material importers and suppliers on the performance of imported glass materials made it difficult to comprehensively assess certain glass properties. Data collected through occupant surveys is subjective and can skew results. There was also limited subject response, as occupants of the office building were unwilling to share data.

1.9. Outline of the proposal

The thesis consists of five chapters. Each chapter examines the content and data of the study accordingly. The elemental chapters within the research are further demonstrated as follows.

Chapter One: The primary chapter contains an introduction, background of the study, statement of the problem, objectives (general and specific), research question, significance and scope of the study, operational definitions, and limitations of the study, and at last, an outline of the research paper.

Chapter Two: Within the second chapter, the border area of the research was examined, evaluated, and stated from different literature within the literature review. It contains an introduction, a basic conceptual definitions and theoretical and empirical views of the research area referred to carefully.

Chapter Three: The third chapter outlines the methodology and materials used for this particular study. It discusses the research approach, research design, research techniques, data collection methods, data types and sources, and finally data analysis and presentation methods.

Chapter Four: The findings of qualitative and quantitative data were reviewed in the Results and Discussion section. The subjective qualitative data is examined and validated by a questionnaire survey as well as field observations from the three office buildings. Field observations, physical feature measurements, and simulation tools are used to examine and support the quantitative data collected.

Chapter Five: The conclusion derived from the previous chapters is summarized and the recommendations for future studies are mentioned.

CHAPTER TWO

LITERATURE REVIEW

2.1. Theoretical literature review

2.1.1. The sun's position

The sun's position in the sky is the key to controlling daylight. As the sun moves throughout the day and across the seasons, its angle and intensity change, affecting the amount of daylight we experience. Tracking the sun's position allows us to predict sunrise and sunset times. This is vital for managing daylight in various applications. When the sun is high overhead, its rays strike the Earth more directly, resulting in brighter, more intense daylight. Conversely, when the sun is low on the horizon, the light is less intense (Ngungui, 2018).

These seasonal shifts in the sun's position also cause variations in daylight duration. Location also plays a role. Near the equator, the sun's position is more consistent year-round, while higher latitudes see more dramatic seasonal changes in daylight. By understanding and controlling the sun's position, we can optimize daylight in building design, lighting, and more. Keeping an eye on the sun allows us to harness its power and make the most of natural illumination (Ngungui, 2018).

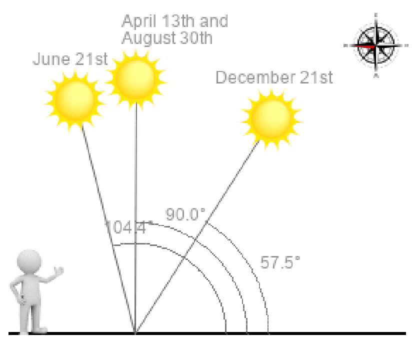


Figure 1: Actual hrs. Of sunshine (Source: https://www.worlddata.info/)

2.1.2. Solar geometry

The earth's movement around the sun results to different solar paths characterized by variable heights and lengths depending on the time of the year and latitude. The sun's apparent movement is from the east to west. Its position at different times of the year can be found though two angular coordinates namely:

- Solar altitude β, represented by the angle between the line joining the Centre of the sun with the observation point and the horizontal plane
- Solar azimuth α, which is the angle, measured on the horizontal plane, from the south-pointing coordinate axis to the projection of above joining line.

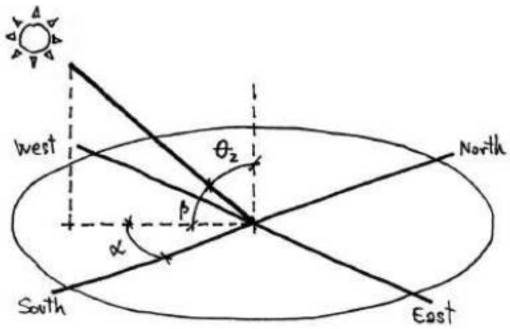


Figure 2 : Angular coordinates of the sun

2.1.3. Sun path diagrams

Sun path diagrams are a convenient way of representing the sun's changing position in the sky throughout the year. They are projected onto a horizontal plane, on which the four cardinal points (North, South, West and East) are represented. The plane has a base with concentric circles and radial lines. The position of the sun at any time of the day can be plotted on the horizontal plane. It is therefore possible to develop specific diagram for any latitude. The values of solar altitude β are represented by the circumferences (outermost corresponds to β = 0°, horizon, while the centre corresponds to β = 90°, zenith). The values of solar azimuth α are indicated by the radial lines, and can be read out as the angular distance from the south-pointing coordinate axis (Ngungui, 2018).

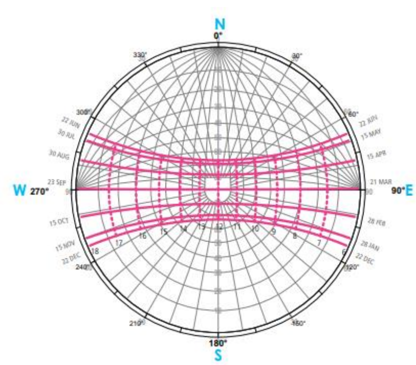


Figure 3: Polar sun path diagram at the equator

2.1.4. Daylight

Daylight is described as the combination of all direct and indirect light originating from the sun during daytime. Of the total solar energy received on the surface of the earth, 40% is visible radiation and the rest is ultraviolet (UV) and infrared (IR) wavelengths.

Daylight availability outside varies for different locations due to different sun paths and sky conditions through the course of the day, the season and the year. Put simply, the amount of light on the ground depends on the solar elevation; the higher the sun, the greater the illuminance on the ground. Daylight levels vary significantly on horizontal and vertical surfaces by time of day and season, directly related to the local sun paths and sky conditions. Of the solar energy received on the surface of the earth, 40% is visible light and the rest is ultraviolet (UV) and infrared (IR) wavelengths. No electric light source can mimic the qualities of daylight (Daylight, 2014).

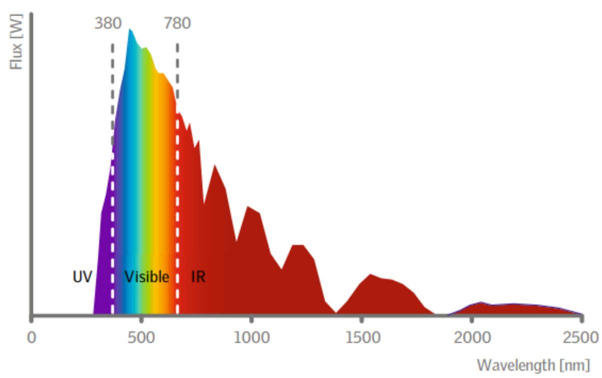


Figure 4: Diagram of the electromagnetic spectrum showing the location

2.1.5. Day lighting

Day lighting describes the controlled use of natural light in and around buildings (Reinhart, 2014). It is the practice of placing windows, or other transparent media and reflective surfaces so that natural light provides effective internal illumination during the day. Successful day lighting requires design considerations at all stages of the building design process, from site planning to architectural, interior and lighting design.

Daylight in buildings is composed of a mix – direct sunlight, diffuse skylight, and light reflected from the ground and surrounding elements. Day lighting design needs to consider orientation and building site characteristics, facade and roof characteristics, size and placement of window openings, glazing and shading systems, and geometry and reflectance of interior surfaces. Good day lighting design ensures adequate light during daytime. Some basic characteristics of daylight outdoors:

- Direct sunlight is characterized by very high intensity and constant movement. The illuminance produced on the surface of the earth may exceed 100 000 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 characterized 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 around 30 000 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 characterized by light (sunlight and skylight) that is reflected from the ground: terrain, trees, vegetation, neighboring buildings etc.

The total amount of reflected light that reaches the building facade will depend on the surface reflectance of the surrounding area. The light reflected from the surrounding surfaces and the ground itself can play a significant role in providing daylight indoors in certain densely populated building scenarios. The objectives of room-day lighting are to save electricity; give the light required for human biological needs, make an appealing visual environment, and sufficiently illuminate visual work. An ideal lighting setup combines comfort, style, relevance, and appropriateness for the intended uses and users (Daylight, 2014).

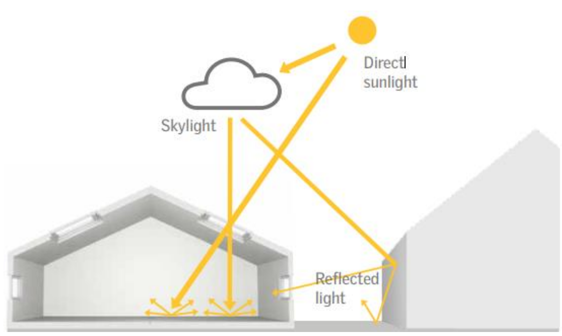


Figure 5: The component of Daylight

2.1.6. Daylight Factor

The amount of light that comes from a full sky is typically far greater than the amount of natural light that illuminates a space. It is impossible to define daylight in terms of a fixed illuminance level in lux since the amount of light the sky provides varies as its brightness does. The functional requirements of the space, seasonal variations, environmental and geographic factors, building locations, and tenant needs all play a role in determining how much daylight is considered appropriate. Moving from an inside area to an exterior one, or vice versa, significantly alters the brightness conditions. The daylighting factor formula determines how much daylight enters the space (Nazanin Nasrollahi, 2016):

DF= SC +ERC+ IRC….. Equation 1Whereas

DF = daylight factor,

SC = sky component,

ERC = externally reflected component and

IRC = internally reflected component.

2.1.7. Benefits of daylight

Human benefits

Appropriate light signals during the day and darkness at night are critical in maintaining key aspects of our overall health. In order to align our body clock, morning light is the most important signal for entrainment. Light in the morning also increases our levels of alertness, allowing increased performance at the beginning of the day. From mid-morning to early evening, high levels of daylight, allow us to regulate our sleep/wake timing and levels of alertness; whereas reduced light levels in the evening and a dark room with blackout promote sleep at night. The inability to provide building occupants with a good overall lighting environment can have subsequent impact on health and place a substantial burden on the individual, society and the broader economy (Daylight, 2014).

Energy savings for electric lighting

Another benefit of using day lighting 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% (Galasiu, 2007), but it depends on the lighting control system used, how well the space is day lit during occupied hours and the intended functions of the space. If no control system is installed, the occupant entering a space will often switch on the electric lights.

2.1.8. Daylight in Office Spaces

Daylight can have both positive and negative impacts on the visual aspect and performance of office occupants. While natural light can provide numerous benefits, such as improved mood and productivity, it can also have negative effects, particularly when it comes to visual comfort and performance.

One of the main negative impacts of daylight in the visual aspect is glare. Glare occurs when the light source is too bright and creates an uncomfortable visual experience for the occupants. It can cause eye strain, headaches, and even temporary blindness, making it difficult for people to focus on their work. According to a study by the Lawrence Berkeley National Laboratory, glare can reduce visual performance by up to 20% .Another negative impact of daylight is the potential for over-illumination. When daylight enters a space through large windows or skylights, it can create an overly bright environment, leading to visual discomfort and eye strain. This can be particularly problematic in areas with high levels of ambient light, such as near windows or in spaces with high ceilings. Over-illumination can also lead to increased energy consumption, as artificial lighting may be used to supplement the natural light, even during the daytime (Kolb, 2017).

Daylight can also affect the performance of office occupants. A study by the University of California, Berkeley, found that employees who work in naturally lit environments have a higher level of productivity and accuracy compared to those who work in artificially lit spaces (Kolb, 2017). However, excessive daylight can lead to the opposite effect, with occupants experiencing eye strain, headaches, and decreased productivity due to the discomfort caused by glare and over-illumination.

In addition to the negative impacts on visual comfort and performance, daylight can also affect the thermal comfort of office occupants. While natural light can provide warmth and comfort, it can also lead to overheating, particularly in spaces with large windows or in areas with high levels of solar radiation. This can lead to increased energy consumption, as cooling systems may be used to compensate for the excessive heat gain (Kolb, 2017).

2.1.9. Visual comfort

Visual comfort is a condition where human eyes receive a suitable amount of light without making an effort to visualize some tasks, which strongly relate to the illumination levels inside the space either artificial or natural light sources (David, 2011). The main focus on visual comfort has traditionally been light levels, contrast, and glare. In the first case, the more intense the task, the brighter the light required. This is the main reason operating rooms are much brighter than offices, which are in turn much brighter than living rooms. The second pertains to contrast: the greater the contrast, the easier the comprehension. The final point is that glare is undesirable, as it makes it difficult to see the object of attention. There are also other effects beyond light levels, contrast, and glare. Color relates to a particular frequency of light, and color can have an effect on one's comfort. Though it is has not been established whether the influence is from the color itself or derived from cultural and historical associations, people react differently to various segments of the spectrum (Daylight, 2014).

2.1.10. Main parameters of visual comfort

The visual environment must allow people to see objects clearly, without strain, in pleasantly toned surroundings. The parameters of visual comfort for which architects play a dominant role are: the level of illumination of visual tasks, the harmonious distribution of light within a space, the ratios of illuminance within a building, the absence of unwanted shadows, an exterior view, good color interpretation, pleasant tones of light, and the absence of glare. (Derek Phillips, 2004).

2.1.11. Visual comfort criteria

There are numerous parameters in human psychology that influence the perception of daylight quality. Such parameters include, amongst others, mood, access to a direct view to the outdoors and the occupants‟ need for privacy, and cannot be objectively measured Some authors argue that, besides enabling visual comfort, "lighting quality" requirements should also comprise proper conditions for task performance and energy efficiency considerations. (Boyce and Eklund 1995) There also seems to be a general agreement that the most basic visual comfort requirements relate to levels of illuminance and to how light is distributed in the visual field (Dubois, 2003).

Illuminance

Illuminance, in the context of office daylighting, refers to the amount of light that falls on a surface in a workspace. It is an important factor in determining the visual comfort and productivity of employees. ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) provides guidelines for office lighting in its standard 90.1, which recommends a minimum illuminance level of 200 lux-500 lux for office spaces.

A study by the University of California, Berkeley found that workers in day lit offices reported a 30% reduction in eye strain and a 25% improvement in visual comfort compared to workers in offices with artificial lighting (R. G. V. Booth, 2003.). Another study by the Lawrence Berkeley National Laboratory found that daylighting can reduce the need for electric lighting by up to 80%, resulting in energy savings and improved visual comfort (Heschong, 2002).

Luminance

Luminance, refers to the amount of light that is emitted by a surface or object in a particular direction. It is a measure of the light intensity, and it is typically measured in candelas per square meter (cd/m2). ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers) provides guidelines for luminance in office daylighting in its standard, ASHRAE 55-2017. The standard recommends the following luminance levels for office spaces:

- 50-100 cd/m2 for general office areas
- 100-150 cd/m2 for task areas with high visual requirements, such as computer workstations and reading areas
- 150-200 cd/m2 for areas with very high visual requirements, such as drafting tables and design studios

These luminance levels are intended to provide a comfortable and visually pleasing environment for building occupants, while also promoting energy efficiency. There have been several research studies that have investigated the impact of luminance on office daylighting. One such study, published in the Journal of Lighting Engineering, found that luminance levels in the range of 50-100 cd/m2 are suitable for general office areas, while levels in the range of 100-150 cd/m2 are more appropriate for task areas with high visual requirements (Kolb, 2017).

Another study, published in the Lighting Research & Technology journal, found that luminance levels in the range of 150-200 cd/m2 are optimal for areas with very high visual requirements, such as drafting tables and design studios (Brown, 2018).

2.1.12. Visual comfort versus Human performance

Lighting quality is one of the determinants of human performance in indoor environment. Various studies have been conducted to compare the effects of different lighting conditions on health, productivity, and well-being and alertness level. With regards to human perception, correlated color temperature (CCT) and illuminance level are the two most important characteristics of light to be considered (van Bommel, 2004).

2.1.13. Visual discomfort/Glare

Glare is visual noise that interferes with visual performance. Two main types of glare exist, direct and indirect (reflected), and each can have very detrimental effects on the ability to see (Lechner, 2015). Direct glare is caused by a light source in the field of the view that is sufficiently bright to cause annoyance, discomfort, or loss in visual performance. Reflection of light sources on glossy surface usually cause indirect glare.

2.1.14. The need for solar control

The two most important climatic factors that influence indoor environment are air temperature and solar radiation even though wind and humidity also have an effect. Solar radiation may cause severe overheating which dramatically increases air conditioning load in addition to occupant discomfort.

Recently, there are a number of non-geometrical solar control technologies like photo chromatic or thermo-chromatic glasses. These however rarely provide the desired control, always reducing the day lighting of the interior spaces. (Wurm, J., 2007). The most effective method of solar control is the use of external shading device, which provides a barrier to solar radiation before it would reach the glass window. This was explained well in the 2nd international conference on sustainable and healthy buildings, in Korea. (kim, J.T, 2009).

2.1.15. Glazed façade and daylight quality

A study conducted by Widyastuti, et al. (2020) provides a comprehensive review of glazed facades and their impact on daylight quality in buildings. The authors discuss the benefits of glazed facades, such as increased natural light and improved visual comfort for building occupants. They also highlight the potential drawbacks, such as increased solar heat gain and glare. The study emphasizes the importance of balancing the use of glazed facades to maximize daylight penetration while minimizing negative effects.

2.1.16. Windows and Glazing

As an office worker's primary point of contact with the outside environment, windows can offer views, light, glare, and even induce overheating. The location, form, and size of windows, along with the type of glass used, determine how much light enters a structure from the outside and how far that light travels into the building's core (Melina Forooraghi 2015).Detailed evaluations of a the glazing, need the specification of the attributes and factors taken into account when selecting glass. These are the following:

U-Values: The thermal transmittance of a building material or façade assembly is a measure of heat transfer and is typically used to characterize the thermal performance of the glazed portions of facade assemblies. Thermal resistance, or R-value, is another way to measure heat loss. R = m2k/w or R = 1/U-value. The less heat transmitted through glass, the lower the u-factor.

Glass's daylight shading coefficient: This metric tells us how thermally efficient a glass building will be. The number represents the amount that the glass shades or thermally insulates the interior when it is exposed to direct sunlight through a panel or window. It is a number with a range of 1.00 to 0.00.Less solar heat is passed through the glass the lower the rating, and the higher the shading ability (Melaku 2016).

Table 1: Shading coefficient for typical windows

GLASS TYPE	SHADING COEFFICIENT

Glass + frame	
Single, clear	0.69 – 0.73
Bronze	0.53 – 0.62
Green	0.50 – 0.61
Gray	0.48 – 0.60
Reflective	0.17 -0.28
Double, clear	0.60 – 0.70
Bronze	0.43 – 0.53
Green	0.40 – 0.52
Gray	0.38 – 0.51
HP green	0.33
Reflective	0.12 – 0.20
Double – low E ,clear	0.32 – 0.60
Bronze	0.23 – 0.48
Green	0.27 – 0.47
Gray	0.21 – 0.46
HP green	0.21 – 0.46

VLT (Visible light transmission of glazing) or **Glass Visible Transmittance (Tvis-glass):** is a factor that impacts glazing's visual performances. It displays the percentage of the solar spectrum that is visible and transmitted via a particular product. A number between 0 and 1 represents VLT. More light is transferred when the number is higher. Tinting and low e-values are two characteristics that affect visual performance.

RHG (Relative Solar Heat Gain): shows the amount of solar radiation that reaches the window and is transferred through it as heat. It combines the effects of U-values with the shading coefficient. The solar gain potential through a particular window grows as the SHGC increases.

2.1.17. Types of Glass

Current researches and technologies aimed at maximizing the performance of glass in terms of light transmission, heat blocking and safety issues. In terms of thermal performance and safety glasses are classified as:

- **Laminated glass:** a transparent sheet of polymer is sandwiched between two or more layers of glass to protect ultraviolet rays and reduces vibration.
- **Insulating glass:** glass layers are separated by sealed dry air or gas space for thermal insulation and condensation control.
- **Coated glass:** covered with low- emissive (low E- coatings which reflects radiation).
- **Tinted glass:** composed of minerals which colors the glass to absorb radiation.
- **Wire glass:** a wire mesh is inserted between glass plates to enable the glass stick together during crack.

2.2. Empirical Literature review

2.2.1. Daylight in glazed office buildings, Sweden

A comparative study of daylight availability, luminance and illuminance distribution for an office room with three different glass areas. In this study, the illumination patterns in office spaces were examined using computer simulations with Ray-front/Radiance and Ecotect software. The impact of various facade options on daylight availability and visual comfort was analyzed, with a particular focus on individual offices and some investigation into open-plan areas. The study compared three distinct facades, each with windows covering 30%, 60%, and 100% of the facade area.

The study's findings suggest that having very large windows does not necessarily lead to better lighting conditions. Achieving a glare-free environment can be challenging, and additional measures such as adding interior curtains or blinds may be necessary. With today's computer-based work, the risk of glare is increased when looking at vertical self-luminous surfaces compared to looking down at a piece of paper. Since the line of sight is raised, the window is likely to be in the central field of view, especially in open-plan spaces. The larger the window area, the higher the likelihood of glare. To further mitigate the risk of glare, computer screens could be moved further away from the window and turned perpendicularly away from it.

2.2.2. Case Study in Kuala Lumpur, Malaysia

Modern buildings in Malaysia are characterized by the use of large glass windows, some of which are partially covered with various types of shading devices primarily for aesthetic purposes. However, the presence of sun shading devices has not effectively addressed glare issues; instead, it has led to either dark interiors or the need for interior blinds and increased use of electrical lighting. Therefore, this paper seeks to examine the performance of glare under daylight using the most prevalent types of shading devices in Kuala Lumpur, Malaysia. The study focuses on four common shading devices: vertical, horizontal, egg-crate, and geometrical pattern. The experiment encompasses the assessment of luminance, illuminance levels, and the subjective responses of the occupants.

All shading mechanisms have significantly reduced the incoming outside illuminance; nevertheless, glare remains visible through all shading devices. The observed glare is consistently perceived as very intense across all shading devices, although only a few participants found the light at the window to be glaring and the shading mechanisms unsuitable. It appears that the participants' eyes tend to adjust to the glare at the window. Based on the subjective perception of the participants in the experiments, vertical shading devices are deemed the most effective in minimizing glare, while the egg-crate shading device is considered the least effective.

2.2.3. Building façade design for daylighting quality in typical government office building

This article discusses the importance of daylighting in government office buildings in Malaysia and presents a study on the daylighting performance of a typical government office building. The study includes field measurements of external and internal illuminance levels and validates the measurements using simulation. The findings show that the internal daylight level was insufficient despite the abundance of external daylight availability. The study experimented with modifications to window glazing and shading devices to improve daylight distribution and reduce glare. Integrating a light shelf with partial blinds tilted at 45 degrees showed improved performance in terms of visual comfort and glare reduction. However, this configuration reduced the daylight distribution uniformity on the horizontal plane. The study concluded that simple modifications to window glazing and shading devices can significantly improve daylighting quantity and quality in tropical climates. The use of blinds needs to be flexible, allowing better daylight penetration and distribution uniformity when there is no direct sunlight.

2.2.4. Barreca & La Varra Studio

The B5 Building, also known as the Barreca & La Varra Studio, is a multi-functional building located in Milan, Italy. It was designed by the architectural firm Barreca & La Varra and completed in 2017. The building serves as a studio and office space for various creative professionals, including architects, designers, and artists.

The building has a total area of 1,000 square meters and is spread over five floors. Each floor has a different layout and design, reflecting the diverse needs of the occupants. The building features a range of facilities and amenities, including Open-plan office spaces, Private studios, Meeting rooms, Exhibition space, and Roof terrace and shared facilities.

Figure 6:B5 Building

In order to create a surface that is far more responsive to its surroundings, it was attempted to define the facade in a more expansive sense than is often necessary. In actuality, the building appears to be able to "read" the site as the surrounding cityscape and context are reflected from the glass, tracing the ideas, histories, and narratives that have given the location its current form on the surface.

The vertical components give the exterior a "color texture," which gives the skin movement and a changing transparency based on the time of day and available light. Despite being bordered by a number of big-scale buildings, the new office building overlooks a vast inner court that acts as a freely flowing outdoor area between buildings. In addition to minimizing energy use and creating a cozy and sustainable work environment, the B5 Building's façade is designed to maximize the amount of natural light that enters the structure. The façade's combination of stone, metal, and glass contributes to the building's dynamic and eye-catching appearance while simultaneously offering the building's residents a practical and sustainable solution.

2.2.5. Daylight in glazed office buildings

The research thematic area delves into exploring how the presence of daylight and visual comfort are influenced by the extent of glazing in office buildings. By comparing different façade options, the study aims to determine the implications on energy savings related to lighting usage and the management of glare issues. To achieve this, advanced computer simulations using tools like Rayfront/Radiance and Daysim are utilized to simulate and analyze the distribution of light within the spaces, assess how rooms are perceived, and evaluate the effectiveness of shading solutions under varying conditions. Through these methods, the research seeks to provide insights into optimizing daylight utilization and enhancing visual comfort in office environments with different levels of glazing.

2.2.6. The Impact of a Glass Façade on Users in Different Climate Contexts in Croatia

The research focused on analyzing the impact of glass façades on users in different climate contexts. The study used qualitative assessments of the façade's resilience to environmental variables and subjective assessments by users as data collection methods. This involved comparing the characteristics of façades on real-world sites and surveying users to assess their experiences of indoor comfort in workspaces. The goal was to understand the mechanisms for indoor comfort in various climatic scenarios by analyzing existing building envelopes and user positions in relation to orientation. The thematic area of the research, therefore, centered on understanding how the design and performance of glass façades affected the comfort and experiences of building occupants in different climate conditions.

2.3. Conceptual review

Urban and climatic factors play a significant role in influencing the performance of glazed building facades. The orientation of the building, the heights of surrounding structures, and the presence of shading elements all have an impact on the visual comfort experienced by occupants. The key criteria for visual comfort include light levels, contrast balance, color temperature, and the presence of glare. However, the study faced certain limitations, such as limited data on the properties of imported glass materials and the subjective nature of occupant surveys. To address these challenges, the research utilized a cross-sectional observational study, with visual charts employed to present the data.

2.4. Methodological review

The research approach combined a deductive approach with a mix of qualitative and quantitative data collection methods. Occupant surveys, and on-site measurements were used to conduct a comprehensive analysis. The data collection methods included questionnaire surveys, field observations, physical measurements, and simulation tools. The analysis utilized Ecotect software for simulations, and the survey data was analyzed both quantitatively and qualitatively.

2.5. Summary of the Literatures

The position of the sun is a critical factor in managing daylight within buildings. As the Earth revolves around the sun and tilts on its axis, the sun's position in the sky changes throughout the seasons. This seasonal shift affects the duration and angle of daylight entering a building, which is an important consideration in architectural design and lighting strategies.

The location of a building also plays a role in the consistency of daylight. Factors such as latitude, climate, and local weather patterns can influence the reliability and quality of natural light available. Understanding and controlling the sun's position allows architects and designers to optimize daylight use in building design and lighting systems.

Empirical studies conducted in Sweden and Malaysia have highlighted the importance of daylighting in office buildings. These studies have examined how the design of a building's facade can impact the quality and distribution of daylight within the interior spaces.These empirical studies provide valuable insights into the practical application of daylighting principles and the impact on building performance and occupant comfort.

2.6. Research Gap

The absence of clear knowledge about the effects of glazed façades on daylight quality in Addis Ababa office buildings is a gap in the current literature. Adequate local studies on this issue are lacking, hindering the ability to build upon prior work. A major practice gap is the lack of clear guidelines and strategies for enhancing visual comfort through daylighting in office buildings with façade glazing systems in Addis Ababa. This hampers architects and designers in optimizing natural light to improve occupant comfort and well-being.

CHAPTER THREE

MATERIALS AND METHODS

This chapter discusses the study area, the data needed for the study, sampling techniques, and the tools and resources used to collect and process the data. Additionally, it discusses and outlines the methods for analyzing the data that is obtained to address the research questions and achieve the study's objectives.

3.1. Description of the study area

The physical environment of Addis Ababa, the capital city of Ethiopia, is characterized by a modern architecture and experiences abundant sunshine throughout the year due to its location near the equator. The city enjoys a relatively consistent mild, subtropical highland climate with warm temperatures from 10°C to 25°C (Kidanu, 2017).

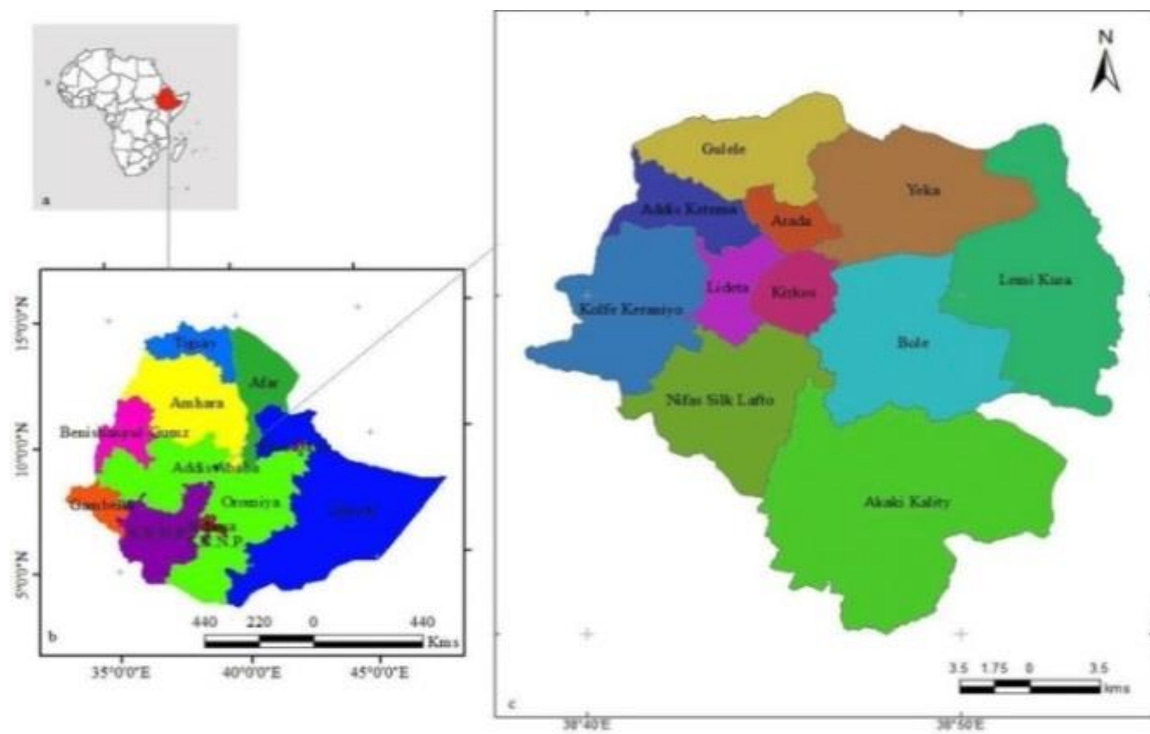


Figure 7: Map of Addis Ababa, with Sub-Cities. Source: Ethio GIS (2022)

Actual hours of sunshine

The period from sunrise to sunset is the astronomical length of the day. In addition, significant deviations can be perceived depending on cloud cover or other visual obstructions. For the Addis Ababa region, the figure below showed the approximate sunshine duration.

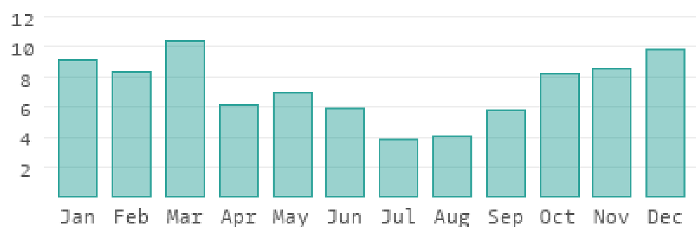


Figure 8: Sunshine duration (Source: https://www.worlddata.info/)

In June, the sun shines for around 5:54 hours a day. In contrast, the day is 12:41 hours long. This means that the visual obstruction is around 6:47 hours per day. In December, on the other hand, it is 1:50 of 11:38 hours.

3.2. Criteria for study structures

3.2.1. Building orientation

Orientation is one of the important factors in building design to use daylight and conserve energy. Well orientated buildings maximize daylight reception through building facades and reduce the need for artificial lighting (Rao, 2015). The size and orientation of windows can significantly impact the amount of natural light that enters a building. Larger windows and windows facing west and southwest can provide more daylight.

3.2.2. Building location and surrounding environment

The location of the building and its surroundings, such as nearby buildings, trees, or other obstructions, can impact the availability of natural light throughout the day.

3.2.3. Glazing color

The color of glazing can affect the visible light transmission properties of the glass. Lighter-colored glazing tends to reflect more light and reducing glare inside the building. On the other hand, darker-colored glazing absorbs more light and heat, potentially increasing glare. Careful selection of glazing color based on the building's orientation and climate can optimize daylight quality (Christoph F., 2010).

3.2.4. Height of the building

The height of a building can affect how far natural light can penetrate into the interior spaces. The height of a building can influence the availability of direct sunlight to interior spaces, particularly on upper floors. Taller buildings have the potential for increased sunlight exposure due to reduced obstructions from surrounding structures.

3.3. Buildings sample size determination

The sample buildings were selected in central business areas of Addis Ababa (Bole, Megenagna and Mexico). Those areas were selected due to the numerous office buildings that have fully and partially glazed facades constructed.

Using the non-probability sampling technique, which helped to select the buildings purposefully that met the criteria based on preliminary measurements, which are the orientation of the buildings, building height, and building location. In the chosen business district areas, buildings with west and southwest orientations were chosen. This resulted in the selection of 3 buildings. Three buildings with fully glazed and partially glazed facades. The office buildings are selected due to occupant sensitivity. Compared to other building types, office occupants spend a significant amount of time in their work environment, making them more susceptible to the effects of daylight quality.

3.3.1. Awash insurance company

The Awash Insurance Company S.C. building is located in Mexico, kirkos sub-city. The building is a 16-story structure constructed for administrative purposes. It is made up of two transparent semicircular wings that are connected by a pedestrian bridge at various levels. The examination was carried out on levels that mostly consisted of open plan office spaces.

On sunny days, the large glazed exterior allows plenty of natural light within the structure. However, this can caused dramatic variations in internal lighting in working areas. In other words, some areas of the workspace received bright sunshine as a result of the illumination; they had to deal with extreme glare and discomfort. This led to eye strain, headaches, and reduced productivity and well-being.

Figure 9: Awash Insurance Company

3.3.2. Hagbes building

Hagbes building, located in Bole sub-city, is a Seven-story structure intended exclusively for private business use. Notably, the building's northern, northwestern, and western faces are totally glass. These glass panels have a reflected blue tinge, which adds to the building's modern and elegant aspect. However, during periods of bright sunlight, differences in interior illuminance levels at various workstations within the building caused discomfort for residents. Lighting disparities caused glare and uneven lighting conditions, reducing the overall comfort and productivity of those working in the room.

Figure 10: Hagebes Building and Interior View

3.3.3. Meklit Building

The Meklit building is a twelve-story building that the Transport Management Agency has authorized for government use. It is situated in Sub City 22 of the Yeka sub-city of Addis Ababa. The north, west, and south faces of the building are designed with partially glass facades. These light-reflecting glazed panels have a noticeable black tint. Although the glass appears to be tinted grey, it is surprisingly designed to allow a high level of daylight transmittance. This feature is significant as it contributes to the building's overall lighting environment and has a notable impact on the occupants within the space. The abundance of natural light penetrating through the grey-tinted glass can influence the building's energy efficiency, aesthetics, and the well-being of those working or visiting the premises.

Figure 11: Meklit Building and Interior View

3.4. Research Design

The research design sets the procedure for the specified data, the methods to be applied to gather and analyses this data, and the way all of this is often visiting to answer the research question (Wilkerson, 2014). A mixed methods design was utilized to achieve the objectives. For the time dimension a cross-sectional observational study was utilized

A mixed methods design was utilized to achieve the research objectives. This approach involves combining both quantitative and qualitative research methods to provide a more comprehensive understanding of the research problem.

Specifically, for the time dimension, a cross-sectional observational study was utilized. In a cross-sectional study, data is collected at a single point in time, rather than following a group of individuals over an extended period (longitudinal study). The cross-sectional observational design allows the researchers to examine the relationship between different variables of interest within the target population at that particular time.

By combining the cross-sectional observational approach with other qualitative methods, the researchers were able to gain a more holistic and contextual understanding of the research problem rom multiple perspectives. This mixed methods design likely provided richer and more nuanced insights to address the study objectives.

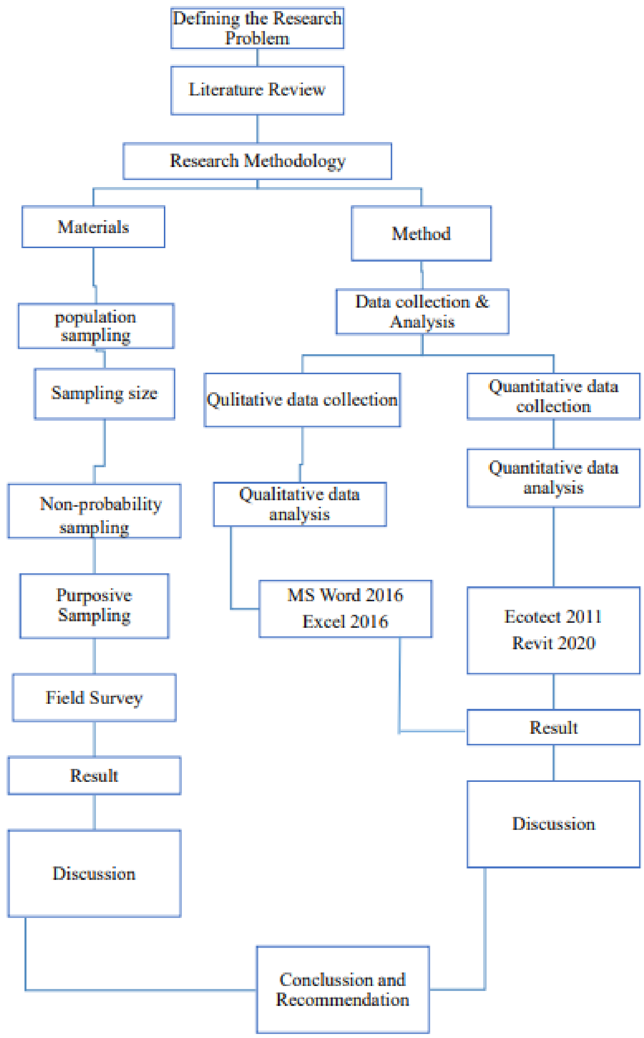


Figure 12: Research Design Chart

3.5. Research approaches

The study applied a general deductive research approach. Through this approach, the study generated information that enabled the use of both qualitative and quantitative data. Qualitative approaches included occupant surveys and in-depth interviews to capture subjective experiences and perceptions of daylight quality. These qualitative data were vital for gathering respondents' attitudes and experiences regarding visual comfort, productivity, and overall satisfaction with the indoor daylight quality. Quantitative approaches involved on-site daylight measurements using light meters and simulation tools to quantify the amount of natural light penetrating the interior spaces. This combined approach aimed to provide a comprehensive understanding of the impact of glazed facades on daylight quality, considering both subjective experiences and quantitative measurements in the context of Addis Ababa's office buildings.

3.6. Research Method

In order to achieve the objectives of this study, the following techniques were employed: The first objective was accomplished through the use of a multifaceted quantitative and qualitative research approach, which allowed for the identification of the daylight quality and conditions. By using a quantitative method to assess the daylight quality in office buildings with glazed facades to a reference or standard, the second objective was achieved. The third objective of the study was to improve the daylight quality of office buildings through research-based design.

3.7. Sample population and Sampling technique

In order to evaluate the effect of the glazed façade on the quality of daylight, building occupants (office employees and employers) were taken into consideration as a sampling unit. The occupants were the focal point since they are susceptible to the daylight. Based on the sample size the questionnaires were distributed. The sample is produced by adding up all three building employees' numbers and applying Yamane's 1967 algorithm.

For known population size, the Yamane formula for determining the sample size is given by:

$$n = \frac{N}{1+N(e^2)}$$

n= corrected sample size,

N = population size, and

e = margin of error (MoE), 95% confidence level e ± 5%, e = 0.05

The population is 700. At 5% MoE, the sample size would be:

$$n = \frac{700}{1+700(0.05^2)}$$

$$n = 254.5$$

$$n = \text{sample size} \approx 255$$

Table 2: Population size of each building

No.	Buildings	population size	Total percent	Sample population size
1	Awash insurance company	300	42.9	109
2	Hagbes	150	21.4	55
3	Meklit	250	35.7	91
	Total	700	100	255

For representativeness, alignment with research objectives, and depth of insight, purposive sampling ensured that the selected buildings and occupants represented a range of relevant factors that could influence the impact of glazed facades on daylight quality. This approach allowed for a targeted and deliberate selection of buildings that aligned with the specific research aims, providing in-depth insights into the influence of glazed facades on daylight quality in office buildings.

Parameter Identification

There are independent and dependent parameters which have high influence on the quality of daylight.

Independent variables

- **Duration of the Sunrise and sunset:** The farther a country is from the equator, the more oblique the sun's path is to the horizon, causing sunset to last for a different duration. Addis Ababa lies on the 9th degree of northern latitude and thus very close to the equator.
- **Room height:** Height of the room the buildings were kept constant, Hence change in the room height would affect the volume of the space which in turn directly related to amount of daylight
- **Material type**: properties and layers of glass materials were identified and kept constant throughout the simulation process
- **Time of Simulation**: the simulation would be conducted in different times of the day, days of the month in order to get an overview about the influence of changing time.

Dependent variables

- **Building orientation**: in order to investigate the effect of the sun position on the buildings' facade and how it would influence the indoor and outdoor luminous environment, building was tested.
- **Daylight quality:** heavily influenced by environmental conditions. The sun's position, which varies throughout the day and seasons, affects illuminance, distribution, and glare. Weather patterns like cloud cover and atmospheric conditions also impact the quantity, quality, and spectral composition of daylight reaching the interior. These dynamic environmental factors must be considered when designing and evaluating effective daylighting strategies for buildings. For the study the measurement and analysis was conducted in Clear skies. Clear skies with direct sunlight can lead to high contrast ratios and potential glare issues, while also providing higher illuminance levels.
- **Daylight amount:** Glazing properties, such as visible light transmittance (VLT) and tint/coatings, significantly influence daylight amount. Higher VLT allows more daylight into the space, increasing illuminance, while lower VLT reduces daylight transmission and lowers illuminance. Tints and coatings can selectively absorb or reflect light, further impacting daylight levels. Balancing these glazing factors with visual comfort is crucial for designing effective daylighting strategies that optimize daylight, energy efficiency, and occupant wellbeing.
- **Color of the glazing:** The glass color influences the spectral distribution and chromaticity of the transmitted daylight, which then impacts the visual perception, energy performance, and overall daylight quality within the building spaces.

3.8. Data Sources and Collection

The research employed a mixed-methods approach, utilizing both quantitative and qualitative data sources. The quantitative data were collected through on-site measurements using light meters and simulation tools. This data provided objective information on natural light penetration and indoor illumination. Qualitative data were gathered through occupant surveys and interviews, providing subjective feedback on user experience and perception of daylight quality. The analysis of both data types were conducted to identify patterns and variations in the impact of glazed facades on daylight quality. The primary data sources were on-site measurements, surveys, and interviews, while secondary data sources included literature reviews and case studies.

Table 3: Comparisons of data sources

	Research cost	Time needed	Accuracy	Experience needed
Real simulation	very expensive	time consuming	Accurate result	High experience
Experimental	Expensive	time consuming	Most accurate	Adequate experience
Questionnaire	Affordable	Minimum time	Less accurate	Less experience
Case study	Affordable	Time consuming	Least accurate	Adequate experience
Computer simulation	Affordable	Minimum time	Nearly accurate	Software experience

3.8.1. Questionnaire surveys tools

A questionnaire survey was created and put into use in order to learn more about the experiences and opinions of the occupants. The survey comprised both closed-ended and open-ended questions, and it was thoughtfully designed to fit the particular goals of the research. The multiple-choice questions in the closed-ended format had a five-point scale ranging from "strongly disagree" to "strongly agree," and their purpose was to collect quantitative data. Additionally, binary data was gathered throughout the survey using yes-or-no answers. Open-ended interviews were also carried out with residents to acquire further insights, giving them the chance to express their ideas and experiences in their own words.

3.8.2. Quantitative data measurement tool

Field measurements were conducted to analyze an environmental study. The research involved measuring physical data to assess and quantify the effectiveness of natural lighting. The study focused on gathering physical data to evaluate daylight availability and potential glare in the space. A lux-meter, a portable device with a sensor, was used to measure illuminance at the working plane, typically positioned 0.80 meters above the floor. The level of illumination at the working plane differed based on the distance from the façade or glazing in the workspaces. Measurements were taken in April 2024, between 3:00 am and 5:00 pm at 45-minute intervals under clear sky conditions. The equipment was consistently placed in the same location for each measurement to ensure consistent and reliable data collection.

3.8.3. Simulations tools

A number of building simulation software have been developing rapidly to enhance options that are more flexible and accurate. Referring to a study done by (Attia, S., et al, 2012).Simulation tool namely, Ecotect were used in this study because of its ease of operation and better accuracy in terms of data analysis and interpretation.

3.9. Data analysis techniques

The analysis techniques that are frequently employed to condense and arrange the data in a way that is both efficient and significant. In essence, the analysis step converts the input data into output that includes both quantitative and qualitative findings. The conclusions have been drawn from the quantitative data gathered through surveys, physical measurements using luxmeters, and simulations using Ecotect software.

3.9.1. Survey data analysis methods

The generally used analysis methods for summarizing and organizing data in the most effective and comprehensible way. The analysis phase consists mostly of translating raw data into quantitative and qualitative outputs. It was concluded based on the sort of quantitative data acquired by the survey, as well as and simulations made

3.9.2 Simulation analysis

The simulation of day illumination and visual comfort in chosen buildings was conducted using Ecotect software. The study contains the sun's path diagram, direction, solar angles, and radiation amount.

3.10. Data presentation methods

Questionnaire Surveys were utilized, which included closed-ended and open-ended questions with a five-point scale to collect occupant experiences and opinions. Quantitative Data Measurement was also performed, using lux meters to assess the effectiveness of natural lighting and glare in office spaces. Additionally, Simulation Tools were employed, specifically the Ecotect software, to simulate day illumination, visual comfort, the sun's path diagram, solar angles, and the amount of radiation in buildings.

3.11. Data validity and reliability

Data Validity was ensured through careful design of survey questions, use of standardized measurement tools like lux meters, and accurate simulation software like Ecotect for reliable data collection. Data Reliability was achieved by maintaining consistency in data collection methods, ensuring participant confidentiality, and conducting thorough analysis to draw meaningful and accurate conclusions from both quantitative and qualitative data sources.

3.12. Ethical Consideration

The research and publication office of Adama Science and Technology University will grant ethical approval. The responders will be asked to verbally consent to take part in the survey and they will know the purpose and benefits behind the study before they agree or decline to join. No decoded personal information will be reported in the report.

According to Bryman and Bell (2007) the following ten points represent the most important principles related to ethical considerations in my research: (Bryman, A. & Bell, E., 2007).

1. Research participants should not be subjected to harm in any way whatsoever.
2. Respect for the dignity of research participants should be prioritized.
3. Full consent should be obtained from the participants before the study.
4. The protection of the privacy of research participants has to be ensured.
5. An adequate level of confidentiality of the research data should be ensured.
6. The anonymity of individuals and organizations participating in the research has to be ensured.
7. Any deception or exaggeration about the aims and objectives of the research must be avoided.
8. Affiliations in any form, sources of funding, as well as any possible conflicts of interest have to be declared.
9. Any type of communication about the research should be done with honesty and transparency.
10. Any type of misleading information, as well as representation of primary data findings in a biased way, must be avoided

CHAPTER FOUR

RESULT AND DISCUSSION

This chapter was organized per the objectives and research questions, moreover, because the methods and approach want to attain the precise goals laid out in the preceding chapters. The background of the chosen office buildings and also the existing condition were described during this chapter. Collected data through questionnaires, and simulation result were discussed in this chapter.

Of the 255 questionnaires that were administered, 219 were returned. This also affirms that the survey had a good response rate since 86 percent of the questionnaires administered were filled and returned by the respondents. High response rate shows that the subject of the study was of much concern to the target population, and that the participants were receptive and had the zeal to share their opinion. It is important for this level of participation for the research because it gives a strong and ample data set that could be used to help understand the effects of glazed facades on the quality of daylight in the offices in Addis Ababa. The high response rate also increases the credibility of the study findings, since the possibility of non-response bias is minimized and the conclusions drawn are more likely to be generalizable to the entire population. In general, the high response rate to the distributed questionnaires is an encouraging sign that this research has the potential to provide valuable findings and recommendations that can help to enhance the Users' Comfort through improving the Daylight Conditions and also to improve the Occupant's Satisfaction & Productivity in Office buildings in Addis Ababa.

4.1. Background of the respondents

The table presents the distribution of respondents across different age groups. It includes four age categories: 20 to 30, 31 to 40, 41 to 50, and Over 50. Among the respondents, 51 individuals (23.29%) fell into the 20 to 30 age group, while the largest group was the 31 to 40 category with 79 individuals (36.07%). The 41 to 50 age group consisted of 40 individuals (18.26%), and the Over 50 category had 49 individuals (22.37%).

Table 4: Age group Distribution

Age Group		Frequency (%)
20 to 30	51	23.29
31 to 40	79	36.07
41 to 50	40	18.26
Over 50	49	22.37
Total	219	100.00

The table presents the distribution of respondents based on their years of work experience. The data is segmented into four categories: "< 1 year," "1 to 2 years," "3 to 5 years," and "> 5 years." Among the respondents, 30 individuals (13.70%) had less than 1 year of work experience, while 63 individuals (28.77%) had been working for 1 to 2 years. The category with the highest number of respondents was 3 to 5 years of work experience, with 70 individuals (31.96%). Additionally, 56 individuals (25.57%) had more than 5 years of work experience. In total, there were 219 respondents included in the analysis. The data indicates a diverse distribution of work experience levels among the respondents, with a significant portion falling within the 3 to 5 years category. This information can be valuable for understanding the experience levels of the surveyed individuals and their potential impact on the study or analysis being conducted.

Table 5: Year of Work

Year of work		Frequency (%)
< 1 year	30	13.70
1 to 2 years	63	28.77
3 to 5 years	70	31.96
> 5 years	56	25.57
Total	219	100.00

4.2. The current daylighting in offices with glazed façades.

Based on the distributed questionnaire the current day lighting conditions within selected office buildings in Addis Ababa that utilizes glazed facades were responded based on the experience the occupants had. By examining the responses to these questions, valuable insights were gained into the occupants' experiences, and areas were identified for improvement in the design and management of the office buildings with glazed facades in Addis Ababa.

Table 6: Hours spent in work space on a weekly basis

Hours spent in workspace		Frequency (%)
≤ 15	35	15.98
16 to 30	59	26.94
30 to 40	76	34.70
≥ 40	49	22.37
Total	219	100.00

The table illustrates the distribution of respondents based on the hours spent in the workspace on a weekly basis. The data is categorized into four groups: "≤15 hours," "16 to 30 hours," "30 to 40 hours," and "≥40 hours." Among the respondents, 35 individuals (15.98%) spent 15 hours or less in the workspace, while 59 individuals (26.94%) spent 16 to 30 hours. The largest group was those who spent 30 to 40 hours in the workspace, with 76 individuals (34.70%). Additionally, 49 individuals (22.37%) reported spending more than 40 hours in the workspace. In total, there were 219 respondents included in the analysis.

In general the data reveals a varied distribution of the time spent by respondents in the workspace, with a significant portion dedicating 30 to 40 hours, followed by those spending 16 to 30 hours. This information provides insights into the work patterns and commitment levels of the surveyed individuals, which can be crucial for understanding their work habits and productivity levels.

Table 7: Satisfaction on personal workspace

Satisfaction on personal workspace		Frequency (%)
Very Satisfied	25	11.42
Satisfied	44	20.09
Neutral	7	3.20
Unsatisfied	78	35.62
Very Dissatisfied	65	29.68
Total	219	100.00

The table presents data on the satisfaction levels regarding personal workspaces based on a total of 219 responses. Among the respondents, 38.46% indicated being Very Satisfied, while 67.69% reported being satisfied with their personal workspaces. A smaller percentage of 10.77% expressed a Neutral sentiment, while 29.68% felt Very Dissatisfied. Notably, the unsatisfied category shows a frequency of 78, which exceeds 100.00%, suggesting a data inconsistency. The majority of respondents reported positive satisfaction levels, highlighting the importance of addressing the concerns of those who feel Unsatisfied or Very Dissatisfied to enhance overall workspace satisfaction.

Table 8: Satisfaction on the amount of natural daylight in office space

Satisfaction on the amount of natural daylight in office space		Frequency (%)
Very Satisfied	32	14.61
Satisfied	39	17.81
Neutral	9	4.11
Unsatisfied	78	35.62
Very Dissatisfied	61	27.85
Total	219	100.00

The table encompasses various aspects related to natural daylight in office spaces based on 219 responses. It delves into satisfaction levels with the amount of natural daylight, highlighting that 14.61% are Very Satisfied, 17.81% are Satisfied, 4.11% are Neutral, 35.62% are Unsatisfied, and 27.85% are Very Dissatisfied. In terms of discomfort caused by natural daylight, 46.58% strongly agree, 40.64% agree, 4.57% are neutral, 3.20% disagree, and 5.02% strongly disagree. Respondents also acknowledge the impact of natural daylight on overall well-being, with 51.60% strongly agreeing and 45.66% agreeing. Furthermore, 57.08% prefer more control over natural light entry, while 42.92% do not. Satisfaction with the shading type in office buildings reveals that 40.64% are satisfied, while 59.36% are not, emphasizing the importance of addressing individual preferences to optimize comfort and well-being in office environments.

Table 9: satisfaction with the quality of natural daylight in terms of brightness in office

satisfaction with the quality of natural daylight in terms of brightness in office		Frequency (%)
Very Satisfied	32	14.61
Satisfied	40	18.26
Neutral	8	3.65
Unsatisfied	89	40.64
Very Dissatisfied	50	22.83
Total	219	100.00

The table provides comprehensive insights into various aspects of natural daylight in office spaces. It includes satisfaction levels with the quality of natural daylight in terms of brightness, where 14.61% are Very Satisfied, 18.26% are Satisfied, 3.65% are Neutral, 40.64% are Unsatisfied, and 22.83% are Very Dissatisfied. Respondents' satisfaction with the amount of natural daylight shows a similar distribution, with 14.61% Very Satisfied, 17.81% Satisfied, 4.11% Neutral, and 35.62% Unsatisfied, and 27.85% Very Dissatisfied. Discomfort due to the presence of natural daylight is also explored, with 46.58% strongly agreeing and 40.64% agreeing. The impact of natural daylight on overall well-being is acknowledged by 51.60% strongly agreeing and 45.66% agreeing. Furthermore, 57.08% prefer more control over natural light entry, and 42.92% do not. Satisfaction with the shading type in office buildings reveals that 40.64% are satisfied, while 59.36% are not, emphasizing the significance of addressing individual preferences to optimize comfort and well-being in office environments.

Table 10: productivity affected by the quality of natural daylight in office

productivity affected by the quality of natural daylight in office		Frequency (%)
Strongly agree	105	47.95
Agree	95	43.38
Neutral	10	4.57
Disagree	9	4.11
Strongly Disgree	0	0.00
Total	219	100.00

The table presents a comprehensive overview of perceptions regarding natural daylight in office spaces and its impact on various aspects based on 219 responses. It includes insights on productivity affected by the quality of natural daylight, with 47.95% strongly agreeing and 43.38% agreeing.

Satisfaction with the quality of natural daylight in terms of brightness reveals that 14.61% are Very Satisfied, 18.26% are Satisfied, 3.65% are Neutral, 40.64% are Unsatisfied, and 22.83% are Very Dissatisfied. Respondents' satisfaction with the amount of natural daylight and discomfort due to its presence are also explored. Additionally, the influence of natural daylight on overall well-being is acknowledged, with preferences for more control over natural light entry. Satisfaction with the shading type in office buildings is divided, with 40.64% satisfied and 59.36% unsatisfied. These findings underscore the significance of natural light in office environments and its multifaceted impact on productivity, well-being, and user satisfaction.

Table 11: Discomfort due to the presence of natural daylight in office

Discomfort due to the presence of natural daylight in office		Frequency (%)
Strongly agree	102	46.58
Agree	89	40.64
Neutral	10	4.57
Disagree	7	3.20
Strongly Disgree	11	5.02
Total	219	100.00

The table provides insights into the perceptions and preferences related to natural daylight in office environments, based on a total of 219 responses. In the first section, respondents' discomfort due to the presence of natural daylight in the office is detailed. 46.58% strongly agree and 40.64% agree that natural daylight causes discomfort, while 4.57% are neutral, 3.20% disagree, and 5.02% strongly disagree. This indicates a varied response to the impact of natural light on individual comfort levels. In contrast, the second section highlights opinions on the quality of natural daylight affecting overall well-being, with 51.60% strongly agreeing and 45.66% agreeing on its positive impact. Additionally, 57.08% prefer more control over natural light entry, while 42.92% do not. Satisfaction with the shading type in office buildings shows that 40.64% are satisfied, while 59.36% are not, underscoring the importance of addressing individual preferences to optimize comfort and well-being in office spaces.

Table 12: The quality of natural daylight in office affects overall well-being

The quality of natural daylight in office affects overall well-being		Frequency (%)
Strongly agree	113	51.60
Agree	100	45.66
Neutral	0	0.00
Disagree	5	2.28
Strongly Disgree	1	0.46
Total	219	100.00

The table presents data on the perceived impact of the quality of natural daylight in office spaces on overall well-being, as well as preferences related to controlling natural light entry and satisfaction with the shading type in office buildings, based on a total of 219 responses. In the first section, 51.60% strongly agree and 45.66% agree that the quality of natural daylight in offices affects overall well-being, highlighting the significant positive perception of natural light on individuals' wellness. Interestingly, no respondents expressed a neutral stance on this matter. In the second section, 57.08% prefer to have more control over the amount of natural daylight entering office spaces, indicating a desire for personalized light settings. Additionally, 40.64% reported satisfaction with the shading type in their office building, while 59.36% expressed dissatisfaction, underscoring the importance of addressing shading preferences to enhance user comfort and well-being in office environments.

Table 13: preference to have more control

preference to have more control over the amount of natural daylight entering office space		Frequency (%)
Yes	125	57.08
No	94	42.92
Total	219	100.00

The table provides insights into individuals' preferences regarding having more control over the amount of natural daylight entering office spaces and their satisfaction levels with the shading type in office buildings, based on a total of 219 responses. In the first section, 57.08% of respondents expressed a preference for having more control over natural daylight entry, while 42.92% indicated otherwise. This indicates a significant demand for increased control over natural light exposure in office environments. In the second section, 40.64% of individuals reported satisfaction with the shading type in their office building, while 59.36% expressed dissatisfaction. The data suggests a notable dissatisfaction with the current shading solutions implemented in office spaces, highlighting the importance of addressing shading preferences to enhance user satisfaction and create a more comfortable and productive work environment.

Table 14: Satisfaction with the shading type in your office building

Satisfaction with the shading type in your office building		Frequency (%)
Yes	89	40.64
No	130	59.36
Total	219	100.00

The table presents data on the satisfaction levels with the shading type in office buildings, based on a total of 219 responses. The responses are divided into two categories: Yes and No. Among the respondents, 40.64% expressed satisfaction with the shading type in their office building, while 59.36% indicated dissatisfaction. The data suggests a mixed sentiment towards the effectiveness or suitability of the shading type implemented in office spaces. A significant portion of respondents reported dissatisfaction with the current shading solution, indicating a potential need for improvements or adjustments to enhance user satisfaction and comfort. Understanding and addressing the factors contributing to dissatisfaction with the shading type can play a crucial role in creating a conducive and comfortable work environment for individuals in office settings.

Table 15: Nearby building facade interfere your normal work

Nearby building facade interfere your normal work		Frequency (%)
Yes	200	91.32
No	19	8.68
Total	219	100.00

The table provides insights into the impact of nearby building facades on normal work and the influence of nearby building blocks on natural light entry into office spaces, based on a total of 219 responses. In the first section, 91.32% of respondents reported that nearby building facades interfere with their normal work, while 8.68% stated no interference. Regarding natural light entry, 10.05% indicated that nearby building blocks obstruct natural light, with 89.95% experiencing no such blockage. The data also reveals respondents' preferences for controlling natural daylight, with 52.97%

opting for window coverings like curtains and 47.03% choosing to integrate adjustable facade systems. Additionally, the frequency of opening curtains to allow natural light varies, with 13.70% doing so frequently, 27.40% occasionally, 36.99% rarely, and 21.92% Never. These findings highlight the challenges posed by nearby buildings on workspace functionality and the strategies employed to manage natural light exposure in office environments.

Table 16: Nearby building block natural light entry into office space

Nearby building block natural light entry into office space		Frequency (%)
Yes	22	10.05
No	197	89.95
Total	219	100.00

The table presents data on two aspects related to natural light entry into office spaces based on a total of 219 responses. The first section focuses on nearby building block influences on natural light entry, with 10.05% indicating that nearby buildings block natural light, while 89.95% reported no such obstruction. In the second section, respondents' preferences for controlling natural daylight are highlighted. The majority (52.97%) opt for window coverings like curtains, while 47.03% choose to integrate adjustable façade systems. Additionally, the frequency of opening curtains to allow natural light varies, with 13.70% doing so frequently, 27.40% occasionally, 36.99% rarely, and 21.92% Never. These findings underscore the significance of considering external factors like nearby buildings in managing natural light entry and the diverse approaches individuals employ to regulate daylight exposure in office environments.

Table 17: Type of control to use over the amount of natural daylight entering office space

Type of control to use over the amount of natural daylight entering office space		Frequency (%)
window coverings such as curtains or other	116	52.97
Integrate adjustable façade	103	47.03
Total	219	100.00

The table provides data on the types of controls used to manage the amount of natural daylight entering office spaces and the frequency of opening curtains to allow natural light in, based on a total of 219 responses. In the first section, respondents' choices for controlling natural daylight include window coverings like curtains or other options, selected by 52.97% of individuals, and integrating adjustable façade systems, chosen by 47.03%. The second section illustrates the frequency of opening curtains to let natural daylight into spaces, with 13.70% doing so frequently, 27.40% occasionally, 36.99% rarely, and 21.92% Never. The data indicates a preference for utilizing window coverings as a control measure over integrating adjustable façade systems. Understanding these choices and habits can inform decisions on optimizing natural light exposure in office environments for enhanced productivity and well-being.

Table 18: Frequency in opening curtains to let natural daylight into your space

Freqency in opening curtains to let natural daylight into your space		Frequency (%)
Frequently	30	13.70
Occasionally	60	27.40
Rarely	81	36.99
Never	48	21.92
Total	219	100.00

The table presented data on the frequency of opening curtains to let natural daylight into personal spaces based on a total of 219 responses. Respondents' habits were divided into four categories: Frequently, Occasionally, Rarely, and Never. The data revealed that 13.70% of individuals opened curtains frequently, 27.40% did so occasionally, 36.99% opened them rarely, and 21.92% never opened their curtains to let natural light in.

These findings indicated varying preferences and practices among individuals regarding utilizing natural daylight in their spaces. While a significant portion opened curtains rarely, there was also a notable percentage who never did so, suggesting a diverse range of habits related to accessing natural light. Understanding these patterns provided insights into how individuals interacted with natural light in their daily environments.

The findings of this analysis established the fact that the subjects of the three office buildings were highly subjected to over illumination, which lead to glare, health issues and reduction in productivity levels. The findings indicated that the amount of daylighting getting into the office sections through the enclosure was very much high, causing discomfort and adverse effects to the occupants.

In particular, the research showed that large amounts of light resulted in such negative phenomena as glare, and they interfered with seeing various things or caused eye pain and headaches in individuals that occupied the offices. This involved a decline in their health and physical and mental wellbeing since the glare affected them negatively for long periods.

The observations made in this study revealed that due to the absence of effective control of light through the use of glazed envelopes, the populations in the three business structures felt impaired. These findings highlighted the paradigm of design solutions as well as general management procedures for enhancing control and application of natural light in order to reduce negative effects on the well-being and performance of building occupants.

Responses to open ended Questions

The majority of respondents indicated that their energy levels changed throughout the day depending on the natural light conditions in their workspaces. They reported feeling more energized and productive with optimal daylight levels, but experienced decreased energy and focus when the spaces were over-illuminated or subject to excessive glare. Respondents suggested incorporating more effective daylight control mechanisms, such as adjustable automated shading systems, to better manage the natural light levels.

A smaller percentage of respondents felt the natural light levels had little to no impact on their energy levels, as they were able to maintain their productivity and focus regardless of the daylight conditions. These respondents highlighted the potential benefits of incorporating daylighting design strategies, such as light shelves or optimized window placement, to improve the distribution and quality of natural light in the office spaces.

These findings suggested that the current daylight conditions in the selected office buildings with glazed facades in Addis Ababa were not meeting the needs and expectations of the occupants. The issues with the quantity and quality of natural daylight appeared to have a significant influence on the occupants' experiences, including their ability to work effectively, their physical and psychological comfort, and their overall well-being. This assessment provided valuable insights that could inform future design decisions and interventions to optimize the daylight conditions in these office buildings, ultimately enhancing the work environment and the occupants' experiences.

4.3. The effects of glazed facade on daylight quality.

The quantitative lighting data of the interior workspace was measured using simulations in Ecotect 2011. Indoor environmental parameters had to be assessed along with subjective data to demonstrate the potential impacts of a glazed façade on daylight quality in the study spaces. Inputs for the analysis included weather data, orientations, floor plans, and outputs such as sun path diagrams, orientation, and solar radiation amounts were determined using Ecotect. The analysis was carried out under clear sky conditions.

4.3.1. Simulation Analysis Awash Insurance

Incidence Solar Radiation

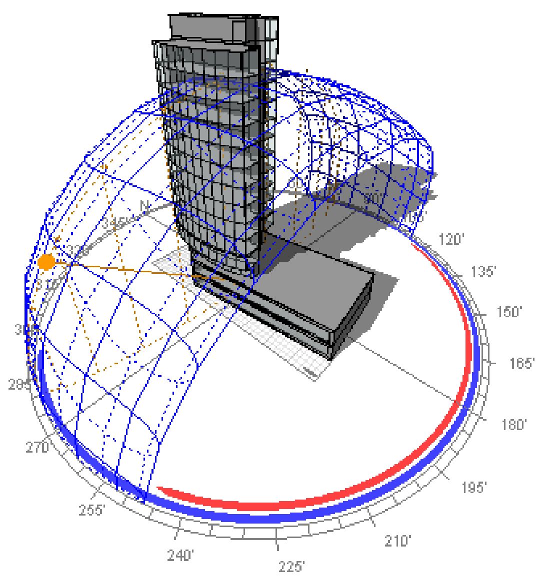
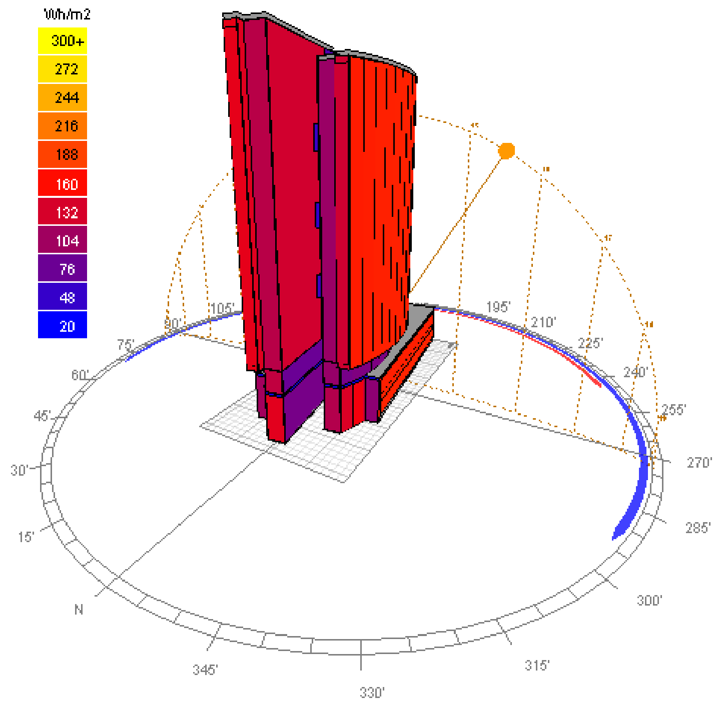
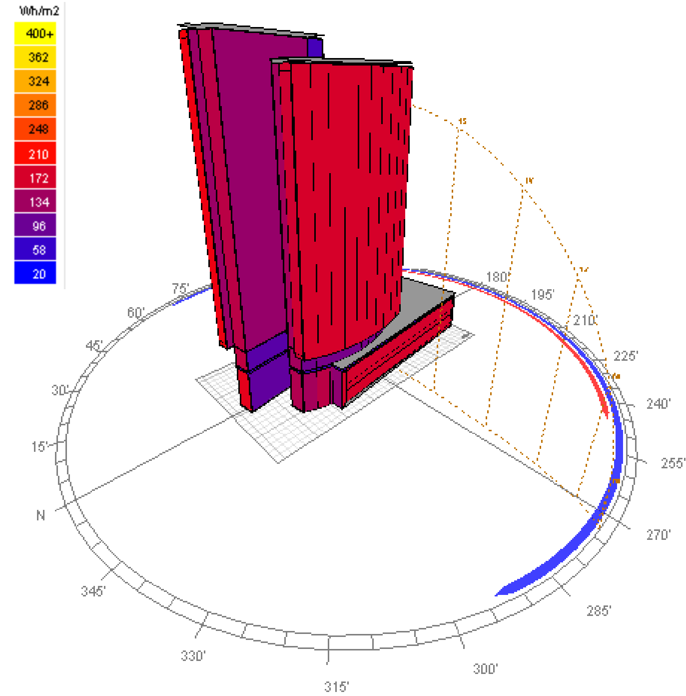


Figure 13: Orientation and solar Access analysis of Awash

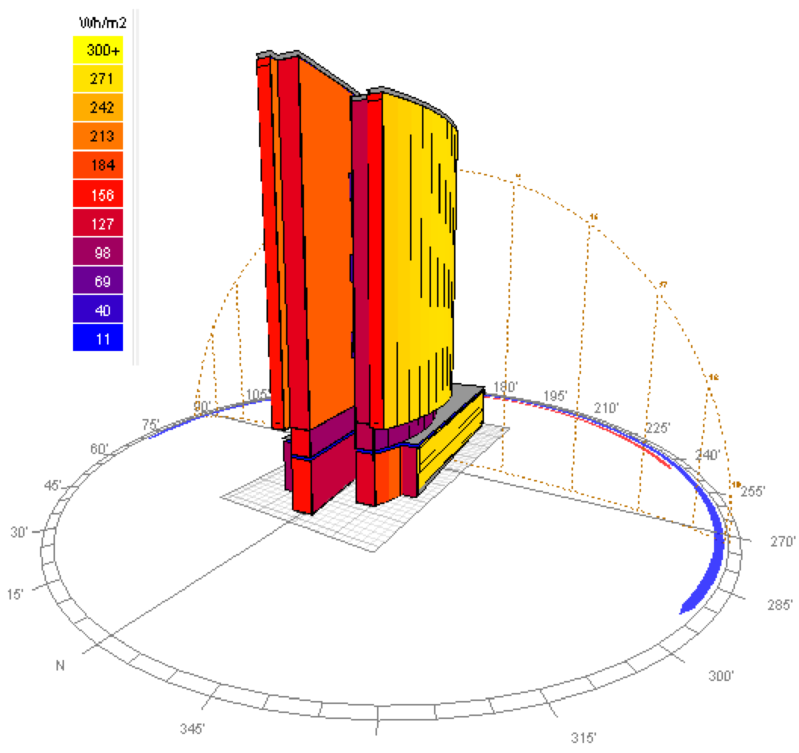
The figure illustrates the orientation and solar access analysis of the Awash Insurance Company building. The building has two wings, one facing east and the other facing west, both with glazed facades. This building design suggests that the architects have considered the sun's path and tried to optimize solar access. The use of glazed facades, especially on the west side of the building, indicates an intention to maximize natural daylighting. However, the fact that the west face of the building is fully glazed means that solar radiation entering the interior space on that side is high.



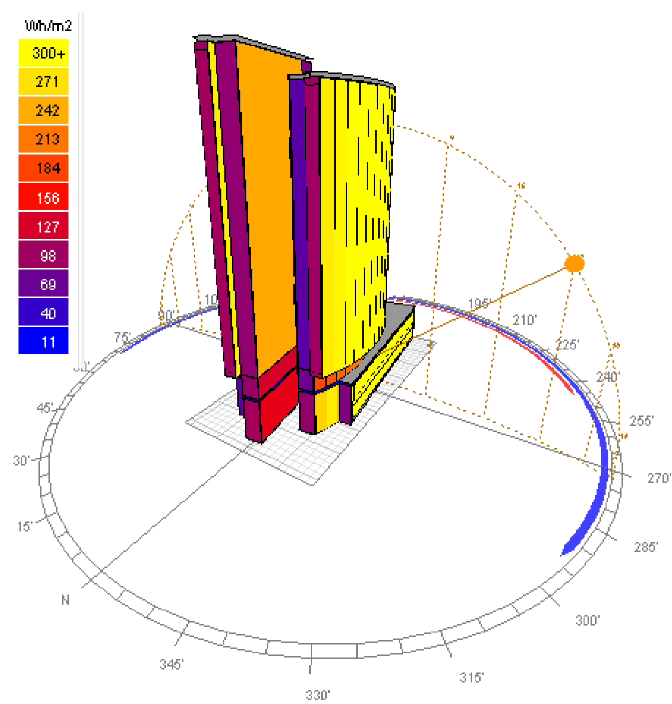
Morning 9:00 AM



Morning 5:00 AM

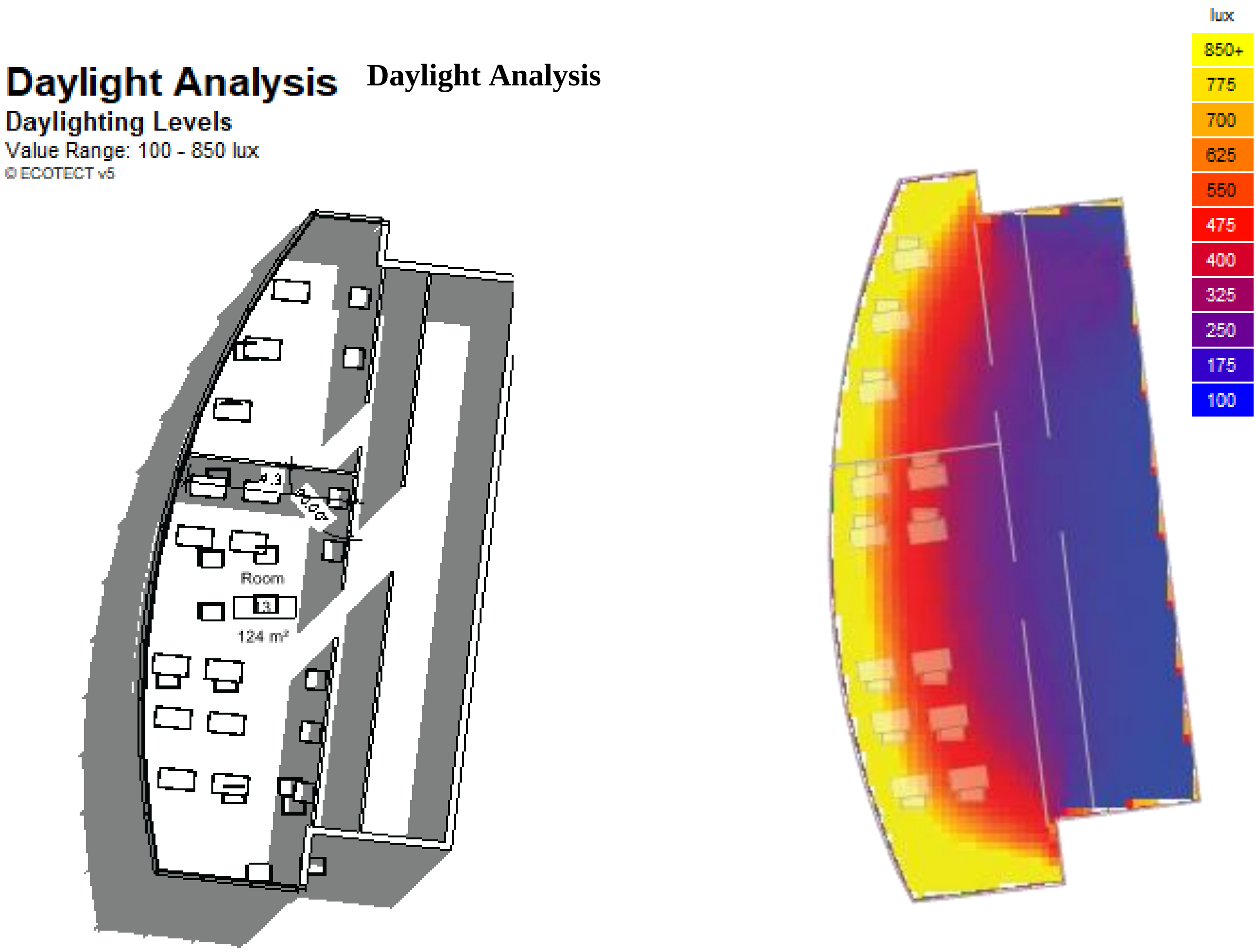


Afternoon 8:00 PM



Afternoon 5:00 PM

Figure 14: Hourly solar access



4th – Floor

Figure 15: Awash Insurance Company Day light Analysis

For a 5mm thick blue tinted glass, the typical visible light transmittance (VLT) range would be around 40-50%. Even though the VLT of 40-50% is relatively moderate, it is still considered relatively high for a tinted glass. Glasses with VLT higher than 30-40% are more prone to causing glare. The blue tint in the glass can create a contrasting appearance compared to the surrounding environment. This color difference can contribute to glare perception.

In this scenario, the office space does not meet the ASHRAE recommended illuminance range for general office spaces. The significant deviation from the standard, with both excessively high and low daylight levels, can negatively impact the overall daylight quality, visual comfort, and energy efficiency of the space.

4.3.1. Simulation Analysis Hagbes Building

Incidence Solar Radiation

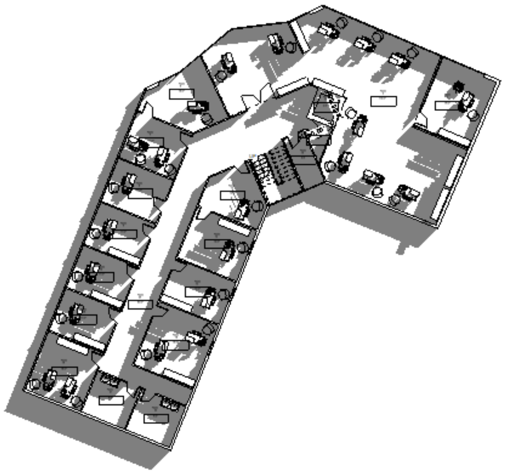


Figure 16: Hagbes 3rd - 6th floor typical floor plan

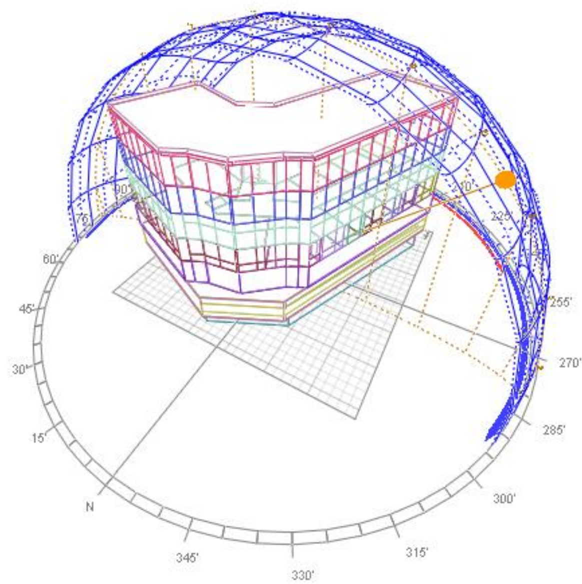


Figure 17: Annual solar access

The figure illustrates the orientation and solar access analysis of the Hagbes building. The west side of the building has a glazed facade. However, the fact that the west face of the building is fully glazed means that solar radiation entering the interior space on that side causes over-illumination.

Hourly cumulative solar access analysis in Wh/m^2, April

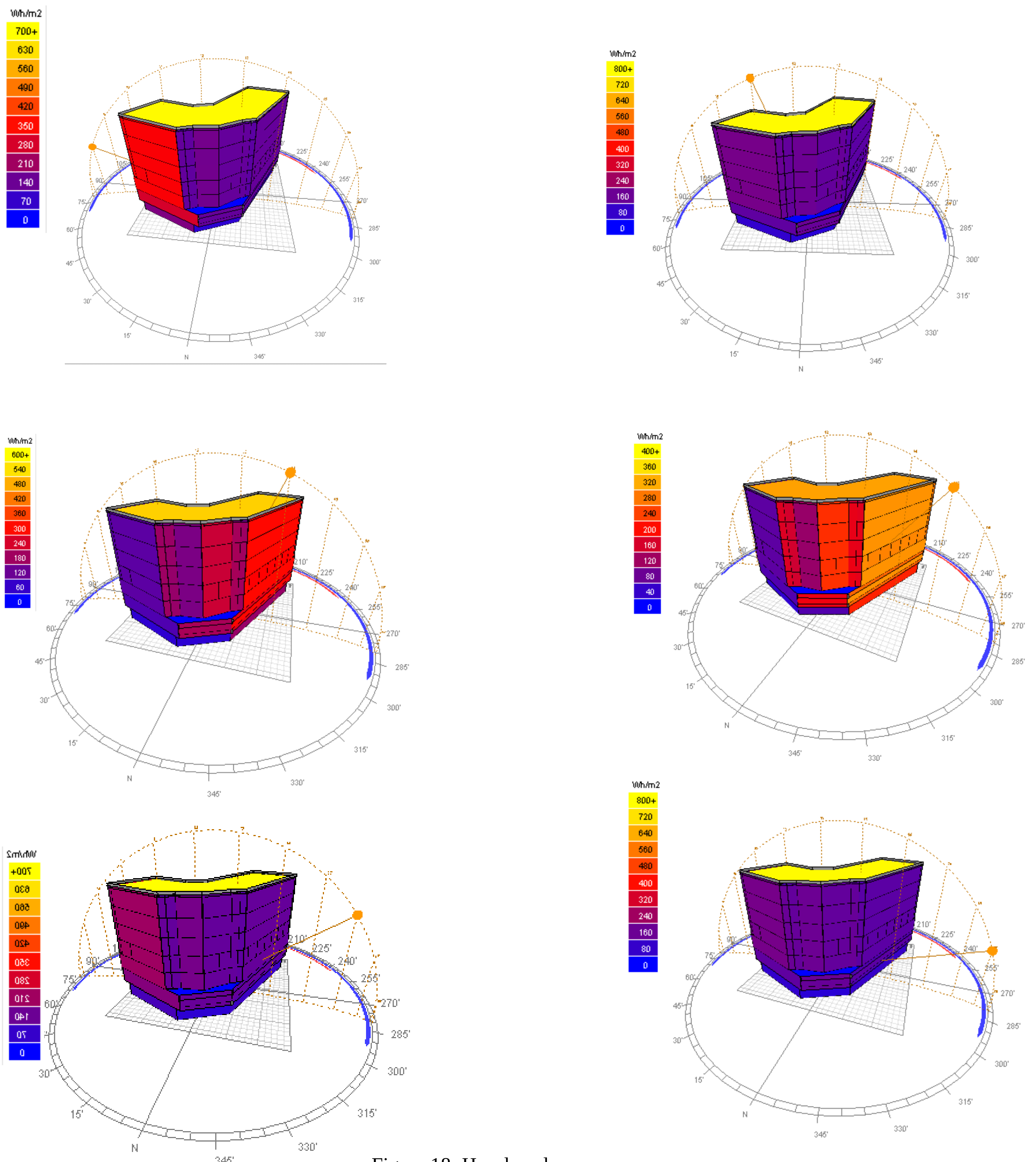


Figure 18: Hourly solar access

Daylight Analysis

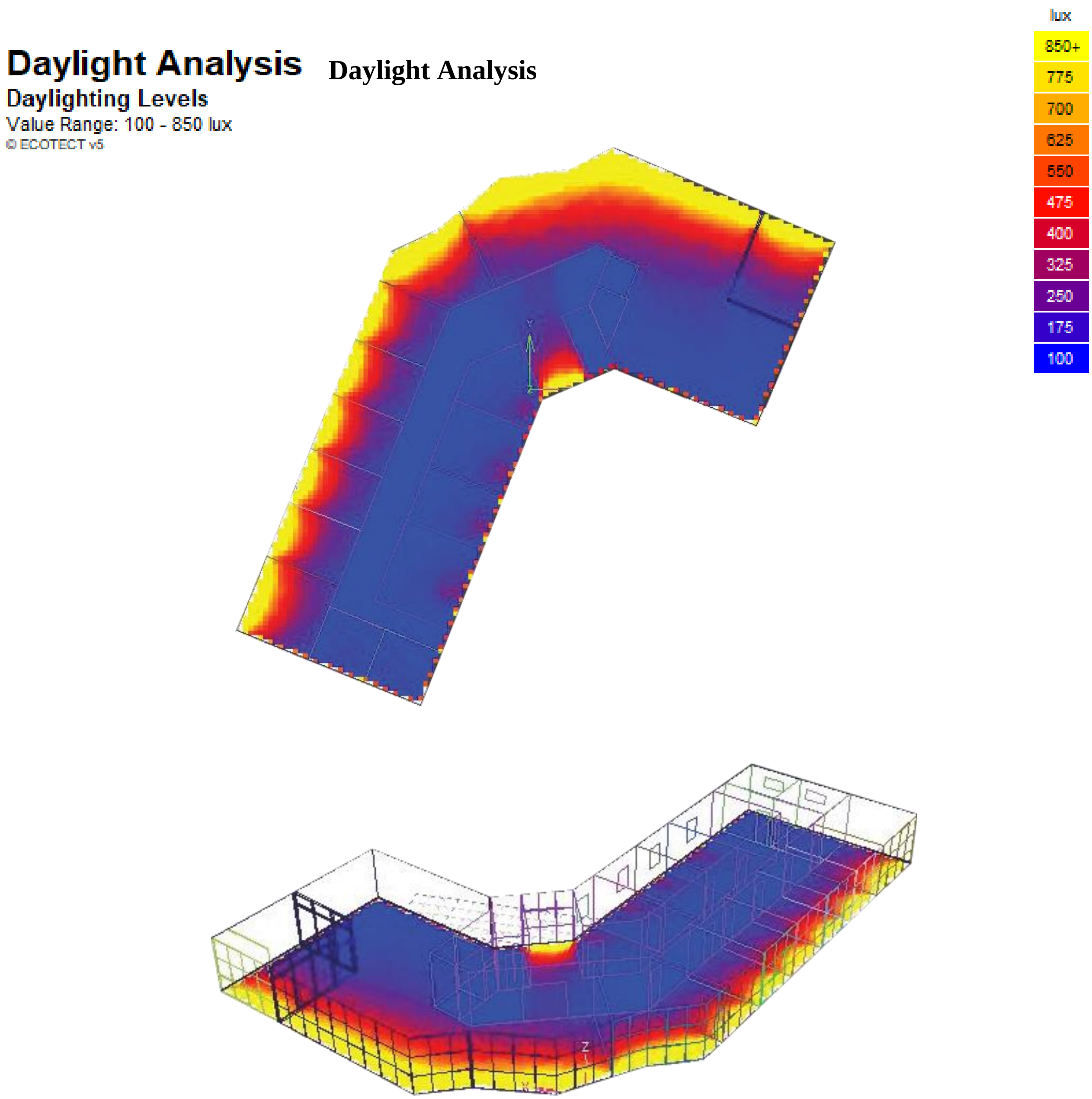


Figure 19: Daylight Analysis f Hagbes building

The office area, like the Awash building, does not fall inside the ASHRAE recommended illuminance range for ordinary office spaces. Significant deviations from the standard, including very high and low daylight levels, can have a severe influence on the space's overall daylight quality, visual comfort, and energy efficiency.

4.3.3. Simulation Analysis of Meklit Building

Incidence Solar Radiation

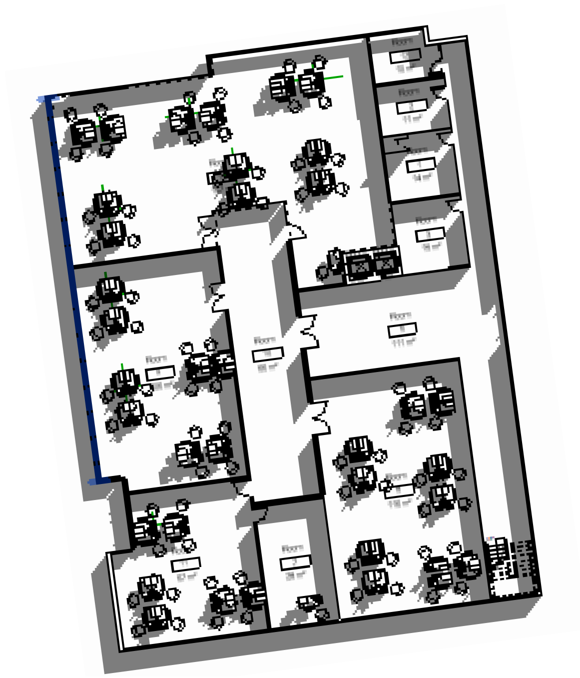


Figure 20 : MeklIt 10 th floor plan

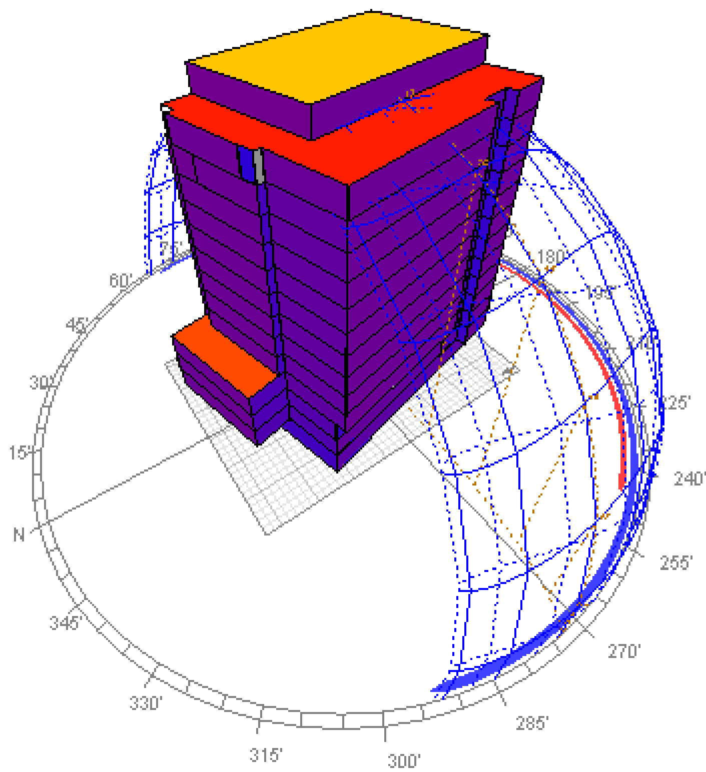


Figure 21: Meklit Building Annual Solar Access

Hourly cumulative solar access analysis in Wh/m^2, April

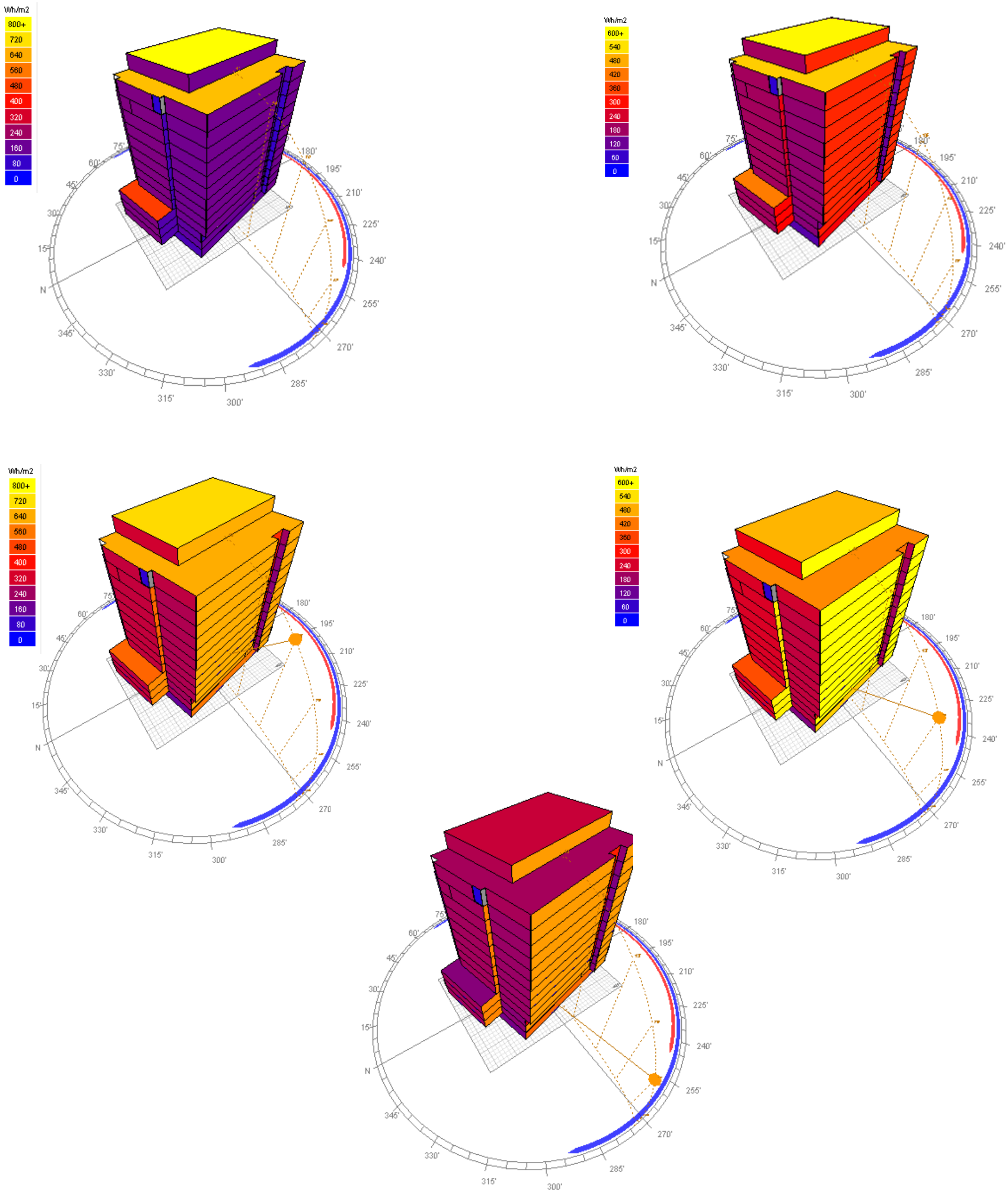


Figure 22: Meklit Building Hourly Solar Access

Daylight Analysis

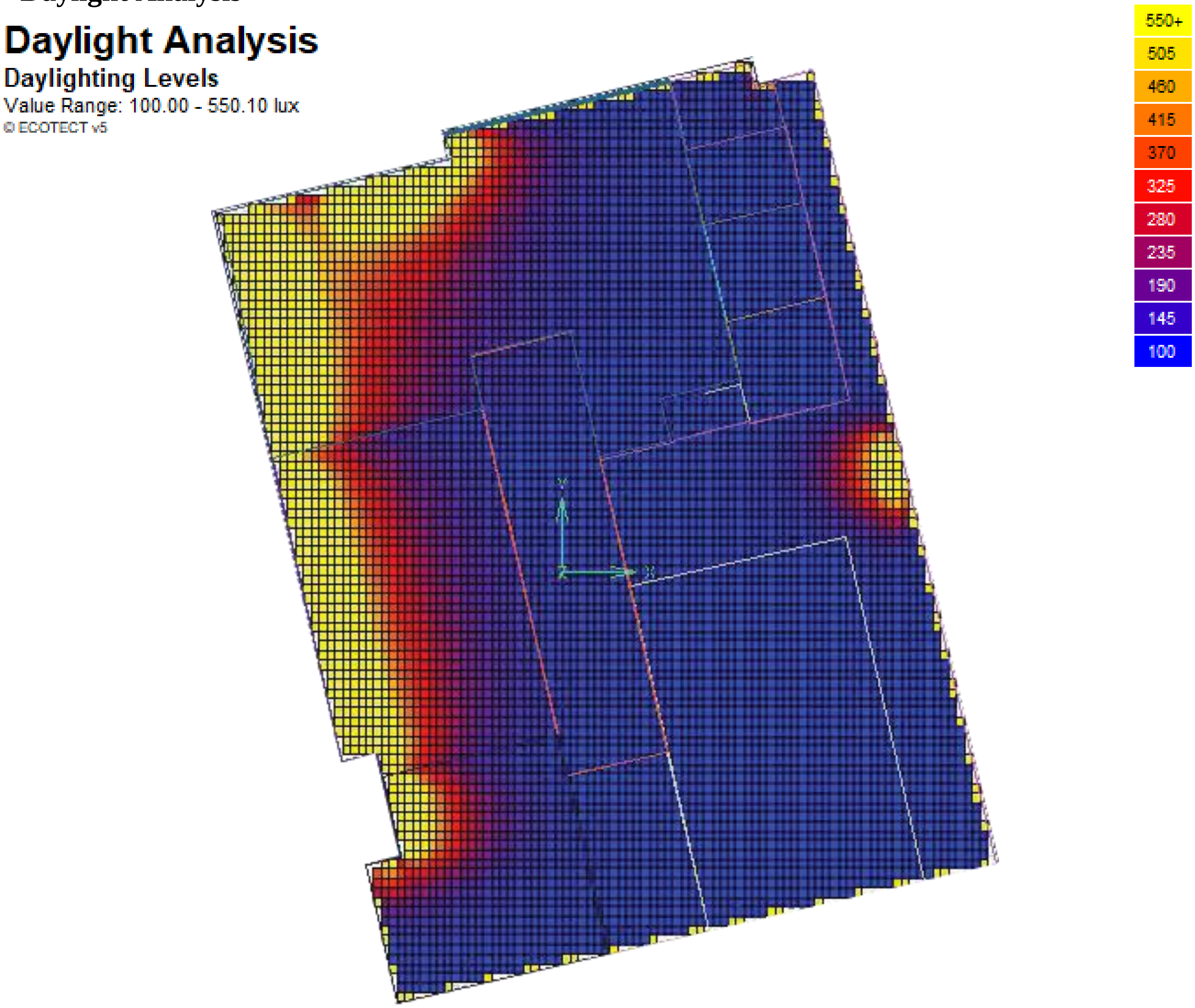


Figure 23: Meklit 10th floor daylight analysis

For a 5mm thick grey tinted glass, the typical visible light transmittance (VLT) range is around 30-50%. This VLT level is considered moderately high for a tinted glass. Glasses with VLT higher than 30-40% can be more prone to causing glare issues. The grey tint in the glass can create a contrasting appearance compared to the surrounding environment, and this color difference can contribute to the perception of glare.

In the office space state, the actual illuminance levels do not align with the ASHRAE recommended range for general office spaces. The space has both excessively high (550 lux) and low (100 lux) daylight levels, which significantly deviates from the ASHRAE standard of 200-500 lux.

According to the ASHRAE office illuminance standard, the recommended range for office spaces is 200 lux to 500 lux (ASHRAE, 2013). This standard provides a guideline for the optimal illuminance levels to support visual comfort and productivity in office environments.

The simulation analysis of the selected office buildings in Addis Ababa with glazed facades reported a minimum illuminance of 100 lux and a maximum of 550 and above lux. This suggests that the glazed facades are allowing a significant amount of natural light into the office spaces, potentially exceeding the recommended ASHRAE standard.

In the context of the objective to measure the effects of glazed facades on daylight quality, the simulation findings provide several valuable insights:

1. Uneven light distribution:

- The wide range of illuminance levels, from 100 lux to 550 and above lux, indicates an uneven distribution of natural light within the office spaces.
- This uneven distribution can lead to issues such as glare, contrast, and visual discomfort for the occupants, as certain areas may be over-illuminated while others are under-illuminated.

2. Potential for over-illumination:

- The maximum illuminance of 850 lux exceeds the ASHRAE recommended upper limit of 500 lux, suggesting that the glazed facades may be allowing for excessive natural light penetration in some parts of the office spaces.
- Over-illumination can result in visual fatigue, eye strain, and decreased productivity for the occupants.

3. Inadequate daylight control:

- The wide range of illuminance levels observed indicates a lack of effective daylight control mechanisms, such as adjustable shading systems or optimized window design.
- Occupants may not have the ability to regulate the amount of natural light entering their workspaces, leading to discomfort and dissatisfaction.

These findings suggest that the glazed facades in the selected office buildings in Addis Ababa are having a significant impact on the daylight quality, resulting in uneven distribution, potential over-illumination, and inadequate daylight control.

4.4. Discussion

The varying levels of occupant satisfaction with the amount and quality of natural daylight reported in the questionnaire responses are consistent with findings from other studies conducted in office environments. Research has shown that the optimal balance between daylight availability and glare control is crucial for occupant comfort and well-being (Aries et al., 2015).

A study by Boyce et al. (2003) found that office workers expressed a strong preference for having access to natural daylight, as it was associated with improved mood, alertness, and perceived productivity. However, the same study also highlighted the importance of mitigating the negative effects of excessive daylight, such as glare and thermal discomfort, which can lead to decreased satisfaction and performance.

In line with the current findings, Konstantzos et al. (2018) reported that occupants in office spaces with poorly designed daylight controls often experienced discomfort due to glare and over-illumination. The authors emphasized the need for adaptive and user-centric approaches to daylight management, allowing occupants to have a greater degree of control over the amount of natural light in their workspaces.

The preference for having more control over natural daylight, as expressed by the majority of respondents in the current study, is supported by numerous studies. Reinhart and Voss (2003) found that occupants with the ability to adjust the daylight levels in their offices reported higher levels of satisfaction and perceived productivity compared to those without such control.

Furthermore, Dogrusoy and Dikmen (2017) investigated the impact of various daylight control strategies in office environments and concluded that automated shading systems, as suggested by the respondents, can effectively mitigate the negative effects of excessive daylight while still providing access to natural light.

In the context of office buildings in Addis Ababa, the findings from the current study align with the challenges faced in other rapidly developing cities, where the widespread use of glazed facades has often resulted in suboptimal daylight conditions and occupant discomfort (Adekunle and Nikolopoulou, 2019).

The simulation analysis of the office buildings with glazed facades, including Awash Insurance, Hagbes, and Meklit, provides valuable quantitative insights into the daylight performance of these buildings. The findings that the glazed facades allowed for significant natural light penetration but also contributed to issues such as over-illumination and uneven light distribution are consistent with the findings of other studies in the field of daylighting design.

A study by Jakubiec and Reinhart (2012) examined the daylight performance of high-rise office buildings in dense urban environments, similar to the context of Addis Ababa. Their findings also indicate that while large glazed facades can maximize the potential for natural light, they can also lead to problems such as glare and uneven light distribution, which can cause visual discomfort for occupants.

Similarly, a study by Konstantzos et al. (2018) investigated the impact of dynamic window shades on daylight glare probability in office spaces. The authors found that even with the incorporation of shading devices, the complex interplay between daylight levels, window size, and facade design can still result in visual discomfort for occupants, underscoring the importance of a holistic approach to daylighting design.

The issues of over-illumination and uneven light distribution identified in the simulation analysis of the selected office buildings in Addis Ababa are also consistent with the findings of a study by Aries et al. (2015). This comprehensive review of the evidence on daylight and health highlights the negative impacts of excessive or poorly distributed natural light, including eye strain, headaches, and decreased task performance.

To address these challenges, the literature suggests that a more nuanced and adaptive approach to daylighting design is required. This may involve the incorporation of advanced daylight control systems, the strategic placement of windows and other architectural elements, and the active involvement of occupants in managing the natural light levels in their workspaces (Reinhart and Voss, 2003; Dogrusoy and Dikmen, 2017).

For example, a study by Lee and Selkowitz (2006) investigated the use of automated shading systems in office buildings, demonstrating their effectiveness in improving occupant comfort and energy performance. Similarly, Aries et al. (2013) highlighted the benefits of personalized lighting controls, which allow occupants to adjust the lighting levels to suit their individual preferences and needs.

In the context of the office buildings in Addis Ababa, the simulation analysis findings emphasize the need for a more holistic and user-centric approach to daylighting design, addressing the challenges of over-illumination and uneven light distribution. This may involve the integration of shading systems, the optimization of window placement and size, and the incorporation of occupant feedback to create a visually comfortable and productive office environment.

Based on the analysis and the results presented, the research-based design recommendations, which are occupant-centric approaches, By incorporating user feedback and preferences into the design process, the daylight management system is tailored to the specific needs of the occupants, leading to a more responsive and satisfactory work environment. The recommended design is presented in Chapter 5.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1. CONCLUSION

Finally, the findings on the extent to which glazed facades affect the quality of daylight in office buildings in Addis Ababa, Ethiopia have been helpful in improving the understanding of the current state of daylight conditions and the consequences of glazed facades on quality and quantity of the natural light. The study has also introduced design improvements for increasing the quality of daylight in offices based on models. Some of the problems affecting the current office environment that has glazed façade facades include; over-illumination, and glare in the current Addis Ababa office buildings' Daylighting.

The effectiveness of glazed facades is also expressed in changes on the quality of daylight as proved by the study. From the existing studies on the impact of daylighting with glazed facade, it was established that the use of glazed facades has desirable daylighting effects such effects as over illumination, glare and inadequate visibility may occur thus offering discomfort to the occupants. It was again identified that the specific position of the sun, direction in which the building and the glazing material used can influence the quality of daylight considerably.

Considering the shortcomings in applying adequate daylighting and the negative effects of glazing of façades, the study suggests model-based solutions, which can improve the quality of the natural light for offices' interior. Solutions that are also an integral part of this project are the installation of dynamic shading systems which allows for the variation of the amount of daylight that is allowed to penetrate the building depending on the time of the day or the season and the application of diffusers which help to spread the amount of daylight that is let into the building in equal manner.

The discussion and recommendations made in the present study are important not only for the prevention and solution of the existing problem of designing and managing office buildings in Addis Ababa but also for other areas, sharing the same climate conditions. As per the findings presented in this study, it is implied that more options to boost the quality of daylight can be found in the glazed facades, and model based approaches improve the daylight and comfort of offices.

Therefore, the findings of this research study regarding the effects of glazed facades on daylight quality of offices in Addis Ababa, Ethiopia should be valuable towards better understanding the current state of daylighting conditions of the building type and the contributions of glazed façades towards it. The proposed remedies in this study can address the energy issues and thermal performance of office building in Addis Ababa and other climatically similar areas. The findings of this study can be greatly valuable and helpful in designing and managing office buildings and to employ efficient methods in the creation of buildings that are energy efficient and sustainable.

5.2. RECOMMENDATION

As I have pointed out from the research done on the quality of glazed office buildings, there exist various unfavorable difficulties. Research carried out in this project demonstrates that they tenets of a glazed office facility have a higher productivity and comfort as compared to the other. The research has the following suggestions.

- Improvement of building orientation and layout: The study found that the orientation and layout of the building can have a significant impact on daylighting conditions. The study recommends the use of building orientation and layout strategies, such as optimizing the building's orientation to maximize natural light and minimize glare.
- Utilize Shading Strategies: Open spaces that are sunny are to be protected adequately by suitable shading devices like external louver, overhangs or parametric shades. This means that the shading system arrangements are placed at a certain angle where it can collect the various sun positions that is characteristic of different seasons. Consider the use of smart shading devices that can alter their position according to the prevailing environmental conditions, and the preferred programs chosen by the users.
- Optimize Glazing Characteristics: Select the glazing material having favorable VLT as well as SHGC in order to allow sufficient light to penetrate in the interior space but restrain heat convection. - With regards to the design issues, it is recommended that high performance, low-emissivity (low-e) coatings are to be installed on the glazing in order to increase its thermal performance and reduce the glazing. Practice identifies the different classes of glazing such as the electrochromic/ thermochromics glazing that changes its attributes based on the conditions in the outside environment.

- Ensure Occupant Comfort and Productivity: By mitigating glare and achieving the right contrast ratio in the office spaces, it is thus necessary to enhance the overlook of the pastel paint in office areas. - Provide them a feature to modify their areas of lighting and shading control to suit the convenience that has been set. For enhancing design solutions related to IEQ, it is essential to quantify and evaluate various indoor environmental parameters such as illuminance levels, daylight variability and control of darkness, and the occupant satisfactory level.

Design recommendation

It is pivotal that a static parametric shade system can be implemented in order to improve the quantity and quality of daylight in the glazed offices. Typically, the shape of the parametric shade does not vary throughout the year and is permanently set in a way that can effectively counter the predominant angles of the sun and other physical conditions that are inherent to the locality. Altogether, the applied concept of parametric design optimizes the shade configuration that allows for achieving the targeted light transmission factor while blocking excessive glare and heat.

The parametric shade is a shape together with its location that has been deemed optimal based on the sun and sky analysis as well as occupant preferences and demands. This is a fixed light system used for making provision of high quality natural lighting that has the effects of improving visual comfort, increased productivity as well as health of the tenants in the building. Despite the lack of adaptability, the parametric design provides some sort of guarantee that the optimal positioning of the shade will minimize the effects by which natural light, heat add restlessness while attempting to work, glare will have on Addis Ababa office buildings.

In addition, the static parametric shade for the southern façade is compatible with integrated design of building envelope and other energy efficient solutions, making a contribution to the performance of daylighting for the office building. From the case of the parametric shade, these trade-offs have been urged to balance since the building’s shade plays a vital role in achieving the intended goals of daylighting and sustainable design of the Addis Ababa office buildings.

Model based solution- Awash insurance company

The openness and closeness of the components relies on the interior program and time of the day, even if the proposed geometrical configuration was set for the critical hours (2:30 pm- 4:00pm in the afternoon). The performance of the proposed skin geometry is tested in terms of direct radiation protection. It protects 80% of direct solar radiation while allowing diffused light and view to the outside. This optimization is brought through solar path study during those critical hours and days of the year.

Material and method of construction

Material and method of construction Aluminum sheet is chosen because of its ease of fabrication, workability, wait and transportation. The shading device is mounted on metal panels for support.

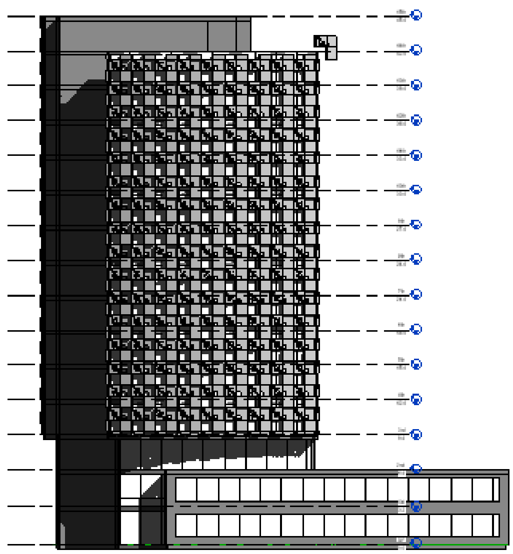


Figure 24: West Elevation

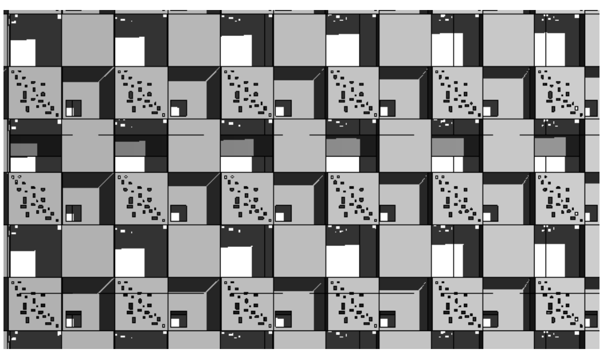


Figure 25: Facade pattern

Figure 26: Awash Insurance 3D with Shading

Model based solution- Hagbes Building

The permeability of the parametric shade components are determined by the interior program and time of day, despite the fact that the proposed shade was designed for the critical hours. The performance of the suggested skin shape is assessed in terms of its capacity to protect against direct solar radiation. It protects the interior from direct sunshine while allowing diffused illumination and external vistas into the space.

The key points are:

- The geometrical configuration was optimized for critical afternoon hours.
- The skin geometry shields against direct solar radiation.
- It permits diffused daylight and outdoor views into the interior.

Material and method of construction

Material and method of construction Aluminum sheet is chosen because of its ease of fabrication, workability, wait and transportation. The shading device is mounted on diagrid metal panels for support. Diagonal pattern is preferable to connect projected points on the shading components as well as allow clear view to the outside and inside the building.

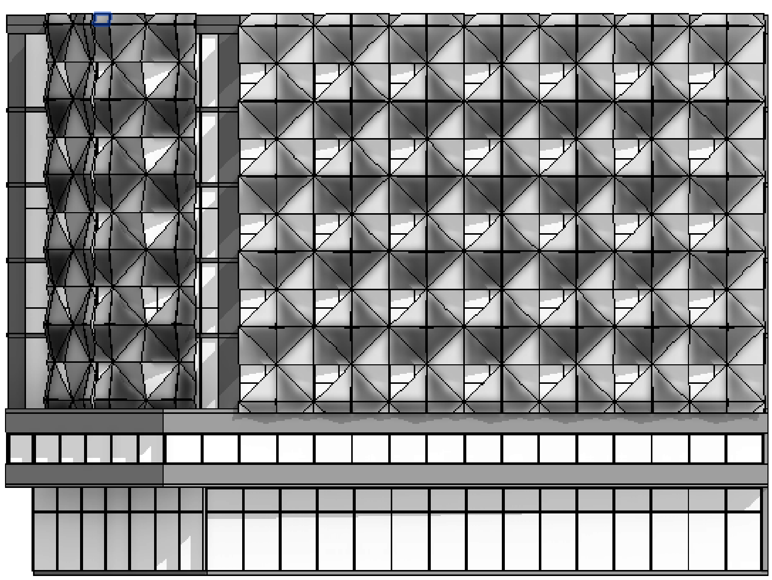


Figure 27: West Elevation

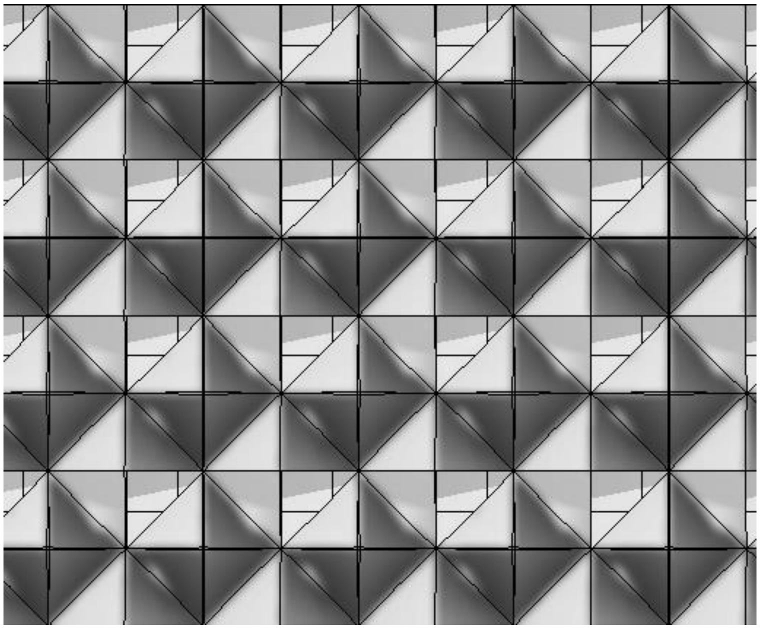


Figure 28: Hagbes Shading pattern

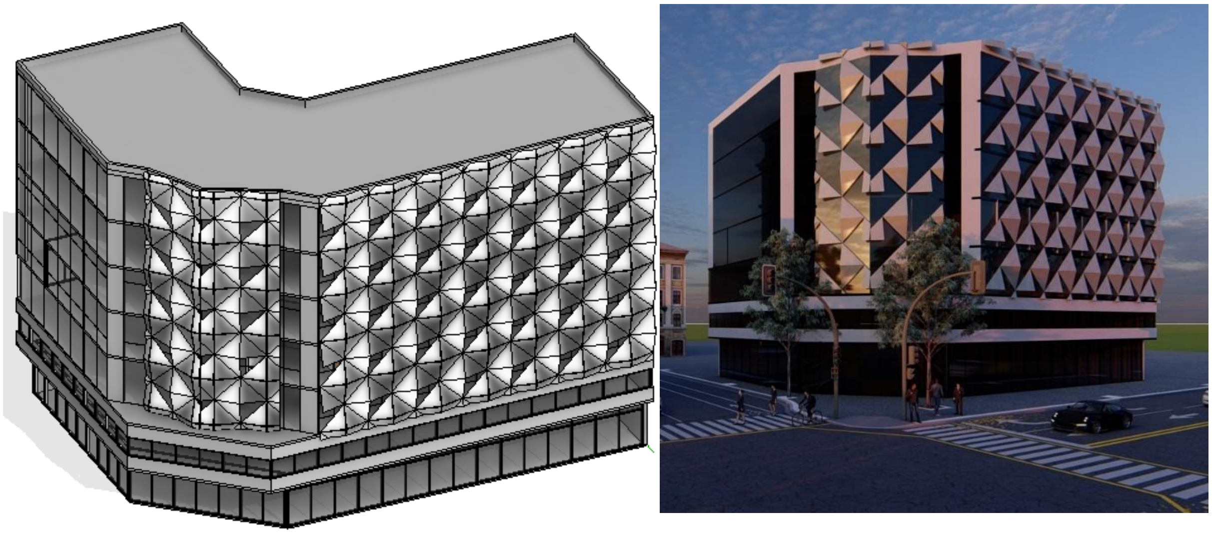


Figure 29: Hagbes Building with Shading

Future studies

Future research should focus on developing effective shade systems for radiation-vulnerable buildings in the metropolis. Studying the types of glasses, shading devices, and effective angles for various orientations might create a municipal guideline for evaluating prospective facade designs before construction permits are issued.

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APPENDIX

Section 1: Close Ended Questionnaire

Directions: please read each statement carefully and tick your answer

1. **Gender?**
   - ☐ Male
   - ☐ Female
2. Age group
   - ☐ 20-30
   - ☐ 41-50
   - ☐ 31-40
   - ☐ Over 50
3. How many years have you worked in this building?
   - ☐ Less than a year
   - ☐ 3-5 years
   - ☐ 1-2 years
   - ☐ More than 5 years
4. In a typical week, how many hours do you spend in your workspace?
   - ☐ $\leq 15hrs.$
   - ☐ 30 $hrs.$ to 40 $hrs.$
   - ☐ 16 $hrs.$ to 30 $hrs.$
   - ☐ $\geq 40hrs.$
5. How satisfied are you with your personal workspace?
   - ☐ Very Satisfied
   - ☐ Unsatisfied
   - ☐ Satisfied
   - ☐ Very Dissatisfied
   - ☐ Neutral
6. How satisfied are you with the amount of natural daylight in your office space?
   - ☐ Very satisfied
   - ☐ Unsatisfied
   - ☐ Satisfied
   - ☐ Very unsatisfied
   - ☐ Neutral
7. How satisfied are you with the quality of natural daylight in terms of brightness in your office?
   - ☐ Very satisfied
   - ☐ Unsatisfied
   - ☐ Satisfied
   - ☐ Very unsatisfied
   - ☐ Neutral
8. Do you agree that the quality of natural daylight in your office affects your productivity?

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

9. How do you agree as you experienced any discomfort due to the presence of natural daylight in your office?
   - Strongly agree
   - Agree
   - Neutral
   - Disagree
   - Strongly disagree
10. How do you agree as you that the quality of natural daylight in your office affects your overall well-being?
    - Strongly agree
    - Agree
    - Neutral
    - Disagree
    - Strongly disagree
11. Would you prefer to have more control over the amount of natural daylight entering your office space?
    - Yes, I would like more control
    - No, I am satisfied with the current level of control
12. Are you satisfied with the shading type in your office building?
    - Yes
    - No
13. Does nearby building facade interfere your normal work?
    - Yes
    - No
14. Does nearby building block natural light entry into your office space?
    - Yes
    - No

15. What kind of control would you like to use over the amount of natural daylight entering your office space?

- ☐ window coverings such as curtains or other
- ☐ Integrate adjustable façade

16. How often do you open blinds or curtains to let natural daylight into your space?

- ☐ Frequently
- ☐ Occasionally
- ☐ Rarely
- ☐ Never

Section 2: Open Ended Questionnaire

17. Do you think your energy levels change over the day depending on how well-lit your area is by natural light?

____

____

18. In your opinion, how could the design or layout of glazed facades be improved to enhance the overall daylight experience in the office environment?

____

____

19. Please share any suggestions or ideas you have for optimizing the natural daylight conditions in the office space.

____

____