OPTIMIZING WINDOW SIZE FOR EFFECTIVE DAYLIGHT ILLUMINATION IN HIGH-RISE BUILDINGS: A CASE STUDY OF NIB INTERNATIONAL BANK HEAD OFFICE ADDIS ABABA, ETHIOPIA.

Samrawit Aychew Demeke

A Thesis submitted to the Department of Architecture
College of Civil Engineering and Architecture.

Presented in Partial Fulfillment of the Requirement for the Degree of
Masters of Science in Environment Architecture

Office of Graduate Studies
Adama Science and Technology University

Jun, 2025
Adama, Ethiopia

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DECLARATION

I declare that this thesis proposal entitled "**Optimizing Window Size for Effective Daylight Illumination in High-rise Buildings: A Case Study of Nib International Bank Head Office Addis Ababa, Ethiopia"** is my own work and has not been submitted to any university for similar purpose. The references used in this proposal are duly recognized by proper citations.

Samrawit Aychew	______________________	______________________
Name of student	Signature	Date

RECOMMENDATION

I, the major advisor of this research proposal, hereby certify that I have closely advised/ the student while developing this proposal and read the draft thesis/dissertation proposal entitled "**Optimizing Window Size for Effective Daylight Illumination in High-rise Buildings: A Case Study of Nib International Bank Head Office Addis Ababa, Ethiopia"** prepared under my guidance by Samrawit Aychew. Therefore, I recommend the submission of the proposal to the department for further review and evaluation.

Dr. Sileshi Azagew (Assistant Prof.)

______________________	______________________	______________
Major Advisor/Supervisor	Signature	Date

APPROVAL OF BOARD OF REVIEWERS

We, the undersigned, members of the Board of Reviewers of the proposal open defense by Samrawit Aychew Demeke has read and evaluated the thesis proposal entitled "**Optimizing Window Size for Effective Daylight Illumination in High-rise Buildings: A Case Study of Nib International Bank Head Office Addis Ababa, Ethiopia**" and assessed the understanding of the candidate about the proposed research. This is, therefore, to certify that the thesis proposal is accepted and we recommend the implementation of the proposal.

Major Advisor/Supervisor	Signature	Date
Major Advisor/Supervisor	Signature	Date
Major Advisor/Supervisor	Signature	Date

Finally, approval and acceptance of the thesis/dissertation proposal are contingent upon the submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

Department Head	Signature	Date
School Dean	Signature	Date
Office of Postgraduate Studies, Dean	Signature	Date

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ACRONYMS AND ABBREVIATIONS

BREEAM: Building Research Establishment Environmental Assessment Method

BS: British Standard

CBE: Commercial Bank of Ethiopia

CES: Compulsory Ethiopian Standard

CIBSE: Chartered Institution of Building Services Engineer

DF: Daylight Factor

EBCS: Ethiopian Building Code and Standard

EN: European Standard

HVAC: Heating, Ventilation, and Air Conditioning

LEED: Leadership in Energy and Environmental Design

LT: Local Time

PV panel: Photovoltaic Panel

UK: United Kingdom

USA: United States of America

W1, W2…W7: Wall1, Wall 2… Wall 7

WFR: Window to Floor Ratio

WWR: Window to Wall Ratio

ABSTRACT

This study explores the optimal Window-to-Wall Ratio (WWR) for enhancing daylighting performance in such buildings based on their orientation. First measurements involved calculating the WWR of an existing bank building in all Cardinal direction, followed by lux meter readings taken in March a month marked by high solar intensity. Daylight levels were recorded in office spaces across various orientations (N, S, E, W, NE, SE, and SW). The study focused on floors 5 to 32 (Head Office of Nib Bank Building), where all windows are uniformly fitted with 5mm clear glass and aluminum frames, ensuring consistent glazing conditions for accurate analysis. As a result the measured WWRs, ranging from 55.56% to 57.03%, significantly exceed the LEED-recommended range of 25%–40%, indicating a strong focus on maximizing daylight penetration. Daylight illuminance was analyzed at 2-meter grid intervals on 3 points (A, B, C) at a height of 76 cm, with results compared to LEED daylighting criteria (sDA300/50%) and CIBSE standards, which recommend 300 lux for general office work and 500 lux for task-intensive activities. On grid points, such as A (1436–1963 lux) and B (704–830 lux), exceeded these standards. To compensate for Excessive daylight daylight, 50×50 cm ceiling panel lights are used with internal curtain to balance the light, with at least two per room and a total of 448 lights across the building. These fixtures consume 0.06 kWh each per hour, resulting in 26.88 kWh of hourly, 161.28 kWh daily, and approximately 58,867.2 kWh of annual energy consumption. The study conclude from the Simulation results WWRs of 30% for west and southwest orientations to reduce glare, 35% for northeast, and 40% for the remaining orientations to maintain comfort and efficiency. It is recommended that architects consider daylight performance alongside aesthetics and functionality, using simulation tools to optimize the Window-to-Wall Ratio (WWR) for improved energy efficiency and lighting quality.

Keywords: Optimum Window size, Effective Daylighting, High-Rise Bank Buildings, Addis Ababa,

CHAPTER ONE

INTRODUCTION

1.1.BACKGROUND OF THE STUDY

The history of daylighting and architecture has evolved since the second half of the twentieth century. Gothic architecture focused on maximum window area, while Renaissance architecture used large windows for facades Today, day lighting can save about half of all electricity consumed by buildings, especially in offices, schools, libraries, and museums; it also minimize heating and cooling energy consumption, as daylighting can be cooler in summer and passively heat in winter. (Lechner, 2015)

Daylight has a positive impact on human well-being; Humans spend most of their time indoors and the majority of the world's population lives in urban areas and work in an office environment (H. Gabay et al, 2014). There has been a global shift in the economy from manufacturing to service and knowledge-based sectors, highlighting the importance of understanding indoor office environments and their effect on occupant productivity. An office environment has a high level of influence on its occupants' productivity (W. Lee, 2013).

Using daylight in buildings is important for comfort and efficient heating and cooling. Energy-efficient buildings rely on sunlight and include systems for solar energy use. The importance of lighting in new and existing buildings is gaining international attention, with laws in Europe and the USA (Sonja Krasic & Petar Pejić, 2013).

The rapid growth of high-rise developments in Addis Ababa, driven by ongoing urban expansion, has led to a flow in bank buildings that primarily function as office spaces with high occupancy rates. This shows the critical importance of adequate daylighting to improve employee productivity and occupant well-being. Also Addis Ababa, experiences relatively stable climatic conditions throughout the year, with minimal seasonal variation.

In Ethiopia, building regulations related to natural daylight, particularly in terms of window size and orientation, are governed by the Compulsory Ethiopian Standard for Building Spatial Design (CES 164). This standard emphasizes the need for adequate natural lighting in all spaces intended for human occupancy, mandating that the net glazed area (i.e., windows) must be at least 15% of the floor area (compulsory Ethiopian Standard, 2015).

However, the regulation does not specify exact dimensions for windows or their orientation. While it point out the importance of providing natural light and ventilation, it allows for flexibility in window design without providing detailed guidance on how window orientation should relate with the sun path to optimize daylight use or mitigate solar radiation. The focus is more on achieving adequate lighting and airflow, rather than prescribing specific window sizes or orientations (compulsory Ethiopian Standard, 2015).

Given the lack of specific regulations in Addis Ababa regarding window sizing and building orientation, a thesis focused on this topic is both relevant and necessary. This research would examine how appropriately sized windows can enhance natural lighting and reduce the dependence on artificial lighting. It would also explore the impact of building orientation on daylight performance within Addis Ababa's relatively stable climate, aiming to inform better architectural design decisions.

1.2.STATEMENT OF THE PROBLEM

Addis Ababa, the capital of Ethiopia, has experienced rapid urban growth in recent years, as evidenced by the construction of high-rise buildings such as the Commercial Bank of Ethiopia (CBE) Headquarters, Wegagen Bank Headquarters, Nib Bank Headquarter, etc. These urban growth reflect the city's developing toward modernization and economic expansion. Alongside this growth, the number of office-based employees has gradually increased, contributing to a workforce that is now estimated at around 527,090 people.

In most high-rise bank buildings in Addis Ababa, including the NIB International Bank Head Office, indoor environmental quality is a growing concern, particularly regarding daylight access. From my personal observation, many employees working in these buildings are not comfortable in their indoor spaces due to issues related to improper daylight management. Specifically, some areas are affected by glare and over-illumination, while others experience low daylight levels. This imbalance causes visual discomfort and reduces work efficiency.

Despite the fact that Addis Ababa benefits from relatively stable and consistent daylight throughout the year, these buildings heavily rely on artificial lighting even during daylight hours. This is largely due to poor window design specifically, window sizes and orientations that are not optimized to effectively utilize natural light. The absence of local daylighting design standards or performance-based window sizing practices increase the problem. Consequently, energy consumption increases unnecessarily, and the overall indoor environment becomes less conducive to health, productivity, and sustainability.

As a student of Environmental Architecture, I am deeply concerned by the widespread use of artificial lighting during daytime in high-rise buildings, particularly in the banking sector of Addis Ababa. Observing this issue firsthand, especially the unnecessary consumption of electric energy, has motivated me to explore practical architectural solutions that promote energy efficiency.

This study is driven by my commitment to contribute toward creating a more sustainable built environment. By investigating and proposing optimized window sizing strategies based on building orientation and daylight performance, I aim to reduce the need for artificial lighting, improve occupant comfort, and support energy conservation. The goal is to inform better architectural practices in Addis Ababa's growing urban context and to demonstrate how design decisions can significantly impact environmental sustainability.

1.3.OBJECTIVE

1.3.1. General Objective

The general objective of the study is to identify the optimum window size for achieving effective daylighting illumination in high-rise bank buildings a case study on Nib international bank head office in Addis Ababa, Ethiopia.

1.3.2. Specific Objectives

The specific objective of the study are to:

- analyze the daylighting performance of existing window configurations in high-rise bank building in a case study on Nib International Bank Head Office in Addis Ababa;
- examine how window size and orientation affect indoor daylight levels in high-rise bank buildings in a case study on Nib International Bank Head Office in Addis Ababa;

- analyze the variation in daylight illumination through simulations based on different window-to-wall ratios (WWR) in a case study on Nib International Bank Head Office in Addis Ababa.

1.4.RESEARCH QUESTION

1. What is the daylighting performance of the existing window configurations in the Nib International Bank Head Office, a high-rise bank building in Addis Ababa?
2. How do window size and orientation affect indoor daylight levels in the Nib International Bank Head Office in Addis Ababa?
3. How does daylight illumination vary with different window-to-wall ratios (WWR) in the Nib International Bank Head Office based on simulation analyses?

1.5. SIGNIFICANT OF THE STUDY

This study on window sizing for daylighting in high-rise bank buildings in Addis Ababa, Ethiopia, is very important for architects, urban planners, building owners, and occupants. It identifies the optimum window sizes to reduce the need for artificial lighting, saving energy and lowering costs while promoting sustainability.

Additionally, optimizing window sizing can improve indoor comfort and looks, benefiting employees and clients. The research offers guidelines for Architects, It also helps to inform building codes that focused on daylight access and energy efficiency, contributing to a sustainable urban environment while filling gaps in existing literature.

1.6. SCOPE OF THE STUDY

1.6.1. Spatial Scope

This study focused on high-rise bank buildings located in Addis Ababa, Ethiopia. The study demonstrated how to optimize window sizing and efficient daylighting in urban environments by looking at a chosen building. Ethiopia's capital city of Addis Ababa, which is rapidly becoming more urbanized, provided a unique setting for this study because of its expansion and architectural tendencies.

High rise building is chosen because it accommodates large number of workers and customers in everyday life cycle, the building is located in-urban area which have more activities and transaction which need effective daylight for both the workers and customers for better productivity of work and welcoming environment also it will improve the energy efficiency by lowering the use of artificial light which it minimize the cost of the bill and maintain sustainable environment.

1.6.2. Thematic Scope:

The thematic focus of this study includes several key areas:

- Daylighting Design: Investigating the role of window sizing in optimizing natural light within high-rise bank buildings.
- High rise building:- high rise building are buildings that have more than 12 stories
- Window size: - Window sizing refers to the dimensions and proportions of windows, including their height, width, and surface area relative to a building's façade.
- Window size for Daylighting: -Is a way of resizing of window size to get the comfortable and effective daylight in room also by considering the glare and overheating. This will save the energy demand of the building

1.6.3. Temporal Scope

The study examined contemporary architectural practices related to window sizing and daylighting in high-rise bank buildings. Data collection was carried out over the course of the academic year, focusing on bank buildings that were structurally completed and already in operation.

1.7. DEFINITION OF MAJOR TERMINOLOGIES

Window sizing refers to the dimensions and proportions of windows, including their height, width, and surface area relative to a building's façade. It plays a key role in daylighting the strategic use of natural sunlight Provide indoor lighting, and it is measured by using WWR and software simulation.

Effective daylighting design optimizing daylight entrance while reducing problems like glare and overheating. This contributes to overall energy efficiency by improving home comfort and lowering reliance on artificial illumination during the day.It is measured by lux meter with grid points and will model on software to match-up with the standard LEED (sDA300/50%) to get effective daylight in office.

High-rise buildings are multi-story structures, typically 12 floors or more, where vertical transportation is dependent on elevators and evacuation poses greater challenges. In this study, high-rise bank buildings refer to tall urban structures that house banking and financial services, requiring specific design considerations for security, customer service, and administrative needs.

Addis Ababa, the capital of Ethiopia, offers a distinct context for this research due to its high-altitude location and mix of modern and historical architecture. These factors influence local daylighting conditions and present unique challenges and opportunities for incorporating daylight strategies in tall office buildings.

1.8.LIMITATION OF THE STUDY

This study is limited to the analysis of a single high-rise bank building in Addis Ababa, selected through purposive sampling based on specific criteria (Campbell, S., Greenwood, M., Prior, S., Shearer, T, 2020) to serve as a representative case. As a result, the findings may not be fully broad to all high-rise buildings in the city due to variations in environmental and contextual factors. Due to time and resource constraints, the research is based on spot field observations and selected point-in-time measurements rather than continuous, long-term environmental monitoring. Furthermore, limited access to detailed architectural documentation and official urban planning data required reliance on visual assessments and secondary sources.

CHAPTER TWO

LITERATURE REVIEW

2.1. GENERAL LITERATURE REVIEW ON DAYLIGHTING

2.1.1. Daylight

The sum of all direct and indirect sunshine during the day is what we refer to as daylight. This covers direct sunshine, diffuse sky radiation, and (frequently) both of these reflected by Earth and terrestrial objects, such as structures and landscapes. Generally, the light that astronomical objects scatter or reflect is not regarded as daylight. As a result, daylight excludes moonlight, even though it is reflected indirect sunshine. (Rehman.T, 2024).

The sun is the largest provider of light and energy on the planet, and the light we get from it today comes in two forms: either directly as sunlight or indirectly as diffused skylight, which has been altered and spread by the atmosphere. Sunlight gives us the ability to see, but it also gives the entire planet's ecosystem energy and power. Daylight may be defined as the interaction of direct sunlight and diffuse skylight. (Baker & Seemers, 2002).

The geographical latitude, the season of the year, the time of day, the local weather, the sky conditions, and the shape of the structure all have an impact on the quality and intensity of sunlight (wong, 2017). Daylight has consistent variations in intensity, direction, and spectral composition, which makes it superior to artificial light for vision and has favorable biological and physiological effects on all living things on Earth (Pokorny.K, 1998). Since artificial lighting generates large carbon emissions, it causes global warming (wong, 2017).

The importance of daylight in architecture is demonstrated by the extensive body of study that has been conducted on the topic in recent years. These have contributed to the development of innovative, high-performance windows and glazing materials. Electric lighting systems account for the majority of energy use, particularly in non-residential buildings. In this sense, it has been claimed that lighting systems consume about 31% of all electricity utilized by the commercial sector. (Borbely & Jan, 2001).

Lighting consumption levels vary considerably from one country to another, due to not only the different climatic conditions or types of design but also to cultural habits. For example, in China, the lighting consumption in commercial buildings is 15% (Min G. F., Mills E, & Zhang Q, 1995), in the USA, 39% (EIA, 1994), whereas in the UK (8206-2, 1992), varies in a range from 30% to 60%. This energy consumption contributes significantly to climate change and global pollution because of the dirty energy production processes (Borbely & Jan, 2001).

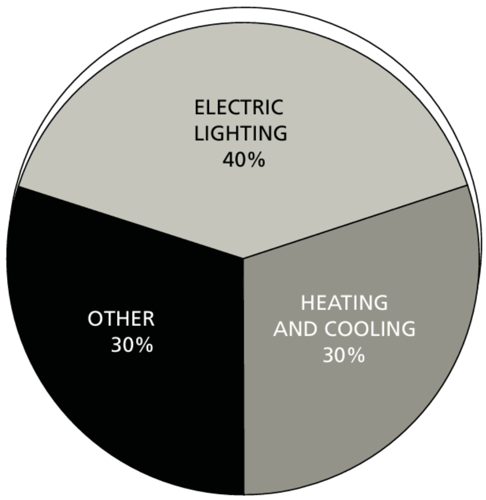

Figure 1 - Typical distribution of energy use for buildings such as offices, schools, and many industrial facilities. (Source: Sustainable Methods for Architects)

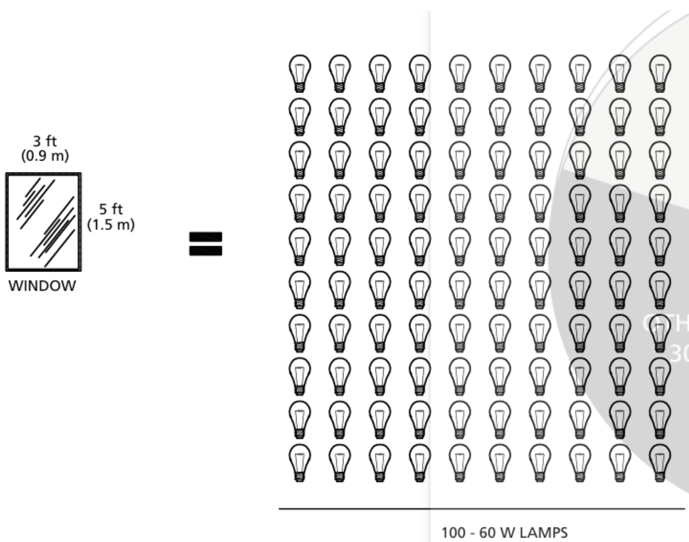

Figure 2 - shows how many 60 W incandescent lamps would be required to produce the same amount of light as a 3 × 5 ft. (0.9 × 1.5 m) window. (Source: - After Rocky Mountain Institute)

Controlling natural light, however, can lead to gains in terms of increased worker productivity and lower absenteeism (Heschong L, 2002). Additionally, we must not overlook the significant role that lighting plays in how people perceive the space and how comfortable it is visually. "There is no noticeable difference between a rift and the Sixtine Chapel in absolute darkness," as historian Sigfried Giedion once observed. We must first comprehend lighting in order to comprehend inside space.(Giedion S, 1964).

Addis Ababa, situated at latitude of approximately 9.03°N, experiences a tropical highland climate characterized by consistent solar exposure throughout the year. The city receives an average of 5.57 to 6.07 kWh/m²/day of solar insolation, with minimal seasonal variation, making it conducive for solar energy applications (Robinson. A, 2019-2025).

2.1.2. High rise building and daylight

The high-rise office building is a modern type of construction that has increased rapidly, especially in developing countries. They are a major part of the global construction market. The total floor area of office buildings is expected to double by 2030. Good design is important for creating pleasant, healthy, and productive work spaces. It must meet user needs while considering design limitations. Natural light is essential in high-rise office buildings (X. Yu, Y. Su, & X. Chen, 2014).

High-rise buildings in urban areas face challenges but also offer chances for innovative and sustainable designs. They significantly change the environment, affecting sunlight and wind. This raises questions about their value. A vision is needed to improve their impact on urban spaces. Current designs focus too much on maximizing floor space, leading to poor shapes and setbacks. Guidelines are needed to enhance performance. Efficient daylighting in high-rises is complex, balancing aesthetics and energy use. It is crucial to explore formalized approaches for effective daylighting designs (Fatehelrahman. D, 2024).

In addition, the researchers discovered that daylighting has the potential to boost retail establishments. The quantity and characteristics of the light from each source differ, including its color, diffuseness, and effectiveness. It's helpful to comprehend daylight from the two extreme conditions sunny sky and overcast sky even if sky conditions might vary infinitely. A daylighting system that functions in both of these scenarios will also work in the majority of other skies (Lechner, 2015).

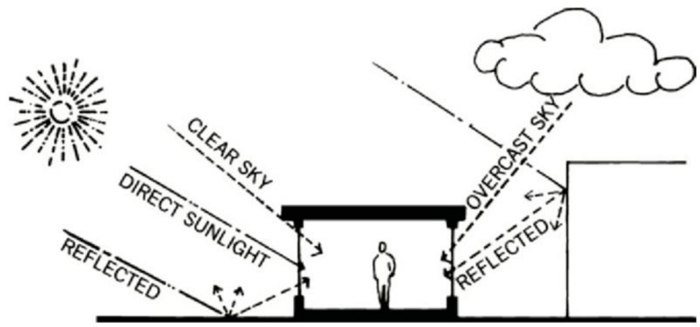

Figure 3 - The various sources of daylight (source: Sustainable Methods for Architects)

Addis Ababa, the capital of Ethiopia, has changed greatly with more high-rise buildings in recent years. This growth is due to population increase, economic development, and the city's role as Africa's political center. While these buildings show Ethiopia's economic goals, they also raise concerns about infrastructure, urban planning, and the preservation of cultural heritage.

2.1.3. Window to wall ratio

Window-to-Wall Ratio (WWR) is one method of finding the proportion of window area to the total wall area. Also it is an essential factor for analysis of daylighting, visual comfort, thermal comfort, and other building performance is essential to use WWR.

In office settings, the recommended standard WWR typically ranges from 20% to 40%, which provides a balanced approach to maximizing natural light while minimizing issues such as heat loss, solar gain, and glare. This range supports energy efficiency and occupant well-being without the need for excessive reliance on artificial lighting or HVAC systems. According to the U.S. Department of Energy and the ASHRAE 90.1 energy standard, a WWR of up to 40% is commonly permitted without requiring additional energy modeling or justification (ASHRAE, 2019).

Similarly, LEED and other green building certification systems promote maintaining WWR within this range to ensure sustainable design outcomes. Higher WWRs, especially those exceeding 60%, can compromise thermal performance unless offset by advanced glazing technologies, external shading, or dynamic facade systems.there for it is recommended to use a WWR between 25% and 40% for best comfortable space and to achieve energy efficient building.

2.1.4. Role of windows in building design

2.1.4.1. Daylight

The main purpose of a window is to penetrate light in building to function.but this can lead high daylight intensity level in work space which is less important than the quality of light.daylight is not used only for function also provide a comfortable space with giving pleasant visual environment for all occupants (CIBSE, 1999).

2.1.4.2. View

The view through a window changes with light and seasons, influencing how we see the outside world. It meets the eye's need for focus and connects us to our surroundings. Beautiful views can bring pleasure, but even ordinary views are valuable. Research shows patients recover faster when they see attractive nature. Architects like Maxwell Connell Ward and Lucas offered new experiences of daylight and views (CIBSE, 1999).

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2.1.4.3. Natural ventilation

One of the natural ventilation strategy can be a window design for building and it have to be consider on planning and design stage of a building. The simplest way of providing fresh air, is using locally and manually controlled mechanism which is open able windows that allow excess heat to be removed to prevent overheating on warm days and provide background ventilation for health and comfort on other days. (CIBSE, 1999)

2.1.4.4. Other constraints

- Noise

Buildings near busy roads or airports may have noise issues from their windows. Normal glass lets in a lot of noise. Solutions include reducing window size, placing windows away from noise, using thick or double/triple-glazed glass, and sealing gaps around frames (CIBSE, 1999).

- Security and impact resistance

Depending on the building's use and location, windows may need to be impact-resistant (see section 2. 3. 8). This includes scenarios like children running into windows at schools or footballs hitting windows in sports halls. Large, unprotected glass panes attract vandals, so designers should consider this issue, as replacing windows can be disruptive and expensive. In some cases where security is crucial, very high impact resistance glass may be needed (CIBSE, 1999).

2.1.5. Basic window strategies

To design effective window daylighting, it's important to understand the drawbacks of ordinary windows, such as glare from sky views and excessive brightness from direct sunlight, which can cause discomfort and overheating. To address these issues, several strategies are recommended. Place windows high on walls and spread them out to enhance daylight penetration ideally, the depth of effective daylight reaches about 1.5 times the window height. (Lechner, 2015).

Use horizontal windows for even light distribution, keeping the total window area under 20% of the floor space to manage heat gain. Bilateral lighting placing windows on more than one wall improves light balance and reduces glare, especially with windows on adjacent walls. Positioning windows next to interior walls allows those walls to act as reflectors, softening light contrast. (Lechner, 2015).

Splaying wall edges around windows also reduces harsh contrast and improves visual comfort. Daylight can be softened using trees, trellises, or screens, though translucent materials may worsen glare. To manage seasonal light and heat, use shading elements like overhangs—preferably white or light-colored—and movable shades to adapt to changing sun angles, especially on east and west exposures. Reflecting light off ceilings is also essential for diffusing light evenly in interior spaces (Lechner, 2015).

2.1.6. Special daylighting techniques

The following daylighting strategies may be useful for special lighting problems

- Light wells or shafts become more efficient as their width-to-depth ratio increases, allowing less light to be absorbed through reflections. Using highly reflective surfaces, like those in the National Gallery of Canada by Moshe Safdie, can transmit light effectively even with small wells. Physical models demonstrated this approach (Lechner, 2015).

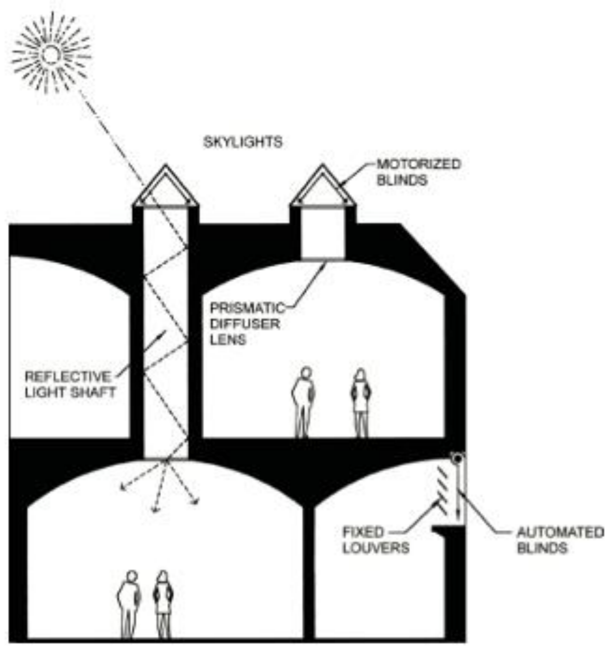


Figure 4 - Light shafts with highly reflective specular surfaces (Source: Sustainable Methods for Architects)

- Tubular skylights: - About 50% of the outdoor light passes through the attic via commercially available duct-like tubes with specular, highly reflective inner surfaces. The diameter and length have a significant impact on the amount of light. Square tubes can be as big as 4 ft2 (1.2 m2) and circular tubes come in a variety of sizes, ranging from 8 to 24 in. (20 to 60 cm) in diameter. Even though they are a cost-effective method to include light shafts into structures with flat, gabled, or single-story roofs, the light dispersion is only slightly better than that of a fluorescent tube light mounted on the ceiling. Splaying the ceiling around the light tub enhances both the amount and quality of the light (Lechner, 2015).

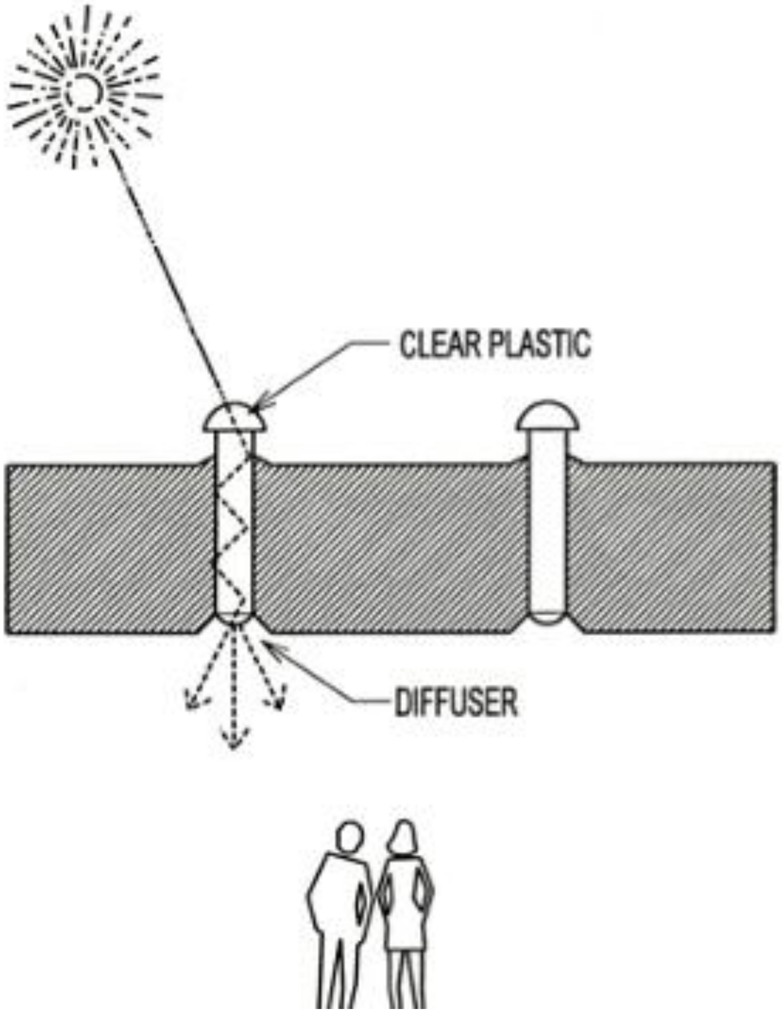


Figure 5 - Tubular light shafts (Source: Sustainable Methods for Architects)

- Skylights with dynamic mirrors: - Several companies now make skylights with built-in rotating mirrors to reflect the sun down into the building. An electric motor powered by its own PV panel turns the mirror to track the sun, thereby collecting more daylight early and late each day as well as during the winter (Lechner, 2015).

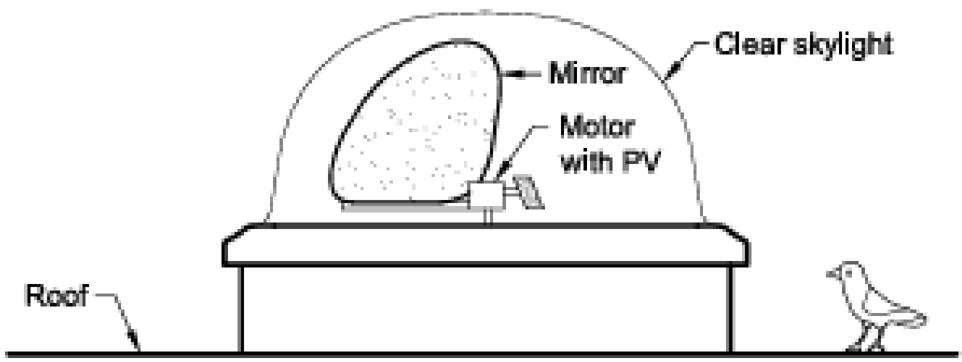


Figure 6 – Skylights (Source: Sustainable Methods for Architects)

2.1.7. Window glazing materials

Choosing the right glazing material is important for good daylighting design. There are many types of transparent glazing, such as clear, tinted, and reflective. Tinted or reflective glazing can help reduce glare with additional light sources. Spectrally selective glazing is best when light is needed without heat. Traditional low-e glazing is recommended for winter. Avoid dark-tinted glazing to prevent a gloomy atmosphere, and glass blocks are not effective for daylighting. Translucent glazing with high light transmittance is typically not suitable for windows. (CIBSE, 1999).

Translucent glazing materials with low light transmittance can effectively be used for daylighting when the glazing area is large. Understanding shading is crucial for understanding daylighting. Dynamic glazing, which can change from high to low-light transmittance, is mainly used for shading and does not change the direction of light transmission or spectral selection (CIBSE, 1999).

2.2. CONTEXTUAL REVIEW

2.2.1. High rise banks building in Ethiopia

Across Ethiopia, the construction of high-rise buildings is still concentrated mainly in major cities, with Addis Ababa being the primary hub. Bank headquarters and financial institutions have been key drivers of vertical development, seeking not only to accommodate growing operational needs but also to project corporate identity. These buildings often adopt modern architectural styles, steel and concrete structural systems, and expansive glazing facades. Notable examples beyond Addis Ababa remain limited but are slowly emerging in cities like Hawassa, Bahir Dar, and Mekelle, often as part of regional development initiatives.

2.2.2. High rise bank building in Addis Ababa

Addis Ababa, as the political and economic heart of the country, houses the headquarters of most major banks. Examples include the headquarters of the Commercial Bank of Ethiopia (CBE), Awash Bank, Dashen Bank, and the newly completed Hibret Bank tower. This building floor levels are ranged from 10 to 50 floors located in high density areas such us mexico square, , and the financial districts around Kazanchis and Bole.

Architecturally, these high-rises incorporate extensive curtain wall systems, often featuring full-height glass panels that aim to maximize natural light. However, this has introduced challenges related to daylight control, thermal comfort, and energy efficiency due to the region's high solar exposure and variable weather conditions. Addis Ababa, located at an altitude of over 2,300 meters, receives a significant amount of daylight throughout the year, which provides both opportunities and challenges for day lighting design in high-rise buildings.

Therefore, the optimum window size is important for achieving the best daylight quality, lowering the energy used in bank buildings. Also, it is significant to know the best WWR for indoor daylighting for each orientation of the building to reduce the reliance on artificial lighting and achieve environmental sustainability.

2.2.3. Ethiopian building codes and standard

Every space for human use must have natural light through windows, as stated in the Ethiopian Building Code and Standard (EBCS) amended in 2014. If half of a shared wall is open, the room should be considered part of the neighboring room for daylight purposes and must have an opening of at least 1/10th of the inner room's floor area, which must be 2.5 m^2. Each room must have a net glazed area of at least 15% of its total floor area. Additionally, indoor workplaces with full-time staff must have a minimum brightness of 200 lux (Ethiopian Monitor, 2022).

2.2.4. Climatic Context of Addis Ababa (Study Area)

Addis Ababa, situated at an elevation of approximately 2,400 meters, experiences a unique climate characterized by a subtropical highland climate with moderate temperatures throughout the year. This climatic context influences solar radiation levels, daylight availability, and thermal performance, which are crucial considerations in window design (Addis Abeba Climate, 2006).

2.3. EMPIRICAL LITERATURE REVIEW

In global context, there is a study conducted on Non-Air-conditioned Buildings in Andhra Pradesh, India.and this paper is focused on the on drawings that have effective penetration of light to internal rooms or spaces.its objective is to analysis the optimum size of window with proper location to enhance the penetration of daylight through the spaces uniformly.

In local study is looking at the relationship of building orientation to indoor thermal comfort and daylighting: the case of condominium building in Adama city, Ethiopia. It is aimed to analyzing the effect of building orientation on indoor thermal comfort and daylighting in condominium buildings. The study is results could help for designers as it gives a chance to orientated buildings to the best optimum orientation.

However, the study does not address the critical variable which is the relationship between the window sizing and daylighting. Importantly this research addresses a gap by analyzing and identifying the optimal proportions needed to achieve a uniform distribution of daylight and appropriate penetration levels.

There is a significant research gap in the field of window sizing for daylighting in high-rise bank buildings in Addis Ababa, Ethiopia. While daylighting is crucial for reducing energy consumption and improving occupants' productivity and comfort, most high-rise bank buildings in Addis Ababa lack effective daylighting systems, resulting in energy wastage and reduced occupant satisfaction.

Current studies on daylighting in Ethiopian high-rise buildings focus on theoretical approaches and case studies from developed countries, neglecting the specific climatic and urban context of Addis Ababa. Furthermore, there is a lack of research on the impact of window size and orientation on daylighting performance in high-rise bank buildings in the city. Therefore, this study aims to investigate the optimal window size and orientation for daylighting in high-rise bank buildings in Addis Ababa, Ethiopia, considering the city's unique climate, urban layout, and building typology.

2.4.CONCEPTUAL FRAMEWORK

A conceptual framework is a tool used by researchers to provide an organized structure and context for their research work. It is composed of relevant perspectives from interdisciplinary fields which then serve as the basis for communication between negotiators. The following figure is a diagram that categorizes variables into three distinct types: dependent variables, independent variables, and controlled variables.

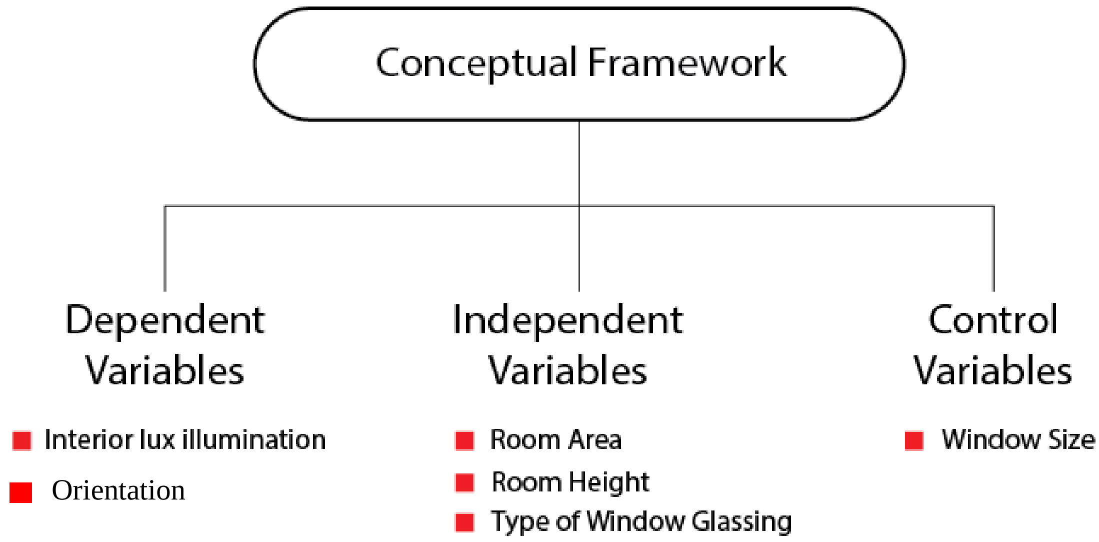


Figure 7: Conceptual Framework (Source: Author)

The dependent variable in this study is the measured daylight level (in lux) within the interior space first recorded in the existing building, and later through simulation. Since the lux values are influenced by window size, daylight levels depend on that factor. The independent variables include room area, room height, and type of window glazingnfactors that can affect daylighting but are treated as constants in this analysis, as they remain unchanged. The controlled variable is the window size, which is systematically adjusted to determine the optimal size for effective daylight performance.

CHAPTER THREE

METHODS AND MATERIALS

3.1. DESCRIPTION OF STUDY AREA

Addis Ababa, the capital city of Ethiopia, is situated at an elevation of approximately 2,400 meters (7,874 feet) above sea level. Addis Ababa is located in the central part of Ethiopia, on the Ethiopian Highlands. The city's geography is characterized by rolling hills, mountainous terrains, and deep valleys. The climate is classified as subtropical highland, experiencing mild, wet summers (from June to September) and drier winters.

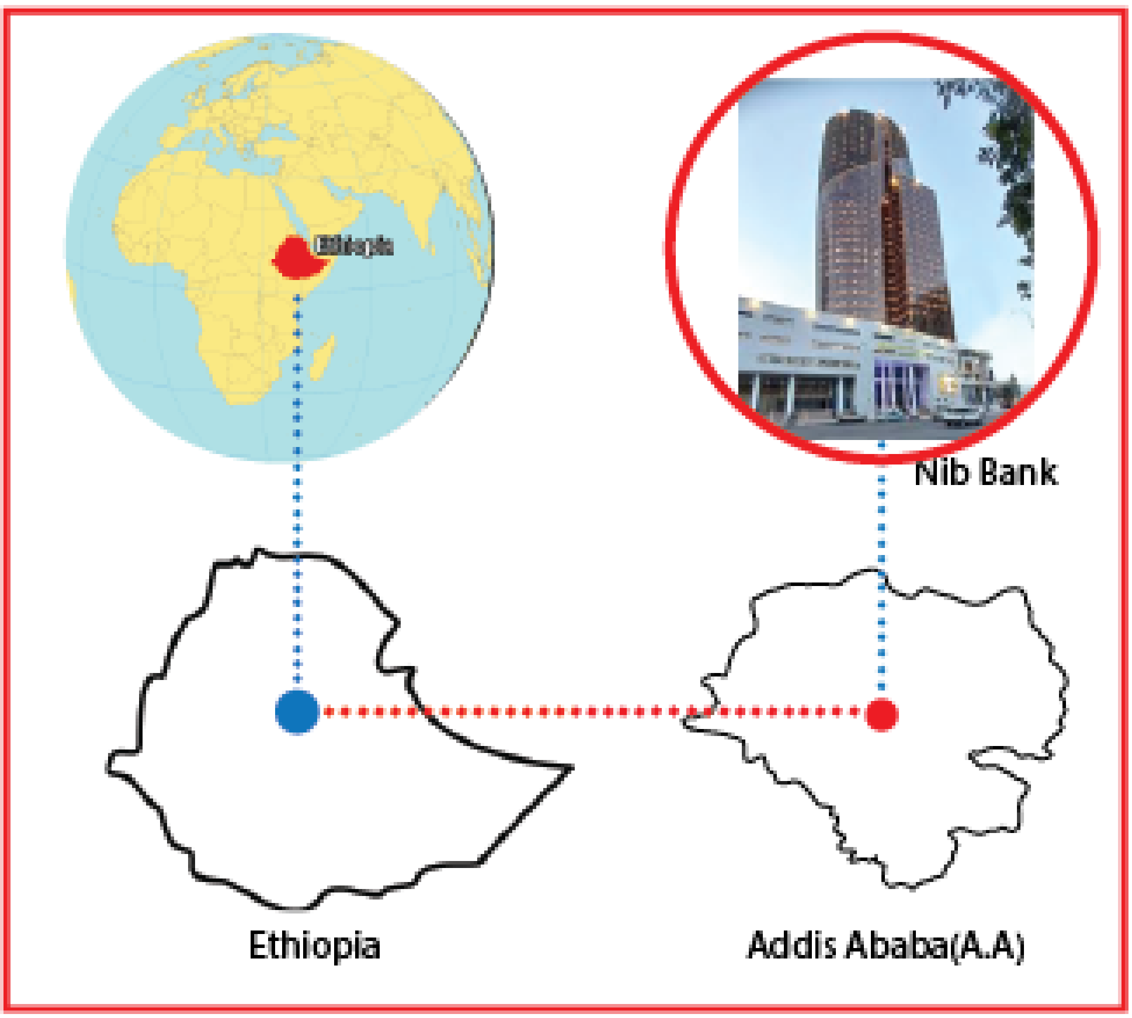


Figure 8 - Study Area (source: Author)

Addis Ababa, situated at latitude of approximately 9.03°N, experiences a tropical highland climate characterized by consistent solar exposure throughout the year. The city receives an average of 5.57 to 6.07 kWh/m²/day of solar insolation, with minimal seasonal variation, making it conducive for solar energy applications (Robinson. A, 2019-2025).

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature °C (°F)	15.1 °C (59.2) °F	16.4 °C (61.5) °F	17.2 °C (62.9) °F	17.2 °C (63) °F	17 °C (62.6) °F	15.7 °C (60.2) °F	14.8 °C (58.6) °F	14.7 °C (58.5) °F	14.8 °C (58.7) °F	14.6 °C (58.4) °F	14.7 °C (58.5) °F	14.4 °C (58) °F
Min. Temperature °C (°F)	8.3 °C (47) °F	9.5 °C (49) °F	10.9 °C (51.6) °F	11.4 °C (52.5) °F	11.3 °C (52.4) °F	10.8 °C (51.4) °F	11 °C (51.8) °F	11 °C (51.8) °F	10.2 °C (50.4) °F	8.3 °C (47) °F	8.1 °C (46.6) °F	7.8 °C (46) °F
Max. Temperature °C (°F)	22.3 °C (72.1) °F	23.6 °C (74.5) °F	23.7 °C (74.7) °F	23.4 °C (74.2) °F	22.9 °C (73.3) °F	21.3 °C (70.4) °F	20 °C (67.9) °F	19.8 °C (67.7) °F	20.1 °C (68.2) °F	20.9 °C (69.5) °F	21.6 °C (70.8) °F	21.5 °C (70.8) °F
Precipitation / Rainfall mm (in)	18 (0)	28 (1)	72 (2)	147 (5)	178 (7)	271 (10)	386 (15)	419 (16)	286 (11)	51 (2)	11 (0)	7 (0)
Humidity(%)	52%	44%	49%	58%	62%	76%	86%	87%	82%	61%	52%	52%
Rainy days (d)	3	4	8	11	10	17	22	22	18	5	2	1
avg. Sun hours (hours)	9.3	9.8	9.6	9.5	9.3	7.8	6.1	5.9	7.1	9.3	9.6	9.3

Figure 9 - 1991 - 2025 Min. Temperature °C (°F), Max. Temperature °C (°F), Precipitation/Rainfall mm (in), Humidity, Rainy days. Data: 2019 - 2025: avg. Sun hours. (Source: - En.climate-data.org)

The headquarters of NIB International Bank is located on Ras Abebe Aregay Street, just behind the National Theatre, in Addis Ababa, Ethiopia, at geographic coordinate's 9°00'54" North latitude and 38°45'01" East longitude. It has 37 stories, four floors, a basement, and 32 floors. The construction cost around two billion Birr, around 400 million Br off budget when construction began five years ago. The area is around 3,600sqm plot of land. The building functions as the main office for the company and is actively used to serve customers.

1 

Figure 10 - Nib Bank Building

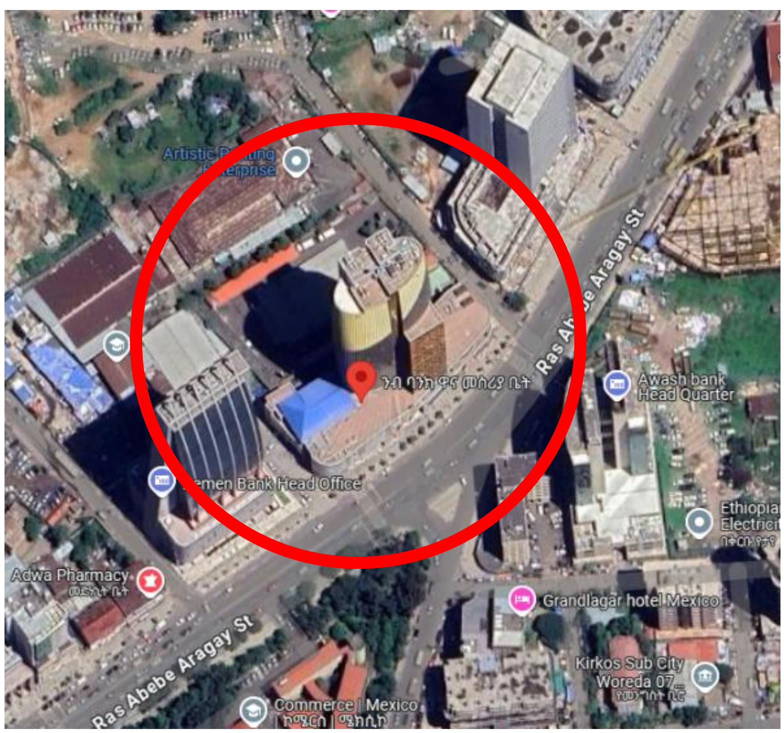


Figure 11 - Nib Bank Building Location (source: Google Earth)

Table 1 - Selected Sample of Building

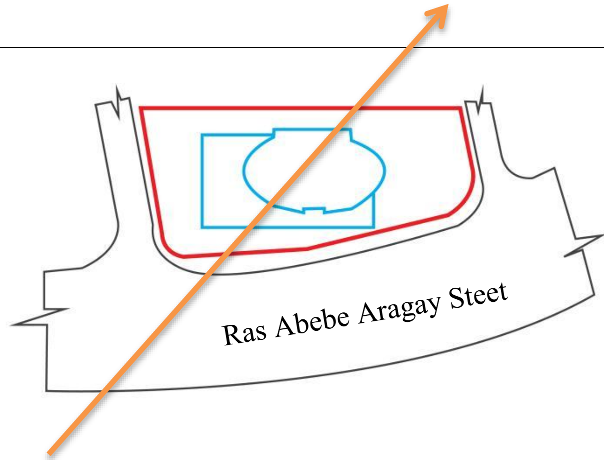
Name of the Building	Building Site Plan with Orientation	Orientation
Nib Bank		S-E oriented

Figure 12 - Site Plan of |Study Area

3.2. RESEARCH APPROACH

This study employs a mixed-method approach, incorporating both quantitative and qualitative data analysis. Quantitative methods include evaluating the Window-to-Wall Ratio (WWR), measuring daylight levels using a lux meter, and conducting simulations using software. Qualitative insights are gathered through on-site observations, describing visual and spatial experiences during the site visit. This combined approach provides a comprehensive understanding of how window sizing influences daylighting performance in high-rise bank buildings.

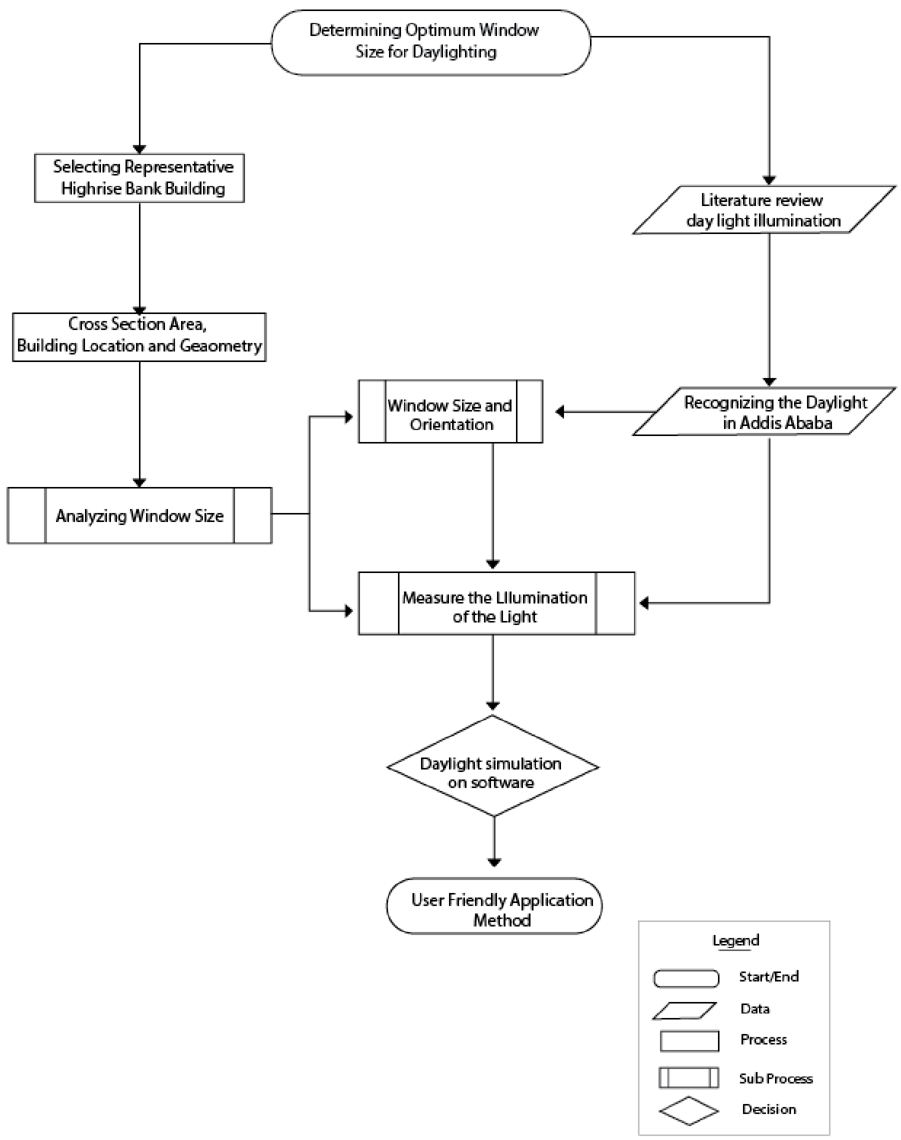


Figure 13 - Research Design (Source - Author)

3.3. DATA TYPE AND SOURCE

This research employed both primary and secondary data to gather comprehensive information. Primary data were collected by measuring window sizes and floor areas from architectural drawings and through on-site visits, where the window-to-floor ratio was calculated to assess compliance with daylighting standards. Additionally, rooms with insufficient or excessive lighting were identified through direct observation and lux meter readings. Secondary data were obtained through a review of relevant literature, including books, academic journals, and technical reports, which provided foundational guidelines on daylighting and informed best practices in window sizing and daylighting design.

3.4. SAMPLING DESIGN AND TECHNIQUES

3.4.1. Study Population

In this research, the study population comprises high-rise office buildings (above 15 stories)

3.4.2. Sampling Technique

The study employs a purposive sampling (targeted selection) approach based on specific criteria to identify a suitable representative case building for in-depth investigation. The objective is to focus on a single representative building that exhibits representative characteristics within the high-rise building in Addis Ababa as the subject of interest, allowing for a daylight analysis for optimum window size. This selection strategy is in line with recommendations by (Campbell, S., Greenwood, M., Prior, S., Shearer, T, 2020). Who emphasize the importance of purposive sampling in research to ensure that the chosen subject aligns with the research objectives.

- **Sampling Criteria**

The NIB Bank Head Office building was selected for this study based on the criteria presented in Table 1. Additionally, its unique ellipsoidal shape allows for the analysis of daylight illumination across all eight cardinal directions. The building also features uniform window glazing, a consistent floor plan, and equal floor-to-floor heights, which are essential for conducting a consistent and comparative analysis. Moreover, the presence of a large number of office spaces beginning from the 5th floor provides a reliable sample for daylight performance evaluation. Another important selection criterion was the availability of detailed working drawings.

Sample floor levels were selected at five-story intervals from the 5th to the 30th floor those are - 5th, 10th, 15th, 20th, 25th, and 30th floors. These floors were chosen because they share the same floor plan and glazing type. The equal interval selection was intended to analyze the impact of building height on daylight illumination in rooms. Office rooms were specifically selected for the study, with orientations covering all cardinal and inter-cardinal directions: North, South, East, West, Northeast, Southeast, Southwest, and Northwest.

Rooms were systematically selected based on their office function, aligning with the study's focus on worker comfort and task performance. The building includes eight different orientations, which are essential to achieving the research objectives. Floor levels were chosen at five-floor intervals to provide a representative sample while accommodating time constraints, with daylight measurements taken at one-hour intervals.

Table 2: Sampling Criteria

Criteria	Description
Building Type	High-rise office building
Construction Status	Operation phase
Geographical Location	Addis Ababa
Façade Composition	Glass curtain wall with aluminum framing
Building Height	Minimum 25 story
Architectural Style	contemporary

- **Sample Size**

Given the specific aims of the research, there is no fixed sample size; the study focuses on a single case building that meets the defined criteria with availability of working drawing.

- **Time Frame**

The data is gathered in one month (March) which is the average sun hour is maximum and under the worst daylight conditions by using Daylight Factor (DF), with the interval of 6 days for 5 days with in time of 3:00AM – 4:00AM, 6:00-7:00, and 9:00 – 10:00 at LT.

- **Grid Point Selection for Daylight Illumination Measurement**

To measure daylight illumination, three grid points were selected at equal intervals of 2 meters from the window, which serves as the primary light source. These points were chosen within a maximum distance of 6 meters, as office desk arrangements extend up to that limit.

Specifically, Point A is located 2 meters from the window, Point B at 4 meters, and Point C at 6 meters. This equal spacing allows for consistent sampling to accurately assess the variation in light intensity across the room.

3.4.3. Data collection tools

Floor plan and drawings or by using meter: - for measuring the window size and wall area to measure WWR based on the standard

Lux meter: - for measuring brightness of high-rise bank building in Addis Ababa in lux to sort out the light insufficient room.

Table 3 - Data Collection Tools

Environmental indicator	**Test instrument**	**Specific objective**	**Image**
To Measure the brightness of the room	Lux meter (Measured on Grid Points**)**	To investigate if the room have enough brightness or not	
To measure the window size and floor area	Floor plan with elevation and drawings or by using Tape meter	To measure WWR based on the standard	 -

3.5. DATA ANALYSIS TECHNIQUES STATISTICAL ANALYSIS

Inferential statistical tests were conducted to evaluate the relationship between window size and daylighting, using data from lux meter readings and window-to-wall ratio (WWR) calculations based on established standards. The analysis helped identify effective strategies to guide architects and designers in selecting optimal window sizes and configurations. These strategies aimed to reduce reliance on artificial lighting, enhance energy efficiency, lower operational costs, and support sustainability while improving occupant well-being and overall environmental performance.

Table 4 - Data Analysis Techniques

No	Specific objective	Data type	Collection method	Instrument	Analysis
1	To analyze the daylighting performance of existing window configurations in high-rise bank building in a case study on Nib International Bank Head Office in Addis Ababa.	Measure Daylight at three(3) point, LEED Standard (from 3:00AM to 10:00 AM)LT	Measured daylighting value, compare to the LEED Standard,	Lux meter	To analysis the efficient of daylight in a room
2	To examine how window size and orientation affect indoor daylight levels in high-rise bank buildings in a case study on Nib International Bank Head Office in Addis Ababa.	Window area, orientation, measured day light in a month (from 3:00AM to10:00 AM)LT,	On site measurement, map, measured daylight value	Lux meter, meter, map	To analysis the relationship between window size, orientation, day light level under Addis Ababa climate condition
3	To analyze the variation in daylight illumination through simulations based on different window-to-wall ratios (WWR) in a case study on	Window area, wall area, WWR calculation And Simulation	Using Software for Simulation and WWR=Windo	Software (Design Builder)	To determine optimum window size with respect to LEED

	Nib International Bank Head Office in Addis Ababa.	(photo)	w area/Wall area		standard (sDA300/50%)

3.6. PRESENTATION AND INTERPRETATION

The qualitative and quantitative data obtained was analyzed were interpreted through descriptive, explanatory techniques and displayed using graphics. And data interpret through organized manner by using presentation techniques like Table, chart, map and figures.

3.7.RELIABILITY AND VALIDITY

In the study of window sizing for daylighting in high-rise bank buildings in Addis Ababa, Ethiopia, ensuring reliability and validity is paramount to producing credible results. Reliability will be achieved through consistent measurement techniques, such as using lux meters to obtain accurate and repeatable lux readings at various interior locations throughout the selected buildings.

The use of standardized protocols for calculating the window-to-wall ratio (WWR) will further enhance reliability by minimizing variability in data collection. To establish validity, the research will incorporate established daylighting standards and guidelines, ensuring that the methods employed are grounded in recognized principles of architectural design and environmental psychology.

3.8. ETHICAL CONSIDERATIONS

The research data was kept confidential throughout the study, and participants provided their permission to take part voluntarily. The dignity and well-being of the respondents were protected. All resources used in the research were properly acknowledged. The measuring equipment was positioned to avoid disturbing the occupants. The results were analyzed in relation to established standards without any manipulation.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1. INTRODUCTION

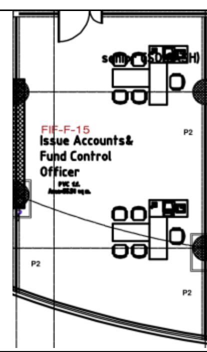
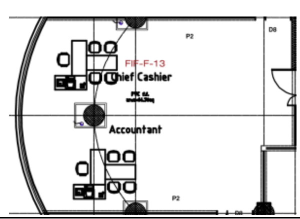
This chapter discusses the result of the data and presents the analyzed data, which is collected during the study to ensure the objectives of the research. Subjective and objective approaches were used, according to BREEAM and LEED. The daylight illumination level of high-rise bank buildings is presented according to the collection of one month and avg. Sun hours of March, 2025.

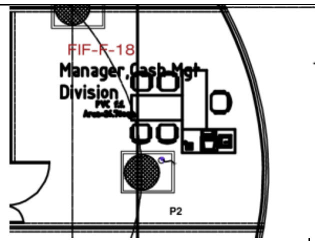
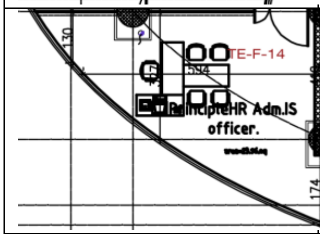
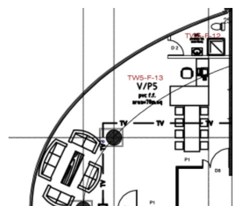
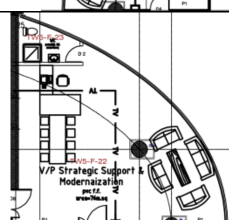
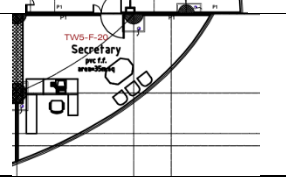
4.2.RESULT AND DISCUSSION

4.2.1. Window-to-Wall Ratio (WWR)

The table shows the Window-to-Wall Ratio (WWR) calculated based on building orientation.

Table 5:- Window to Wall Ratio (WWR) from 5th Floor to 32 Floor

No	**No**	**Window Orientation**	**Glassing Type**	**Floor plan**	**Window glass Size (m^2)**	**Aluminum frame(m^2)**	**Wall Area (m^2)**	**WWR%**
	W1	**S-E**			20.3538	0.0012	36.344	56%
5TH	W-2	**S-W**	5mm Thick Clear Glass with		9.4396	0.0006	16.551	57.03%

Floor to 32 Floor	W-3	**N-E**	Aluminum frame		4.7171	0.0003	8.2755	57%
	W-4	**S**			6.1796	0.0003	11.12282	55.56%
	W-5	**W**			10.84638	0.0006	19.0269	57%
	W-6	**N**			10.84638	0.0006	19.0269	57%
	W-7	**E**			4.7171	0.0003	8.2755	57%

All windows from the 5th to 32nd floors are fitted with 5mm thick clear glass and aluminum frames, ensuring uniformity in glazing materials. This consistency allows for a more precise analysis of daylight performance in relation to window orientation and size. The Window-to-Wall Ratios (WWR) for the building range from 55.56% to 57.03%, showing minimal variation. These values are significantly higher than the commonly recommended WWR range of 30% to 40%, indicating a strong emphasis on maximizing natural daylight penetration throughout the building.

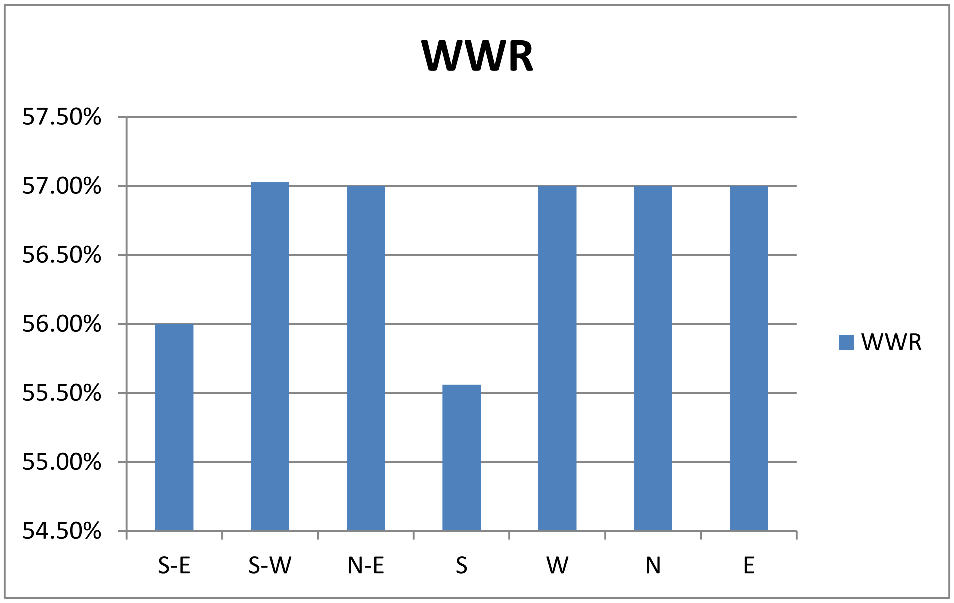


Figure 14 - The figure shows the relationship between Window-to-Wall Ratio (WWR) and the orientation of the building

4.2.2. Floor Plan Showing Grid Points in Various Orientations

Points A, B, and C are positioned at distances of 2 meters, 4 meters, and 6 meters from the window, respectively. This equal spacing ensures consistent sampling, allowing for an accurate assessment of how light intensity varies throughout the room.

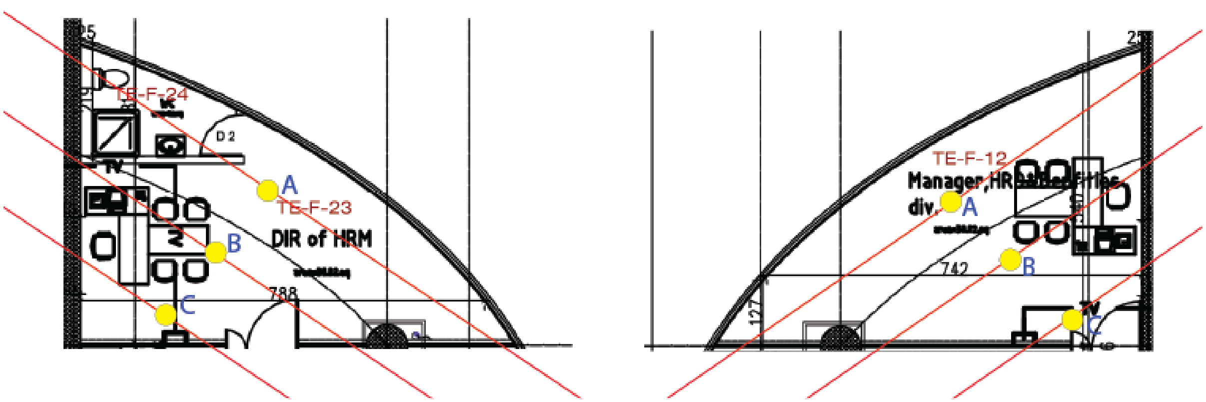
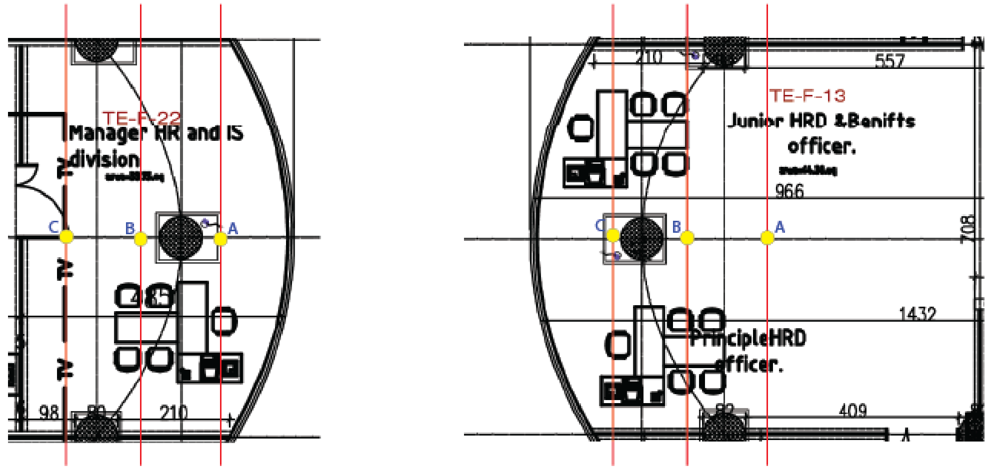
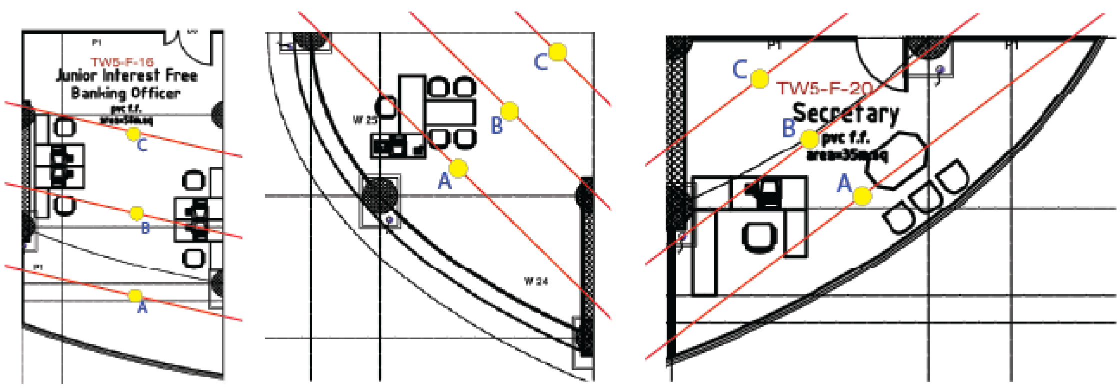


Figure 15 - Floor Plan Showing Grid Points in North and West Orientations



NE (North East) SW (South West)

Figure 16 - Floor Plan Showing Grid Points in North-East and South-West Orientations



SE (South East) S (South) E(East)

Figure 17 - Floor Plan Showing Grid Points in South East, South, and East Orientations

4.2.3. Daylight Illumination

Tables showing daylight measurements at grid points using a lux meter, with respect to time intervals, floor levels, and building orientation

Table 6:- Measured Daylight Illumination on 5th Floor

Floor Level	Orientation	Time(LT)	Average daylight in the month of March at a grid points daylight illumination(Lux)		
			A	**B**	**C**
5th floor	**S-E**	3:00 AM - 4:00 AM	1423	725	432
		6:00 AM - 7:00 AM	1432	738	447
		9:00 AM -10:00 AM	1422	726	433
	S-W	3:00 AM - 4:00 AM	1944	811	542
		6:00 AM - 7:00 AM	1953	816	550
		9:00 AM -10:00 AM	1950	810	545
	N-E	3:00 AM - 4:00 AM	1466	705	452
		6:00 AM - 7:00 AM	1470	708	457
		9:00 AM -10:00 AM	1472	704	455
	S	3:00 AM - 4:00 AM	1424	721	430
		6:00 AM - 7:00 AM	1435	729	436
		9:00 AM -10:00 AM	1433	725	433
	W	3:00 AM - 4:00 AM	1820	807	561
		6:00 AM - 7:00 AM	1827	810	572
		9:00 AM -10:00 AM	1824	805	567
	N	3:00 AM - 4:00 AM	1622	740	451
		6:00 AM - 7:00 AM	1630	744	455
		9:00 AM -10:00 AM	1631	748	453

Table 7:- Measured Daylight Illumination on 10th Floor

Floor Level	Orientation	Time(LT)	Average daylight in the month of March at a grid points daylight illumination(Lux)		
			A	**B**	**C**
10th floor	**S-E**	3:00 AM - 4:00 AM	1424	727	433
		6:00 AM - 7:00 AM	1436	738	447
		9:00 AM -10:00 AM	1422	729	438
	S-W	3:00 AM - 4:00 AM	1944	812	540
		6:00 AM - 7:00 AM	1955	816	550
		9:00 AM -10:00 AM	1951	810	546
	N-E	3:00 AM - 4:00 AM	1467	707	453
		6:00 AM - 7:00 AM	1470	710	457
		9:00 AM -10:00 AM	1472	707	455
	S	3:00 AM - 4:00 AM	1424	723	431
		6:00 AM - 7:00 AM	1436	729	438
		9:00 AM -10:00 AM	1433	725	433
	W	3:00 AM - 4:00 AM	1821	810	563

		6:00 AM - 7:00 AM	1827	814	572
		9:00 AM -10:00 AM	1823	805	566
	N	3:00 AM - 4:00 AM	1622	741	450
		6:00 AM - 7:00 AM	1633	744	455
		9:00 AM -10:00 AM	1631	748	452

Table 8:- Measured Daylight Illumination on 15th Floor

Floor Level	Orientation	Time(LT)	Average daylight in the month of March at a grid points daylight illumination(Lux)		
			A	**B**	**C**
15th floor	**S-E**	3:00 AM - 4:00 AM	1423	731	434
		6:00 AM - 7:00 AM	1436	739	449
		9:00 AM -10:00 AM	1421	729	438
	S-W	3:00 AM - 4:00 AM	1945	815	541
		6:00 AM - 7:00 AM	1955	820	551
		9:00 AM -10:00 AM	1951	811	547
	N-E	3:00 AM - 4:00 AM	1468	709	453
		6:00 AM - 7:00 AM	1473	715	459
		9:00 AM -10:00 AM	1470	707	457
	S	3:00 AM - 4:00 AM	1426	723	433
		6:00 AM - 7:00 AM	1438	729	440
		9:00 AM -10:00 AM	1433	725	433
	W	3:00 AM - 4:00 AM	1821	813	564
		6:00 AM - 7:00 AM	1827	812	573
		9:00 AM -10:00 AM	1823	809	566
	N	3:00 AM - 4:00 AM	1623	740	451
		6:00 AM - 7:00 AM	1633	745	456
		9:00 AM -10:00 AM	1631	748	452

Table 9: Measured Daylight Illumination on 20th Floor

Floor Level	Orientation	Time(LT)	Average daylight in the month of March at a grid points daylight illumination(Lux)		
			A	**B**	**C**
20th floor	**S-E**	3:00 AM - 4:00 AM	1428	743	436
		6:00 AM - 7:00 AM	1441	749	453
		9:00 AM -10:00 AM	1423	735	439
	S-W	3:00 AM - 4:00 AM	1948	818	544
		6:00 AM - 7:00 AM	1959	824	554
		9:00 AM -10:00 AM	1953	815	550
	N-E	3:00 AM - 4:00 AM	1472	710	456
		6:00 AM - 7:00 AM	1479	721	464
		9:00 AM -10:00 AM	1471	711	460
	S	3:00 AM - 4:00 AM	1425	726	439
		6:00 AM - 7:00 AM	1442	732	446
		9:00 AM -10:00 AM	1436	727	435

	W	3:00 AM - 4:00 AM	1822	816	569
		6:00 AM - 7:00 AM	1833	821	577
		9:00 AM -10:00 AM	1825	811	567
	N	3:00 AM - 4:00 AM	1626	750	454
		6:00 AM - 7:00 AM	1638	763	460
		9:00 AM -10:00 AM	1635	753	453
	E	3:00 AM - 4:00 AM	1470	711	458
		6:00 AM - 7:00 AM	1476	719	468
		9:00 AM -10:00 AM	1472	712	457

Table 10:- Measured Daylight Illumination on 25th Floor

Floor Level	Orientation	Time(LT)	Average daylight in the month of March at a grid points daylight illumination(Lux)		
			A	**B**	**C**
25th floor	**S-E**	3:00 AM - 4:00 AM	1436	747	444
		6:00 AM - 7:00 AM	1445	752	457
		9:00 AM -10:00 AM	1429	739	445
	S-W	3:00 AM - 4:00 AM	1954	822	552
		6:00 AM - 7:00 AM	1962	829	562
		9:00 AM -10:00 AM	1956	820	555
	N-E	3:00 AM - 4:00 AM	1479	719	460
		6:00 AM - 7:00 AM	1485	727	469
		9:00 AM -10:00 AM	1476	718	462
	S	3:00 AM - 4:00 AM	1432	728	441
		6:00 AM - 7:00 AM	1448	738	451
		9:00 AM -10:00 AM	1438	732	446
	W	3:00 AM - 4:00 AM	1826	828	572
		6:00 AM - 7:00 AM	1839	827	580
		9:00 AM -10:00 AM	1827	816	573
	N	3:00 AM - 4:00 AM	1632	758	463
		6:00 AM - 7:00 AM	1645	769	473
		9:00 AM -10:00 AM	1633	759	457
	E	3:00 AM - 4:00 AM	1475	718	463
		6:00 AM - 7:00 AM	1482	724	475
		9:00 AM -10:00 AM	1475	717	467

Table 11:- Measured Daylight Illumination on 30 Floor

Floor Level	Orientation	Time(LT)	Average daylight in the month of March at a grid points daylight illumination(Lux)		
			A	**B**	**C**
	S-E	3:00 AM - 4:00 AM	1436	749	443
		6:00 AM - 7:00 AM	1446	754	457
		9:00 AM -10:00 AM	1429	739	444
	S-W	3:00 AM - 4:00 AM	1953	825	552
		6:00 AM - 7:00 AM	1963	830	563

30th floor		9:00 AM -10:00 AM	1955	821	554
	N-E	3:00 AM - 4:00 AM	1480	719	461
		6:00 AM - 7:00 AM	1484	726	469
		9:00 AM -10:00 AM	1477	712	463
	S	3:00 AM - 4:00 AM	1433	728	442
		6:00 AM - 7:00 AM	1449	739	452
		9:00 AM -10:00 AM	1439	731	446
	W	3:00 AM - 4:00 AM	1826	828	573
		6:00 AM - 7:00 AM	1840	826	581
		9:00 AM -10:00 AM	1828	815	574
	N	3:00 AM - 4:00 AM	1632	759	463
		6:00 AM - 7:00 AM	1643	770	474
		9:00 AM -10:00 AM	1632	759	457
	E	3:00 AM - 4:00 AM	1474	720	465
		6:00 AM - 7:00 AM	1483	728	474
		9:00 AM -10:00 AM	1476	721	468

From the tables showing daylight measurements at grid points using a lux meter, with respect to time intervals, floor levels, and building orientation (from Table 6 - Table 11)

The measured daylight illumination between 6:00 AM and 7:00 AM (local time) is higher compared to the intervals of 3:00 AM–4:00 AM and 9:00 AM–10:00 AM (local time). Additionally, the illumination levels are slightly higher on the southwest (SW) and west (W) orientations compared to other directions. This indicates that window orientation particularly in the SW and W directions has a noticeable impact on daylight availability and should be considered when evaluating or optimizing window size and placement.

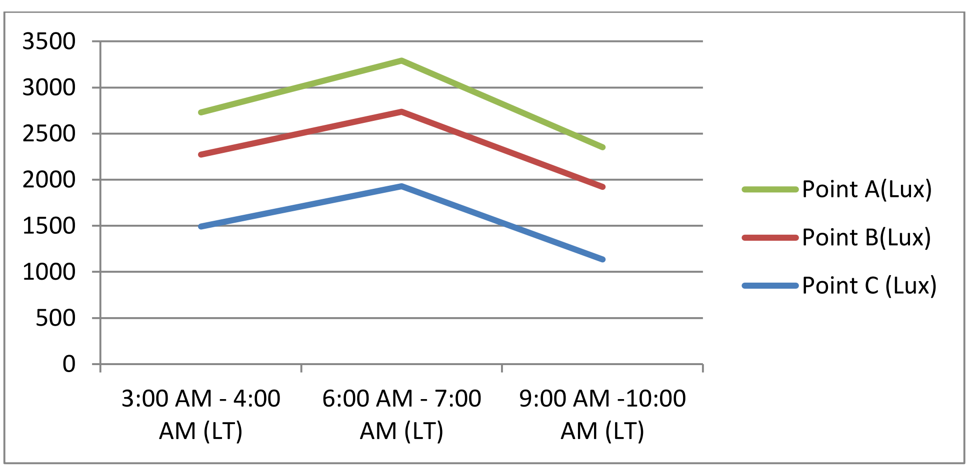


Figure 18 - The figure shows the average daylight illumination at grid points A, B, and C.

4.2.4. Simulation Analysis

The simulation was conducted using DesignBuilder software, incorporating the climate data of Addis Ababa to model and determine the optimum window size for the building.

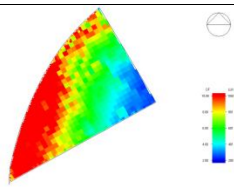
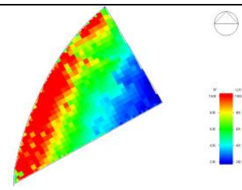
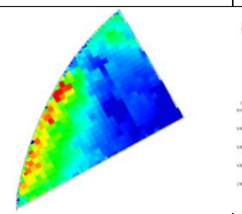
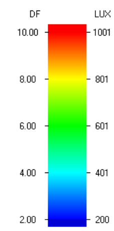
Orientation	west			Illumination of light (lux)
Simulation				
WWR	57%	40%	30%	

Figure 19 -Simulation of optimal window-to-wall ratio (WWR) for west-facing orientation using DesignBuilder software

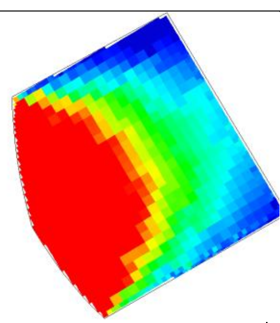
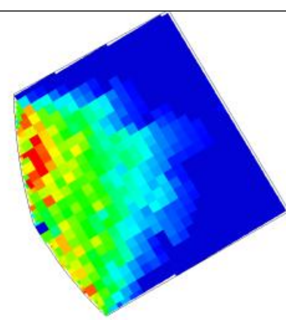
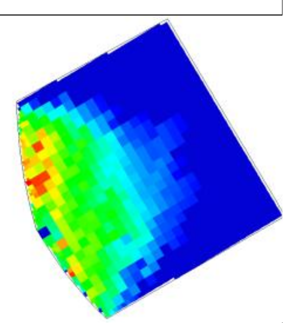
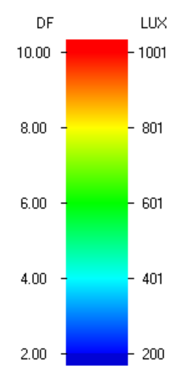
Orientation	South West			
Simulation				
WWR	57%	40%	30%	

Figure 20 -Simulation of optimal window-to-wall ratio (WWR) for South West-facing orientation using DesignBuilder software

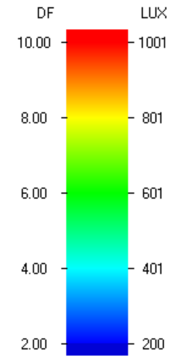
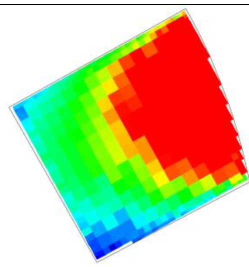
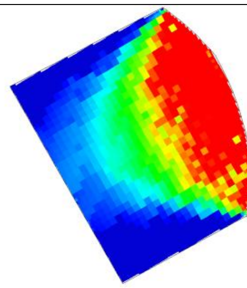
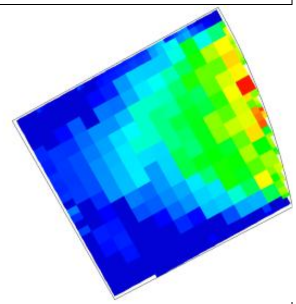
Orientation	North East			
Simulation				
WWR	57%	40%	35%	

Figure 21 -Simulation of optimal window-to-wall ratio (WWR) for North East-facing orientation using DesignBuilder software

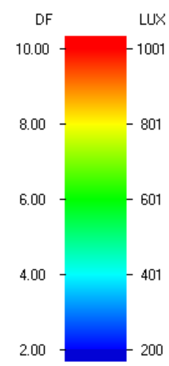
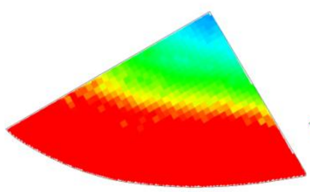
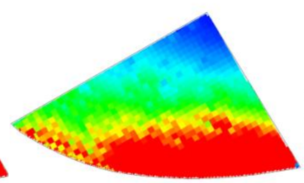
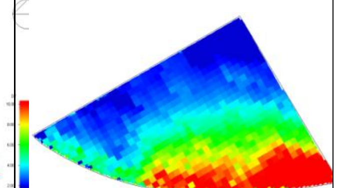
Orientation	South			
Simulation				
WWR	56%	40%	30%	

Figure 22 - Simulation of optimal window-to-wall ratio (WWR) for South-facing orientation using DesignBuilder software

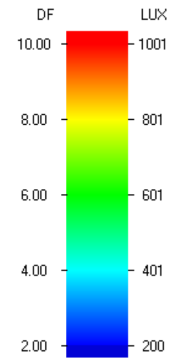
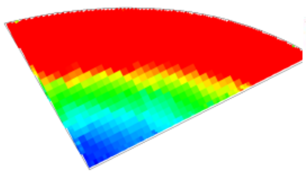
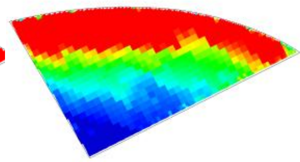
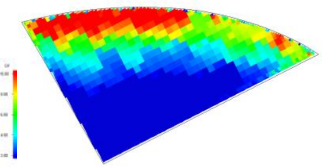
Orientation	North			
Simulation				
WWR	56%	40%	30%	

Figure 23- Simulation of optimal window-to-wall ratio (WWR) for North-facing orientation using DesignBuilder software

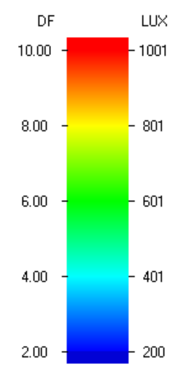
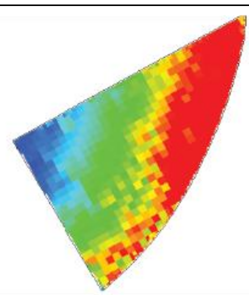
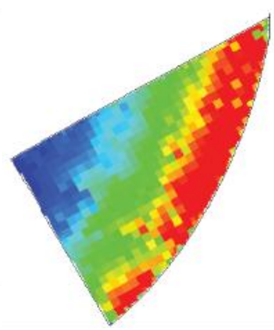
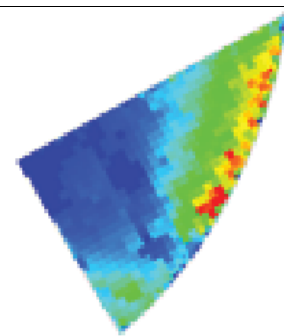
Orientation	East			
Simulation				
WWR	57%	40%	30%	

Figure 24 -Simulation of optimal window-to-wall ratio (WWR) for East-facing orientation using DesignBuilder software

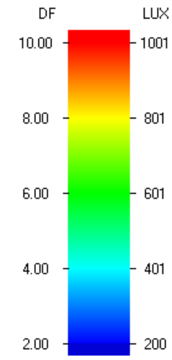
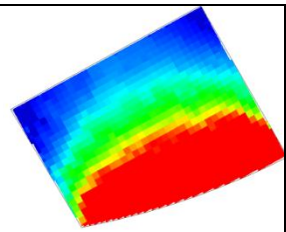
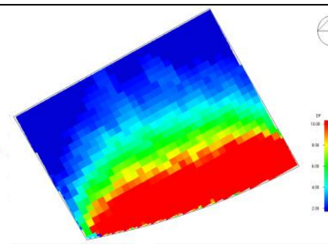
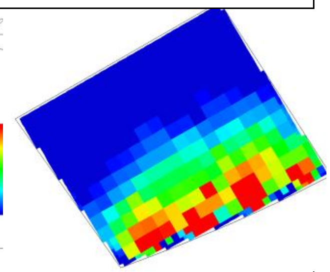
Orientation	South East			
Simulation				
WWR	57%	40%	30%	

Figure 25 - Simulation of optimal window-to-wall ratio (WWR) for South East-facing orientation using DesignBuilder software

Based on the simulation results, the optimum window size for each orientation was determined using the LEED daylighting standard (DA300/50%), which requires that at least 55%, 75%, or 90% of the regularly occupied floor area receive a minimum of 300 lux for at least 50% of annual occupied hours.

According to the simulation, a 30% Window-to-Wall Ratio (WWR) is recommended for the west and southwest orientations due to higher daylight exposure, which helps avoid glare and overheating. For the northeast orientation, a 35% WWR is suggested. For the remaining orientations east, north, south, and southeast a 40% WWR is recommended to ensure adequate daylighting while maintaining comfort and energy efficiency.

The measured daylight illumination on the upper floors specifically the 20th, 25th, and 30th levels shows slightly higher values compared to the lower floors, such as the 5th and 10th. This difference is primarily due to the building's compactness at the lower levels, where daylight entering the rooms is more likely to be reflected or diffused from surrounding objects, rather than received directly.

Figure 26 - shows the nearby surrounding building (source: Author)

4.2.5. Observation

In the southern room, reflections from the Zemen Bank building between 8:00 and 9:00 AM (at Local Time) cause glare, leading to an uncomfortable working environment for occupants. Rooms facing the NE, SW, N, and NW directions also experience higher daylight illumination levels. To minimize the overlight, use a curtain and use artificial light to balance the overall illumination of light intensity in the rooms.

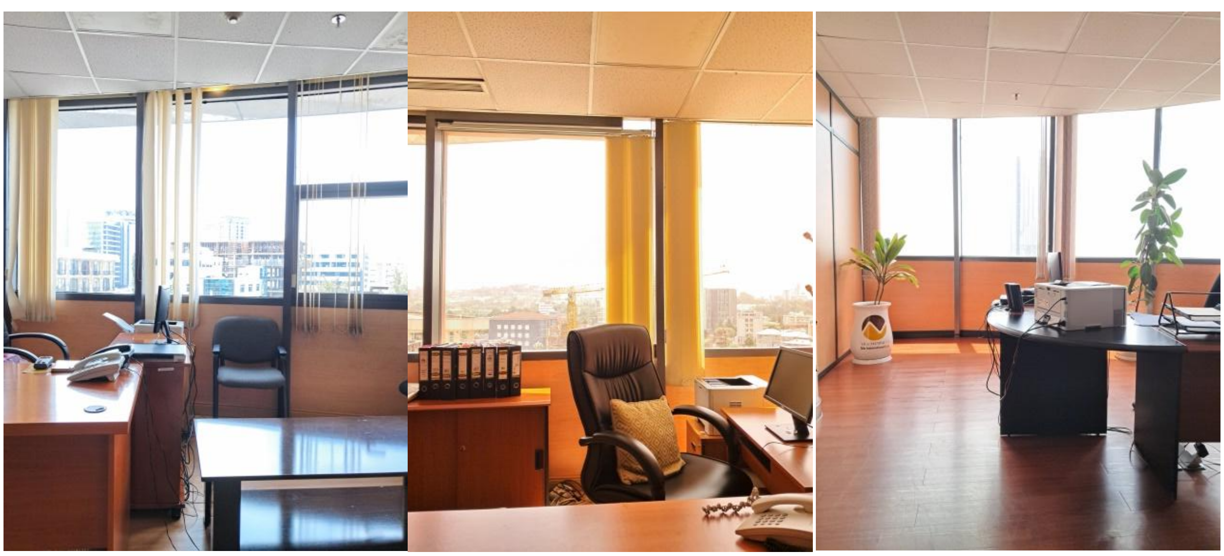


Figure 27 - Image of the Nib Bank office interior (source: Author day march 6, 2025 at 6:00 AM LT)

Based on observations, 50×50 cm ceiling panel lights are used to balance indoor lighting in place of daylight. A minimum of two panel lights are switched on in each room. With at least 7 rooms per floor, this results in a minimum of 14 panel lights used on one floor. Given that the building has 32 floors, the total number of panel lights amounts to 448.

Each panel consumes 0.06 kilowatt-hours (kWh) per hour, resulting in a total hourly energy consumption of 26.88 kWh. If these lights are used for a minimum of 6 hours per day, the daily energy consumption becomes 161.28 kWh. Over the course of a year, this adds up to approximately 58,867.2 kWh.

Figure 28 - The figure shows that 50×50 cm ceiling panel lights are used during the day in the office of the Nib Bank building (Source: Author march 12, 2025 at 9:00 AM LT)

The Zemen Bank building is located to the southwest of the building, which results in unwanted glare entering the rooms on the southwest orientation. This glare forces the workers to use curtains to block the light.

Figure 29 - Zemen Bank Building (Source: Author March 24, 2025)

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1. CONCLUSION

The analysis of daylight performance in the Nib Bank building shows a strong architectural focus on maximizing natural daylight through high and consistent Window-to-Wall Ratios (WWRs), ranging from 55.56% to 57.03% (S-E:56%, S-W:57%, N-E:57%, S:55.56%, W:57%, N:56%, E:56%). While this exceeds the commonly recommended range of 25–40 %,(LEED standard) it provides abundant daylight access across the building's occupied floors. Additionally, measurements and simulations indicate that orientation plays a critical role in daylight distribution, with the southwest and west façades receiving the highest levels of illumination often resulting in glare and thermal discomfort.

Simulation results suggest that current WWRs could be optimized further by orientation: reducing them to 30% on the west and southwest façades, while allowing 35–40% on other sides to balance daylight provision and visual comfort. Floor level also influences daylight penetration, with upper floors benefiting from greater exposure compared to the lower, more enclosed levels.

Despite the building's high daylighting potential, observations show heavy reliance on artificial lighting during the day. The workers preferred artificial light over daylight because they could control illumination by adjusting the number of lights turned on or off. The use of panel lights contributes to significant energy consumption estimated at approximately 58,867.2 kWh annually show the gap between daylight availability and its effective use.

Zemen building which is located nearby Nib Bank buiding have glare on the side of SW direction of office rooms, where occupants resort to using curtains to block excessive sunlight, thereby negating the intended benefits of natural daylight

.In conclusion, while the design strategy of maximizing daylight in the High rise Bank building is commendable, a more nuanced approach incorporating orientation-specific WWRs, glare control solutions, and improved integration between natural and artificial lighting is essential to enhance occupant comfort and reduce energy use sustainably.

5.2. RECOMMENDATIONS

- Based on the results obtained from the research, adequate daylight for high-rise bank buildings is affected by window size based on the orientation and microclimate.
- On the orientation of WS and W side have greater daylight illumination based on that the WWR have to be minimized on the WS and W orientation other than other orientation.
- Architects have to consider the window size based on the orientation by using software analysis additional to the aesthetic of the building.
- Also in Addis Ababa micro climate it is recommended to have 30% of WWR by S and SW direction and other direction 35 %- 40 % recommended.
- It have to be consider the future urban development of building for shading, reflects of light from other building also consider the using material that do not disturb the surrounding by reflective.
- In terms of modern design designers use curtain walls without considering the day light illumination of the building rooms there for architects have to consider the modern design with sustainability.
- Material selection is also critical; highly reflective materials should be avoided if they disturb neighboring buildings or contribute to glare.
- In modern architecture, the frequent use of curtain walls often prioritizes visual appeal over daylight performance. Therefore, architects must integrate modern design principles with sustainable daylighting strategies, ensuring that both form and function contribute to energy efficiency and occupant well-being.

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APPENDIX-I

Figure 30 : Measuring equipment being placed in the study area (Source: Author)

Figure 31: HQ of Nib Bank Building Office Space

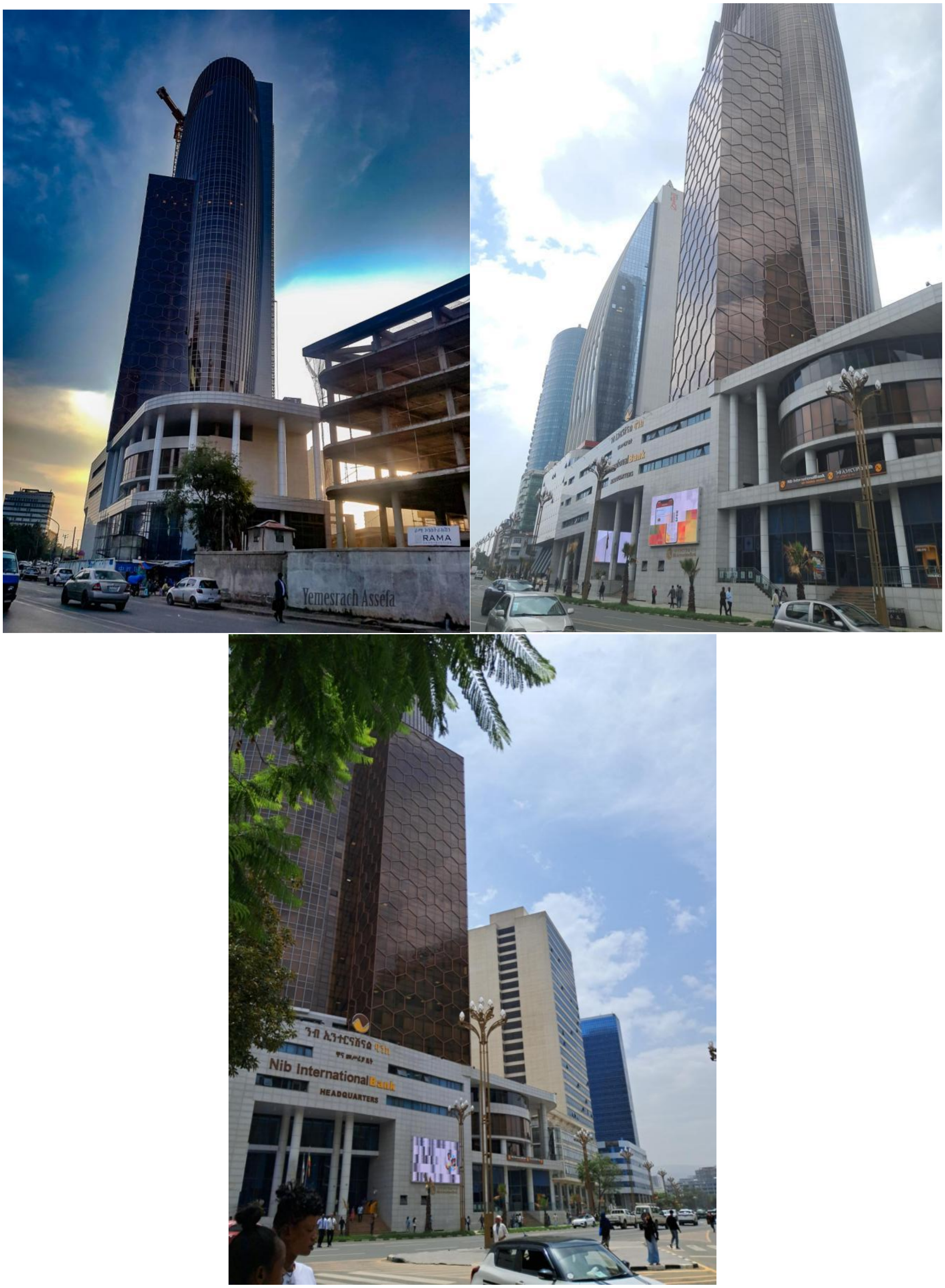

Figure 32 : Surrounding nearby building from 2024 to 2025 (Source: Wikipedia and Author)

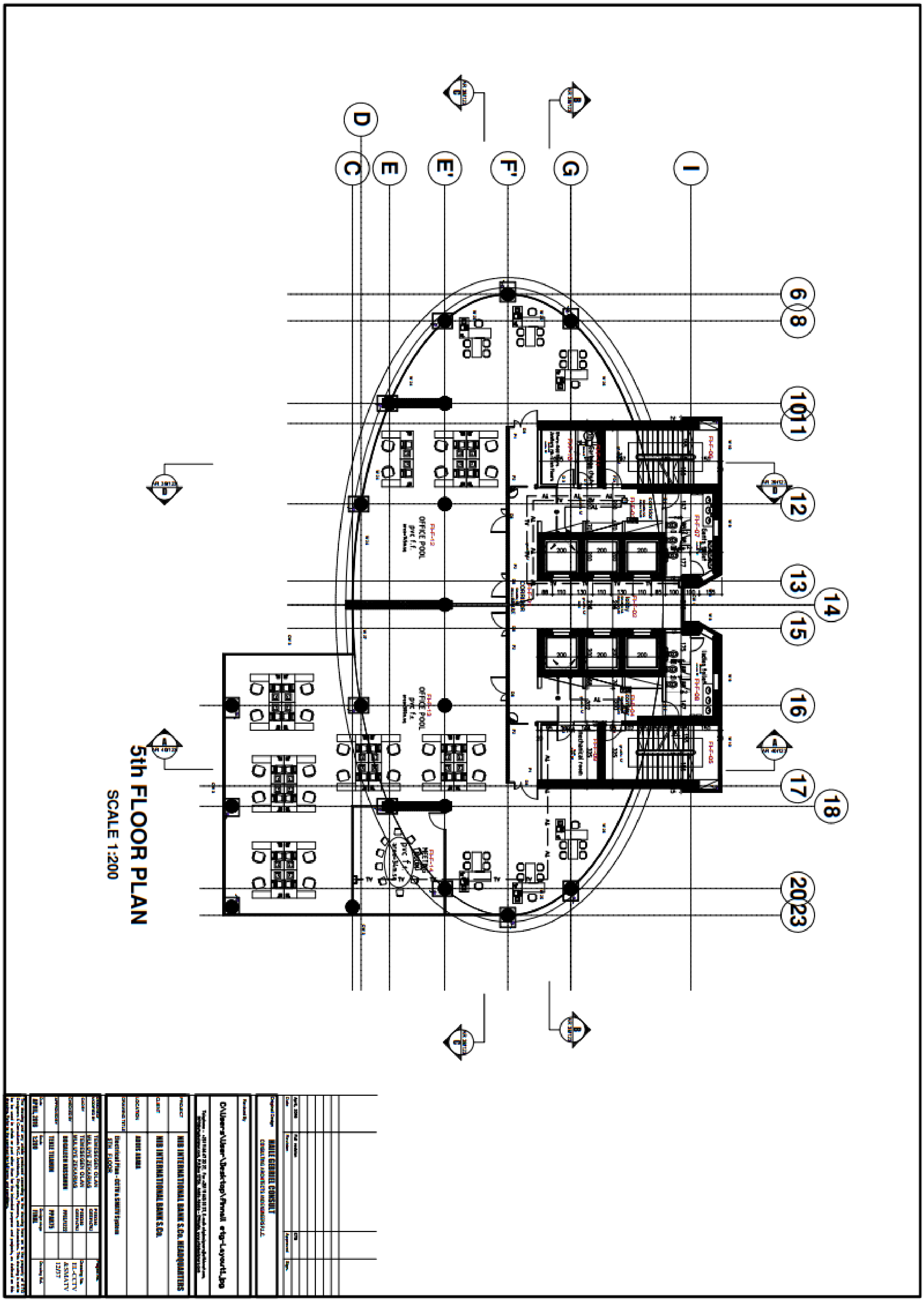

Figure 33-Nib Head Quarter 5 floor plan

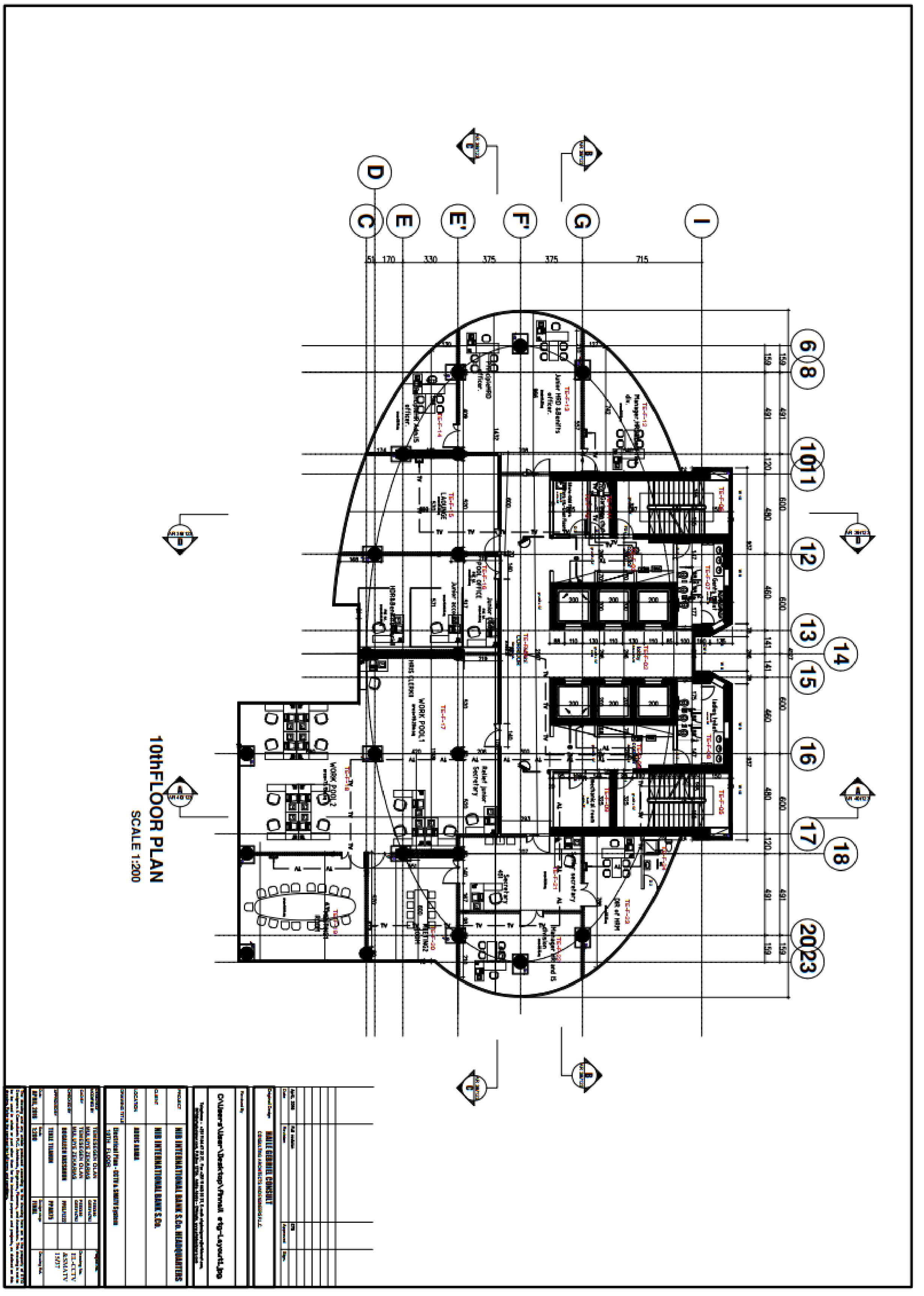

Figure 34 - Nib Head Quarter10 floor plan

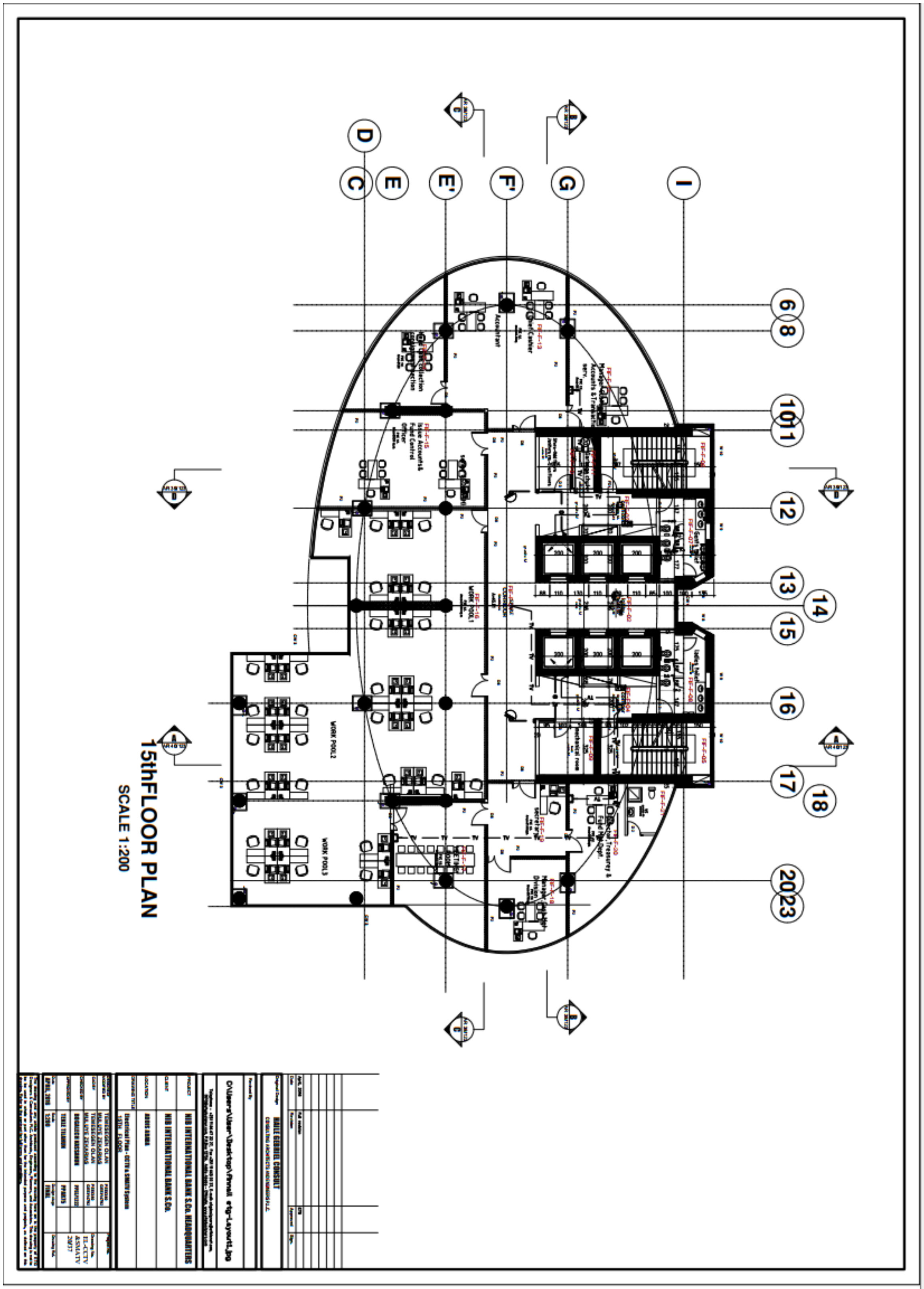

Figure 35 - Nib Head Quarter 15 floor plan

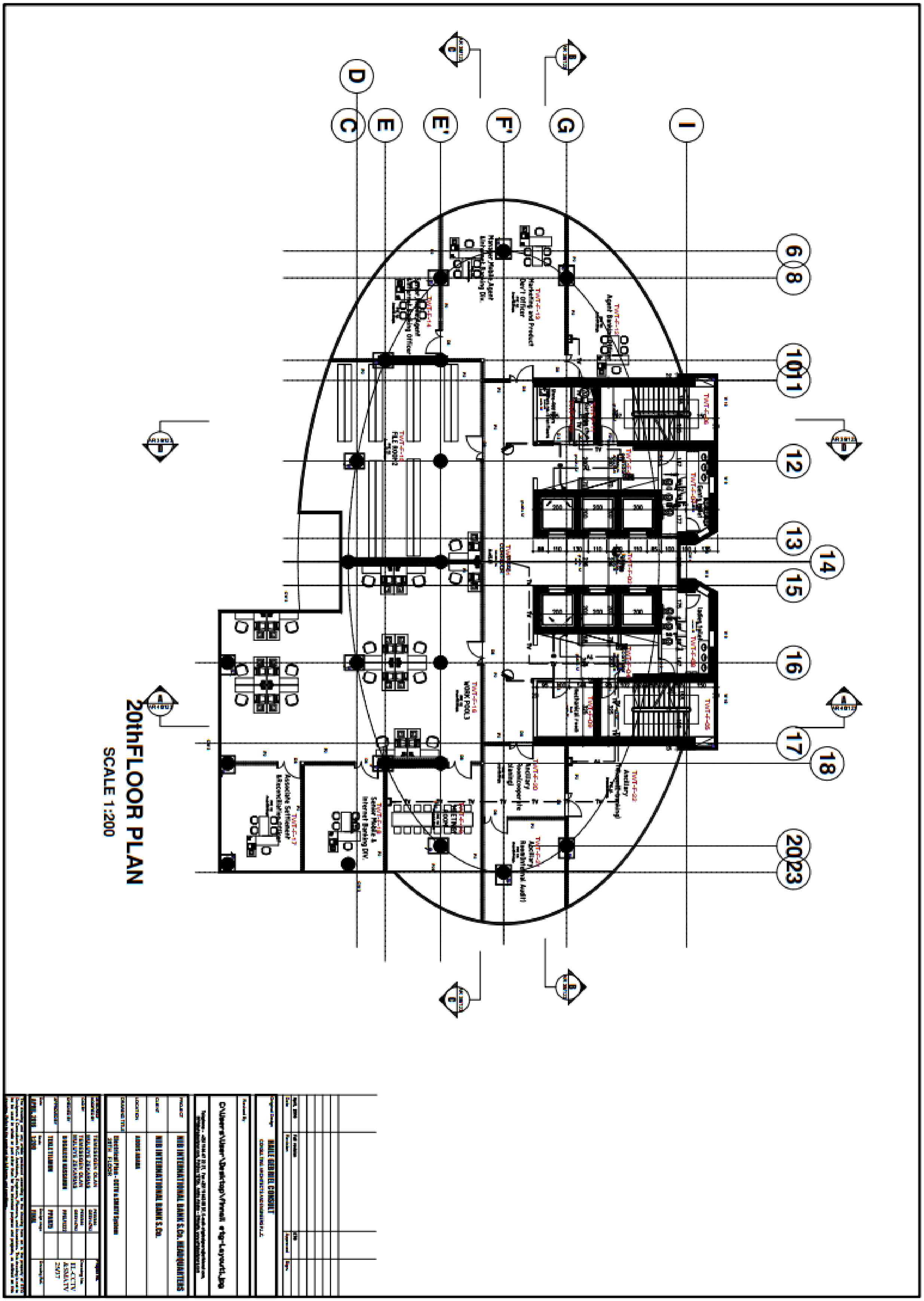

Figure 36 - Nib Head Quarter 20 floor plan

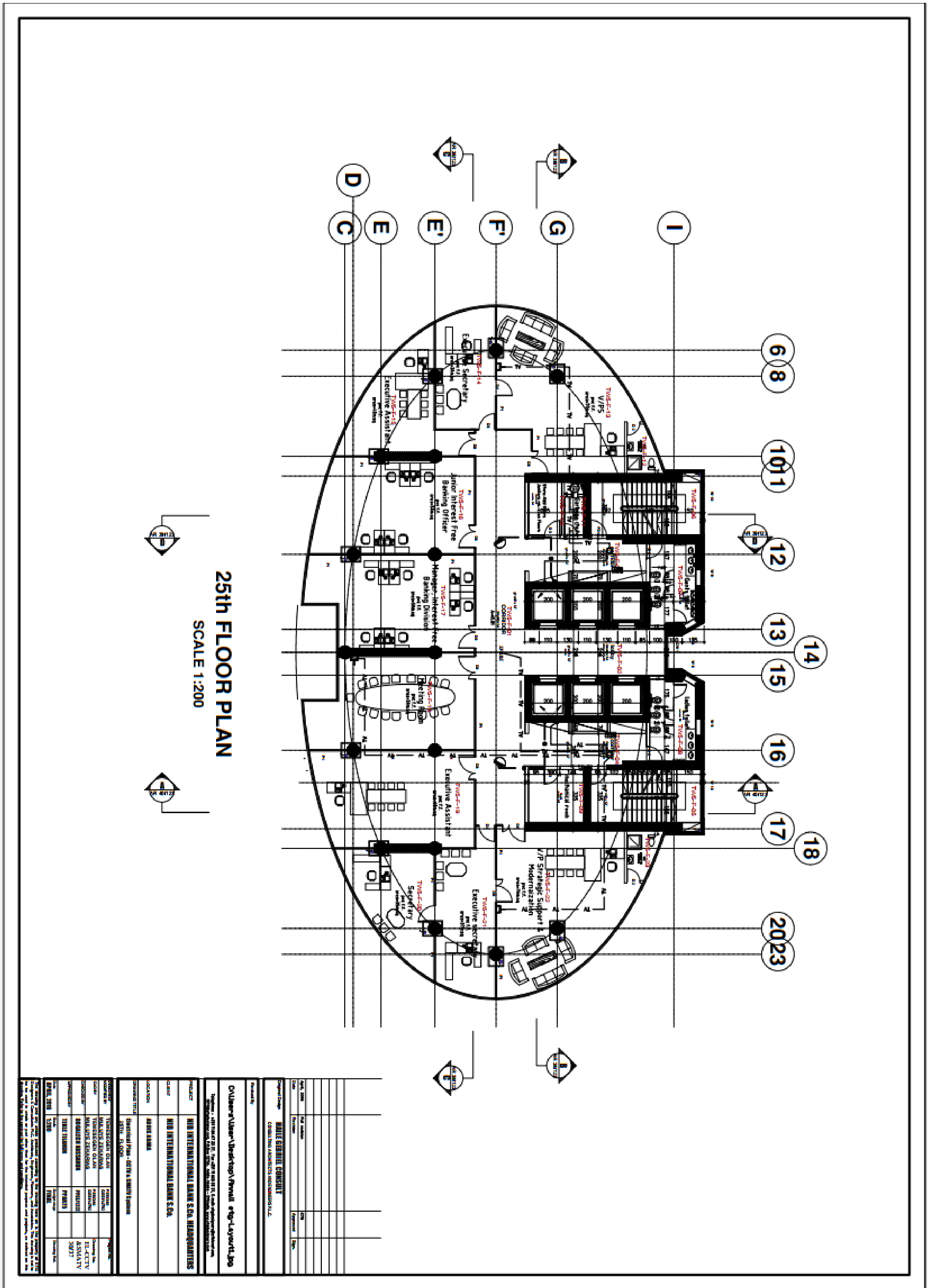

Figure 37- Nib Head Quarter 25 floor plan