INVESTIGATING BUILDING ORIENTATION AND LEVEL OF DAY LIGHT OF COMMERCIAL BUILDINGS IN BALE ROBE TOWN

By: Anatoli Alemu Gemechu

A Thesis Submitted To Department Of Architecture

School Of Civil Engineering and Architecture

Presented In Partial Fulfillment of the Requirement for the Degree

Of Master's In Environmental Architecture

Office of Graduate Studies

Adama Science and Technology University

May, 2024

Adama, Ethiopia

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Declaration

I hereby declare that this master thesis entitled "**Investigating Building Orientation and Level of Day Light of Commercial Buildings in Bale Robe Town"** is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Anatoli Alemu ______________________ ___________________

Name of student signature date

Recommendation of advisor

I, the advisor of this thesis, hereby certify that i have read the revised version of the thesis entitled "**Investigating Building Orientation And Level Of Day Light Of Commercial Buildings In Bale Robe Town**" prepared under my guidance by Anatoli Alemu submitted in partial fulfillment of the requirements for the degree of master's in environmental architecture. Therefore, i recommend the submission of revised version of the thesis to the department following the applicable procedures.

Prof. Ambuj kumar	______________________	______________________
Major advisor	signature	date

Approval sheet

I, the advisors of the thesis entitled "**Investigating Building Orientation and Level of Day Light of Commercial Buildings in Bale Robe Town"** developed by **Anatoli Alemu Gemechu,** hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Prof. Ambuj kumar ______________________ ______________________

Major advisor signature date

We, the undersigned, members of the board of examiners of the thesis by Anatoli Alemu Gemechu have read and evaluated the thesis entitled "**Investigating Building Orientation And Level Of Day Light Of Commercial Building In Bale Robe Town"** 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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Internal examiner signature date

______________________ ______________________ ______________________

External examiner signature date

Finally, approval and acceptance of the thesis is contingent upon submission of its final copy to the office of postgraduate studies (OPGS) through the department graduate council (DGC) and school graduate committee (SGC).

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Department head signature date

______________________ ______________________ ______________________

School dean signature date

______________________ ______________________ ______________________

Office of postgraduate studies, dean signature date

Acknowledgment

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List of Acronyms and abbreviations

ASHRAE American Society of Heating, Refrigerating and Air Conditioning Engineers

EPA Environmental Protection Authority

GBC Green Building Council

HVAC Heating, Ventilation, Air Conditioning

IAQ Indoor air quality

SEA Strategic Environmental Assessment

SHGC Solar Heat Gain Coefficient

VC visual comfort

VCI visual comfort indices

WWR window to wall ratio (%)

MR Metabolic Rate

N North

NE North East

S South

SW South West

W West

Max Maximum

Min Minimum

List Local terms

Belg - season (short rainy season) in the months of February to May

Kiremt - (the main rainfall season) extending from June to September

Dega - Highland

Weina - dega midland

Quolla - lowland

‘Kalus’ - spiritual fathers pray to god

Abstract

A good performance of day lighting system with proper building orientation can maximizing daylight energy efficiency enhances occupants' wellbeing and productivity. A well-designed building with proper orientation can maximize daylight utilization, reducing the need for artificial lighting and consequently lowering energy consumption. The study was focused investigating building orientation and level of day light of commercial building in Bale Robe town. Bale Robe town is one of the fastest growing town in southern parts Oromia regional state. Robe town have been facing Commercial buildings are most frequently used should be on the side of the building facing the sun. This research design and methods such as collecting, analyzing, and combining quantitative like literature, secondary data from sectors, physical measurements, simulations and qualitative questionnaire survey, interviews, field measurements. To investigate the impact of sun position on buildings' facade and its effects on indoor and outdoor lighting, a building was examined. Physical measurements of environmental variables can compare subjective outcomes with existing criteria for success or failure. A simulation, a precise technique, involves sun and sky simulators in existing buildings, enhancing accuracy. The sample buildings were selected were chosen because they contain numerous commercial buildings with fully or partially glazed façades, and the orientation of the buildings has an impact on the level of daylight. The analysis phase involves transforming input data into quantitative and qualitative results. Quantitative and qualitative data were analyzed separately. The illuminance level of light was measured onsite at workspaces and recorded at 45-minute intervals. The results were then compared with standard lux levels for commercial building workspaces. Day lighting and visual comfort simulations in selected buildings were analyzed using energy plus software. Energy plus and metronome 7 were used to process climate/meteorology data. According to the data gathering and analysis, the result selected existing commercial buildings in robe town are south west faced and south east faced which is 60% and 40%. Summarizes responses to overall discomfort survey which includes from 1:00- 3:00 o'clock L.T all five buildings are discomforted time. Daylight illuminance was measured in two interior locations within each of the five buildings - one location less than 3m away from a window and the other more than 3m away. The lux meter recorded the light levels on a table at 45-minute intervals. Finally existing internal solar controls failed to provide comfortable lighting environments for most of the occupants. Recommendation should the regulations and monitoring systems regarding building orientation to improve thermal comfort. Keep the building's longer sides away from direct sun radiation.

Key words; investigate, building orientation, day light, Bale Robe town

CHAPTER ONE

INTRODUCTION

Motivation

I was inspired to choose the title investigating building orientation and level of daylight of commercial buildings in bale robe town for the following reasons. Bale Robe town is my birthplace, and i have been affected by issues related to building orientations and daylight. In my town, the weather is very cold in the morning and at night. During the day, harsh sunlight enters buildings that are exposed to direct sunlight on their long sides. I would like to apply what i have learned about design parameters and strategies to make a significant breakthrough.

Another motivation for studying this topic is to explore the potential benefits of optimizing building orientation for day lighting. Reducing energy consumption, improving occupant well-being and productivity, and creating more sustainable and environmentally friendly buildings. This can lead to the development of new strategies and technologies for improving day lighting in commercial buildings, ultimately leading to more comfortable and efficient spaces for occupants.

Day lighting in buildings is a term used to describe sunlight which is reflected to indoor spaces through openings and affecting its interior quality and function. The application of day lighting in buildings promotes the use of renewable energy sours and reduces energy coast (janda 2021).

A well-designed building with proper orientation can maximize daylight utilization, reducing the need for artificial lighting and consequently lowering energy consumption. A survey was conducted to evaluate the perception of occupants regarding the quality of daylight in the commercial building. Proper orientation of windows and skylights to allow direct and diffused daylight to enter the building, producing the best combination of light entering the building while controlling glare. The selection and placement of windows and skylights should be determined by the amount of light needed and based on climate and the architectural design (shemirani, 2017).

1.1 background of the study

One of the most critical factors to consider in commercial building design is building orientation and the provision of daylight. Proper building orientation and maximizing daylight not only improve energy efficiency but also enhance occupants' wellbeing and productivity. A good performance day lighting system initially requires a significant investment. But, if an integrated design approach is undertaken the overall long-term savings make up for the initial costs spent on day lighting. (Salaima at el, 2010 ; bryan).

Commercial buildings are frequently used should be on the side of the building facing the sun. Similarly, the used spaces should be on the less frequently used side of the building. The global buildings sector accounts for 40% of the world's total energy consumption, and the proportion of commercial buildings consumption is within the limits of two-thirds and commercial buildings within one-third, according to the organization for economic co-operation and development (ecdo) (hussein, 2011).

Day lighting requires control of the amount of heat that enters a building. Sun is the source of light and heat entering a building, if not planned properly; using natural lighting can result in undesirable heat gains, particularly in hot areas. It may seem that it would be difficult to increase the amount of light without bringing in extra heat (alambeigi, 2013).

Building orientation represents the relation between its elevations and the original geographical direction. In the design process, it is important to consider the actual quantity of solar radiation on the facades of a building as a whole, as it affects the thermal load of the building and controls the thermal behavior and the amount of thermal comfort of the space (morrissey, 2011)

1.2 statement of problem

The orientation of a building is important to its overall energy efficiency. A well oriented commercial building can save a lot of money in reduced heating and cooling costs. (eCreswell, J. 2014Alzoubi, A. Al-Zoubi. 2010) this is especially beneficial with the ever-increasing fuel prices and the rising cost of electricity. Building orientation has strong correlation with wind direction and sun radiation by having orientation options for a building; you can reduce energy costs by up to 80%. (prianto et al., 2010)

Robe town is one of the fastest growing towns in Oromia regional state. Robe town have been facing with current buildings are problem of building orientations which cause for day light. Building currently has problem of lack of orientation and there is a problem of effective day light. Commercial building in Robe is mostly affected by sun due to orientation problems that the main town road exposed for harsh sun.

The southwest facade building is covered with a glass curtain wall that provides high daylight effectiveness and visual comfort for occupants. The reflected daylight enhances the environment. However, occupants only have exterior views through windows on one facade, and single glazing transfers direct sun heat into the room. Limit views to one facade and hinder bilateral daylight for occupants, resulting in discomfort in the interior working environments on sunny days.

The buildings have rectangular shape glazing facing the main asphalt road and the facade facing south, southwest, and west. It primarily utilizes a commercial plan with transparent partitions. Occupants near the corners of the building have access to views through two exterior facades and some amount of bilateral daylight illuminance. The large glazed façade at south and southwest causes glare effect to the interior and outside environment.

1.3 objective of the study

1.3.1 General objective

To investigate building orientation and level of day light of commercial building in Bale Robe town

1.3.2 Specific objective

A. To investigate existing commercial building orientation due to sun effect of study area.
B. To investigate existing level of day in the light study area.
C. To propose strategies to enhance building orientation and level of day light study area.

1.4 research question

A. What is existing orientation of commercial building due to sun effect in Bale Robe town?
B. What is existing level of day light of commercial building in Bale Robe town?
C. Which orientation and level of day light is optimum for commercial building in Bale Robe town?

1.5 significance of study

The purpose of this study is to investigate the building orientation and the level of daylight in commercial buildings. By examining various studies and data, this essay aims to explore the impact of different orientations on the availability and quality of daylight within these structures. The significance of investigating building orientation and level of daylight is that it can have a significant impact on the energy efficiency, comfort, and overall performance of buildings. By understanding how the orientation of a building and the amount of daylight it receives can affect factors such as heating and cooling needs, natural lighting, and occupant well-being, architects and designers can make more informed decisions when planning and constructing buildings.

By conducting a study on building orientation and level of daylight, can provide valuable insights and data that can be used to improve building design practices, inform building codes and standards, and ultimately create more sustainable and comfortable built environments.

1.6 scope

The study focused Investigating building orientation and level of day light of commercial building Bale Robe town. Thematically the study focused on the effects is to investigate the existing commercial buildings at Robe town to investigate level of day light and proper orientation conditions in selected ten commercial building study areas. The thesis will research on cold climate commercial buildings, specifically how to create right building orientations to gate effective day light and setting design strategies in a possible way in the case Bale Robe town.

1.7 organization paper of thesis

This thesis is composed of five chapters according to the hierarchy of the study. Chapter one contains introduction. Chapter two deals about comprehensive literature reviews related to the topic. The research methodologies and materials were addressed in the chapter three. The research design, size of the sample, data source and method, and the material used are specified. Chapter four has result and discussion parts. Chapter five has conclusion and recommendation.

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

This literature reviews the building orientation and level of day light of commercial building. The review starts with theoretical backgrounds, which includes similar works in global level, and then it comes to theoretical background, reviewing according to the context of Ethiopia. Building orientation refers to the positioning of a building in relation to the sun, wind, and other environmental factors. The orientation of a building can have a significant impact on its energy efficiency, interior comfort, and overall sustainability. Day lighting refers to the use of natural light in a building to illuminate interior spaces. The level of daylight in a building is determined by factors such as the size and placement of windows, the use of skylights and light wells, and the building's orientation. Maximizing day lighting can reduce the need for artificial lighting, lower energy costs, and create a more pleasant and healthy indoor environment. In order to maximize the benefits of building orientation and level of daylight, architects and designers carefully consider factors such as the site location, climate, building shape, and interior layout. By strategically positioning a building to take advantage of natural light and ventilation, they can create spaces that are energy efficient, comfortable, and visually appealing.

2.2. Theoretical review

2.2.1 Day light

The amount of daylight entered to a building from the openings is related to creation of space illumination, yielding in visual comfort enhancement. It is significant to address the daylight both outside and inside of buildings as well as recognizing its impact on saving electrical energy (DH. 2010). Daylight and operable controls that manage lighting conditions can have a positive impact on human health, wellbeing, and productivity. By stimulating the human circadian rhythm, they can lower depression, improve sleep quality, reduce lethargy, and prevent illness. Daylight also offers a connection to the outdoors, promoting restoration and enhancing visual comfort. (Day et al. 2019)

Light represents the segment of the electromagnetic spectrum our eyes perceive. In modern physics, electromagnetic radiation is acknowledged for possessing two characteristics: waves and particles. Natural light or white light - the sole type facilitating precise color differentiation for the eye - comprises visible electromagnetic radiation with wavelengths from 380 to 780 nm. It serves as radiant energy that activates the visual sense. (Nazanin Nasrollahi, 2016).

Day lighting has physiological benefits. Ultraviolet radiation is crucial for human health, preventing rickets, maintaining healthy skin, widening skin capillaries, lowering blood pressure, increasing pulse rate and appetite, stimulating energy levels, promoting a sense of well-being, reducing fatigue, and potentially boosting work productivity. The presence of direct sunlight in the indoor environment offers significant psychological benefits. A proper amount of direct sun in the right location can be stimulating and desirable. Additionally, having a view to the exterior also provides psychological benefits to the occupants of a building. (Boubekri, 2008).

Daylight, with operational controls dictating lighting conditions, has a beneficial effect on human health, well-being, and productivity. It can regulate the circadian rhythm, leading to reduced depression, enhanced sleep quality, decreased lethargy, and illness prevention. Incorporating daylight into sustainable development enhances visual comfort, energy efficiency, and promotes green building practices. Natural light access creates enjoyable indoor spaces and fosters a visual link to the outdoors. Daylight is a valuable resource for vibrant renderings. (Cheung H-D, 2008).

Daylight, and corresponding operable controls that manage preferred lighting conditions, can positively impact human health, wellbeing, and productivity by stimulating the human circadian rhythm, which can lower depression, improve sleep quality, reduce lethargy, and prevent illness. Additionally, day lighting provides a connection to the outdoors and can increase restoration and improve visual comfort (day et al, 2019)

As illustrated on the challenge of defining "effective day lighting," day lighting performance is often defined differently by different stakeholders in the design and use of the building or operational life-cycle of buildings. Building occupants may judge the day lighting performance of the building based on their perception of daylight sufficiency, visual comfort, and available views (kyle konis selkowitz, 2017)

Daylight, and corresponding operable controls that manage preferred lighting conditions, can positively impact human health, wellbeing, and productivity by stimulating the human circadian rhythm, which can lower depression, improve sleep quality, reduce lethargy, and prevent illness. Additionally, day lighting provides a connection to the outdoors and can increase restoration and improve visual comfort (day et al, 2019).

2.2.1.1 Day lighting design

Day lighting design is an essential aspect for creating brighter, healthier buildings for everyone. Considering that daylight has a unique ability to shape the experience of a space, it is important for architects and designers to take it into account in order to build healthier, more sustainable buildings. Good day lighting design can improve the health, mood, cognitive abilities and productivity of the occupants of homes, schools or workplaces, while reducing the energy consumption of the building. Source: lighting hand book by (zumtobel lighting gmbh, 2018).

2.1.1.2 Climate and latitude

The prevailing climatic conditions of a building site define the overall preconditions for its day lighting design in terms of sunlight availability, visual comfort, thermal comfort and energy performance.

The location latitude determines the solar altitude for any given time of day and year. The summer and winter solar altitude properties are important design inputs for the availability and control of direct sunlight. For example, the figure below shows the difference in outdoor illuminance (lux) levels and length of daytime between northern and southern European locations. *(Source arc daily how to factor in day lighting design for healthier buildings)*

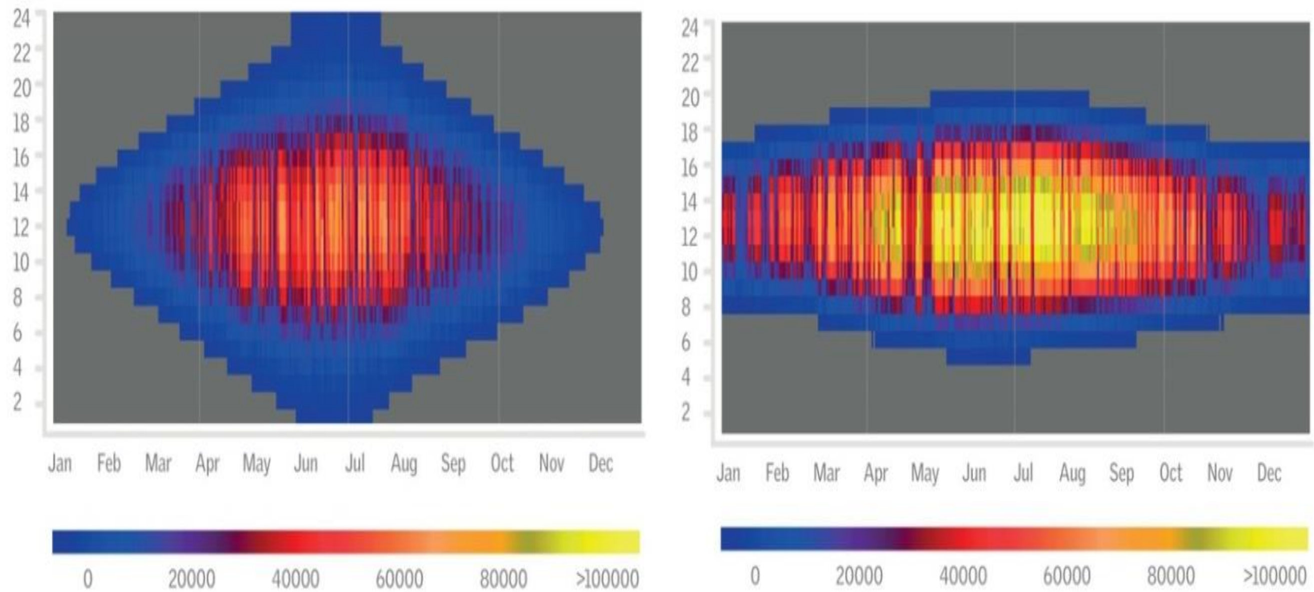

Figure 2.0.1 length of daytime between northern and southern European locations

2.1.1.3 External obstruction

External obstructions from surrounding elements on the building site (buildings, vegetation, ground surface, etc.) It is a crucial element to consider when analyzing the daylight performance of a building design. The figure below shows the significant difference in obstruction levels between rural and urban environments, underlining the need for rigorous daylight planning when designing in dense urban environments. *(Source arc daily how to factor in day lighting design for healthier buildings)*

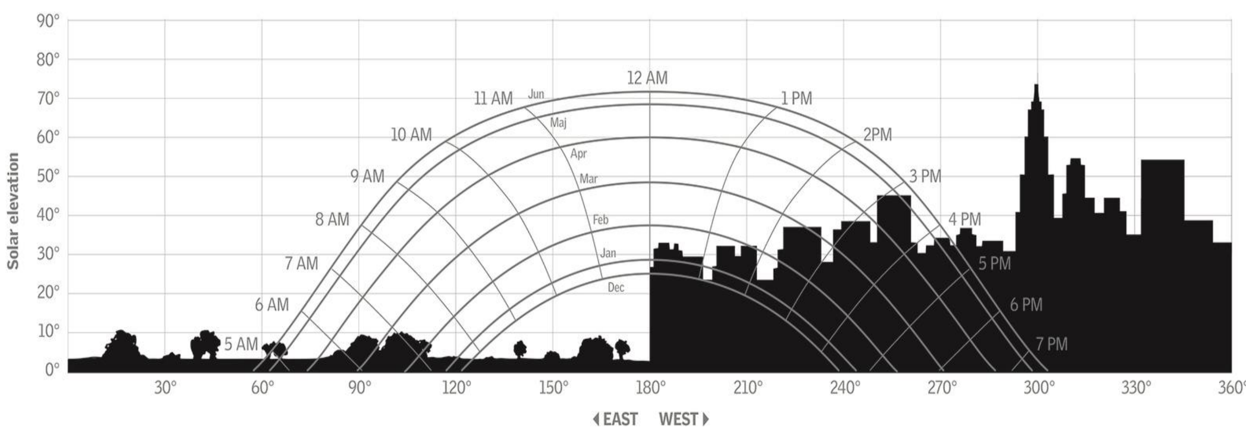

Figure 2.0.2 significant difference in obstruction levels between rural and urban environments

2.1.1.4 Building geometry

The geometry of a building influences its capacity to deliver adequate levels of daylight to interior spaces. When the building is deep, day lighting solely via facade windows has its limitations. No matter how much glass there is in the facade, it will only be possible to achieve an adequate daylight distribution a few meters from the facade (in spaces with typical ceiling heights). The figure below shows the daylight factor (df) levels obtained in a deep room with 3 different window configurations. *Source arc daily how to factor in day lighting design for healthier buildings*

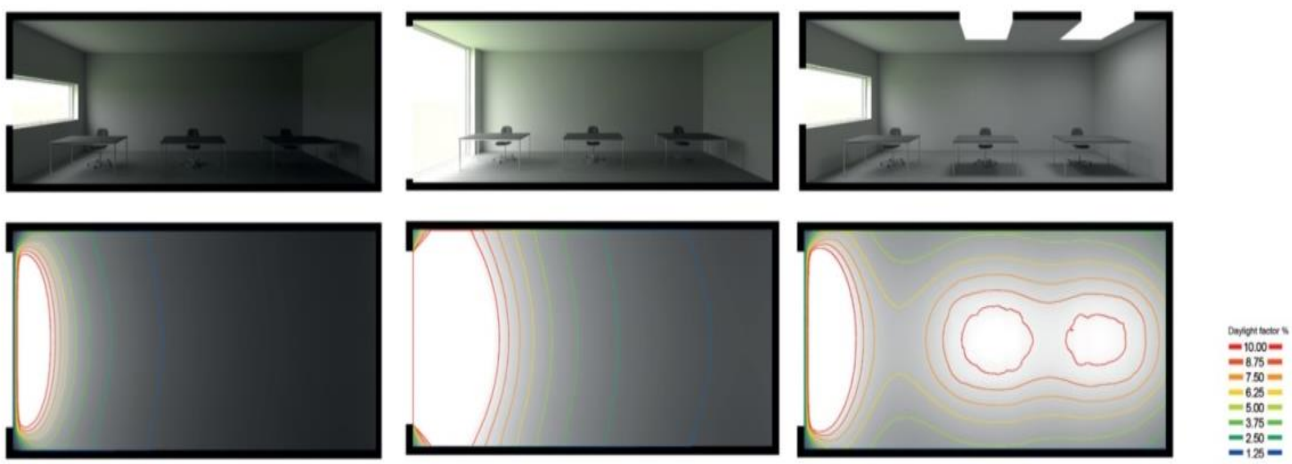

Figure 2.0.3 df levels obtained in a deep room with 3 different window configurations

2.1.1.5Material properties

The color and reflectance of room surfaces are part of the day lighting strategy. Dark surfaces reflect less light than bright surfaces, and the result is likely to be an unsatisfactory luminous environment in which there is little indirect or reflected light. Bright vertical surfaces inside the room are generally preferred to dark ones, but shading devices used to control sunlight should use darker materials in order to limit the risk of glare when prominently positioned in the field of view of building occupants. The figure below shows the impact of surface color and reflectance on luminance levels. Source arc daily *(Source arc daily how to factor in day lighting design for healthier buildings)*

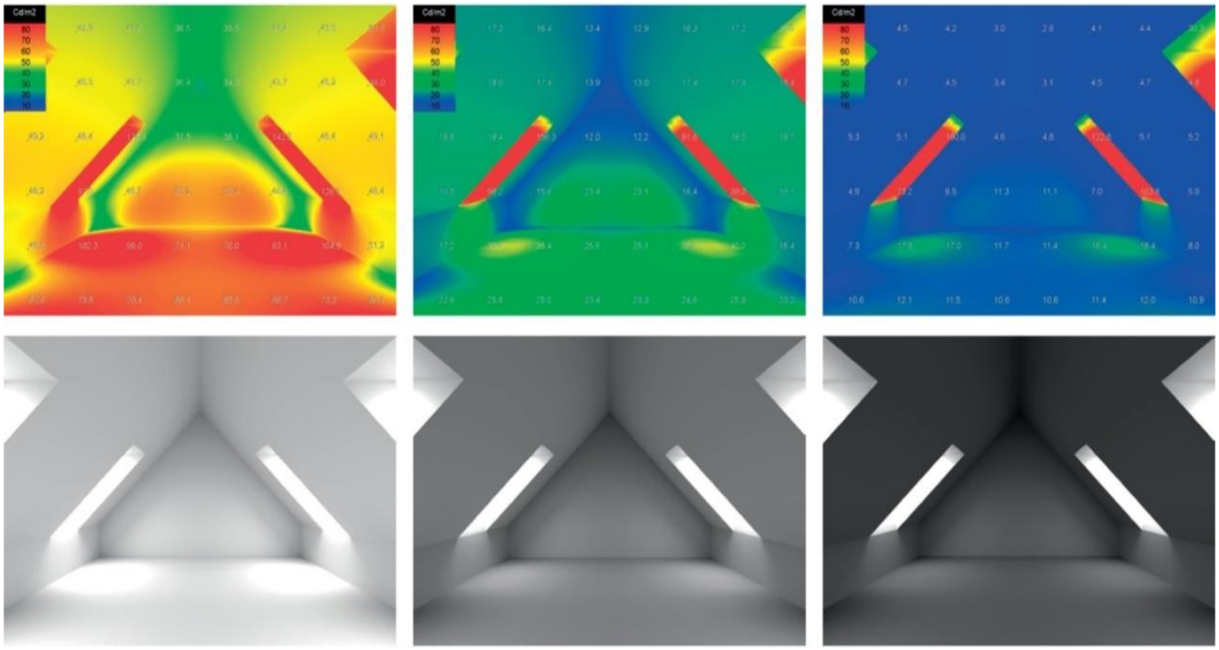

Figure 2.0.4 impact of surface color and reflectance on luminance levels

2.1.1.6 Window orientation, size and position

The orientation of windows influences the availability and qualities of daylight in interiors, most notably with regards to the presence of direct sunlight. Roof windows installed on a flat or low roof pitch are less sensitive to orientation if they have an unobstructed view of the sky.

The amount of daylight entering a room is directly linked to the total glazing area of the windows in the room and the visible transmittance value of the glazing. As a rule of thumb, double glazing (with no coating) lets in approx. 80% of the light, while triple glazing (with no coating) lets in approx. 70% of the light.

The positioning of windows will influence the distribution of daylight in the room and determine the amount of 'useful' daylight. Window position should also account for the relation between the view to the outside and the eye level of the occupants.

Velux daylight visualizer is a free easy-to-use and powerful day lighting simulation tool that can be used to evaluate the impact of all these factors on the daylight performance of your building projects. The figure below shows how daylight conditions are improved by the addition of roof lights in a school project in germany. (how to factor in day lighting design for healthier buildings)

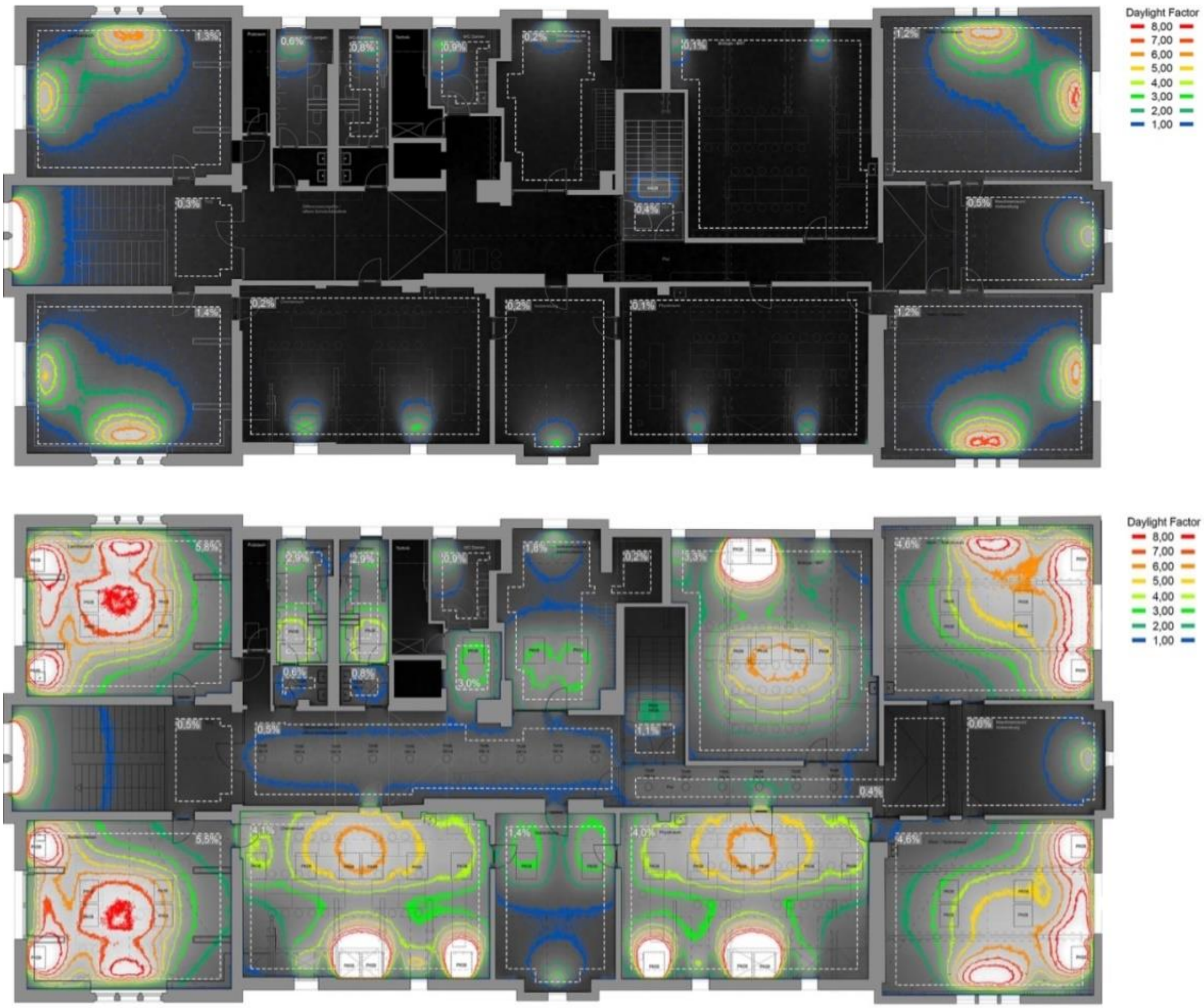

Figure 2.0.5 daylight conditions are improved by the addition of roof lights in a school project in Germany

2.2.2 Building orientation

Building orientation is the positioning of a building in relation to seasonal variations in the sun's path as well as prevailing wind patterns. Good orientation can increase the energy efficiency of your home, making it more comfortable to live in and cheaper to run. With rising energy costs, it's becoming increasingly important for builders to orient buildings to capitalize on the sun's free energy. Thus, building orientation, along with day lighting and thermal mass, are crucial considerations of passive solar construction that can be incorporated into virtually any new home design. (day et al, 2019)

Building orientation is mostly associated with the street orientation; the optimum ventilation potential could be obtained in an oblique orientation. According to ASHRAE, the optimum angle, which provides the best air circulation inside spaces, could be obtained by orienting the inlet 45° to the prevailing wind. Inlet openings facing the incoming wind at 90° provides the maximum airflow. The long façade of the building and the majority of the openings should be oriented with respect to the prevailing summer breezes i.e., north-south orientation for westerly wind. (day et al, 2019)

Building orientation refers to the position of a building in relation to the sun and wind. Proper building orientation can significantly impact the level of daylight inside commercial buildings, as well as the overall energy efficiency and comfort of the space. Building orientation refers to the positioning of a building in relation to its surroundings, specifically the cardinal directions. The significance of building orientation lies in its impact on the level of day lighting within commercial buildings, which plays a crucial role in energy consumption, occupant comfort, and overall building performance (shemirani, 2017).

2.2.2.1 Goals for building orientation

Positioning built spaces to optimize its surroundings increases its efficiency. Orientation defines the building's direction depending on factors like sunlight, wind, and rainfall. It is an analytical process that defines the massing and structure of the building. (Konis selkowitz, 2017)

The main goals of building orientation are as follows, Provide the optimal position depending on its surroundings, Increase the natural light and ventilation for the dwellers, Protection against external dust and noise, Protection against climatic changes like rainfall and hurricanes, Provide privacy for the users, Increase aesthetic value.

The orientation of a building is done to: Give the correct direction to the building according to the surroundings, Provide natural light and air to the inhabitants, Save the inhabitants from dust and smoke, Save the inhabitants from noise, Provide privacy to the inhabitants, Save the building from damages due to rain, Save the inhabitants from the bad effects of the worst weather. (Konis selkowitz, 2017)

2.2.2.2 Orientation for thermal needs

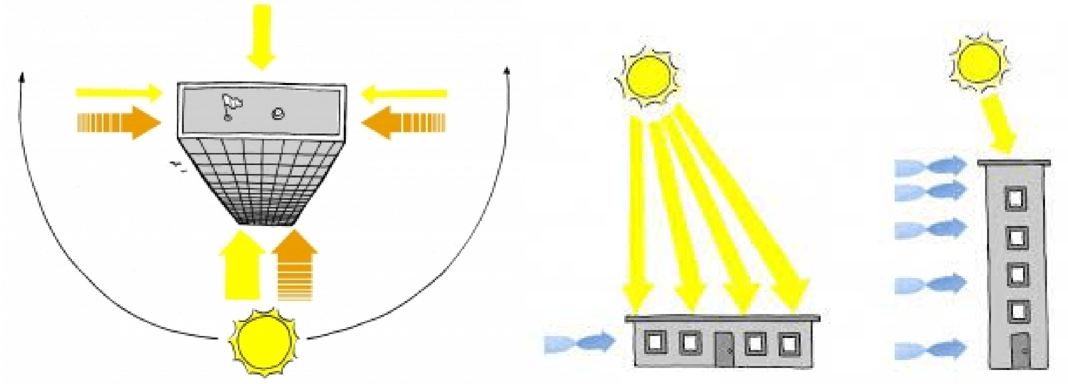

Figure 2.0.6 building orientation to optimize heat gain

Sun being the strongest form of heat source, it's crucial to acknowledge it while massing and orientation. Both sunlight and heat behave the same way. However, the thermal heat gain is relevant only to certain sides of the building, while some sides don't have any radiation on them. Whereas with sunlight, the incident of these rays is dispersed. Even the sides lacking thermal heat gain receive sunlight as diffused light. (janda 2021).

The built spaces gain thermal energy through direct and indirect heating. But retaining the heat allows it to regulate the internal temperature at night. Thus optimizing these sides is vital in the colder region to increase the heat gain while minimizing the surface exposure in hot climates can avoid further heat gain. Even small footprints with vertical massing can optimize the solar rays. (shemirani, 2017).

2.2.2.3 Orientation for visual needs

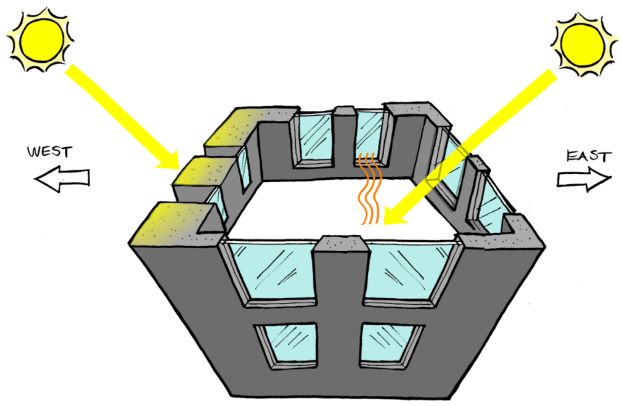

Figure 2.0.7 building orientation to enhance visual connectivity and vista

One of the important factors in building orientation is visual aspects. Strategic positioning maximizes your visual connectivity and increases your comfort. These factors depend on neighborhood conditions, thermal gain, and wind directions. We decide the size and direction of mass and apertures depending on all these factors. (alambeigi 2013).

Large open spaces on the eastern facades while minimizing them in the western direction protect you from harmful evening rays. As for visual connectivity, we optimize the built spaces with respect to the neighborhood to highlight the aesthetic appeal and vista.

2.2.2.4 Orientation for ventilation

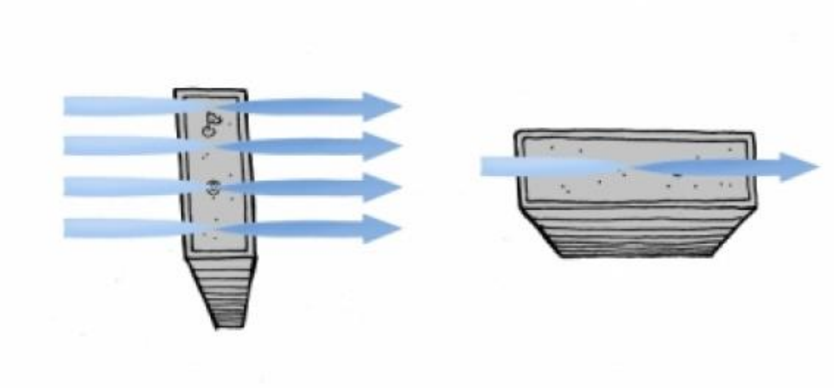

Figure 2.0.8 air flow by building orientation.

Natural and cross ventilation is vital in any structure. These increase comfort ability within the interior. However, deciding the building orientation in architecture involves analyzing the prevailing wind direction and its topographical location. It would be best to plan airy interiors for hot regions and block the same for colder terrains. (shemirani, 2017).

Most of the time, the data mentioned about the wind direction might not match the site conditions. Existing vegetation, nearby trees, or surrounding built structures can alter the course of the wind flow. Measuring the on-site wind flow is advisable to get the maximum benefits. (janda 2021).

Another major recommendation is to place the building orientation perpendicular to the wind flow. You limit the air circulation within interiors when you position the buildings parallel to the wind flow. However, even these design strategies alter when you create courtyards and similar spaces.

2.4 contextual reviews

2.4.1 Ethiopian building code standards 12 (EBCS 12)

Every Space intended for human occupancy shall be provided with natural light by means of exterior glazed opening (EBCS 12). The minimum gate glazed area of a space intended for human occupancy shall not be less than 15 percent of the floor area of the room served (EBCS 12). Exterior glazed opening shall open directly onto a public way or onto a yard (EBCS 12).

Required exterior openings are permitted to open in to a roofed porch, where the porch. Abuts a public way, yard or court. Has a ceiling height of not less than 2100 mm. longer side at least 65 percent open and unobstructed.

Skylights are not required to open directly onto a public way, yard or court. Glazed wall openings and skylights shall be free of obstructions and provided with means for cleaning in order to maintain adequate supply of natural light and prevent the use of artificial light (EBCS 12). All occupancies other than dwelling occupancy shall be provided with means to generate at least 5% of their energy consumption themselves (EBCS 12).

For the purpose of natural lighting, any room may be considered as a portion of an adjoining room where one-half of the area of the common wall is open and unobstructed and provides an opening of not less than l/l0th of the floor area of the interior room or 2.5 m2, whichever is greater (EBCS 12). All building spaces shall be provided with artificial light of an average illumination complying with relevant standards and (EBCS l0).

Research gaps

Research gaps refer to areas within a particular topic investigating building orientation and level of day light of commercial building where there is a lack of existing research or where further investigation is needed. In the context of investigating building orientation and the level of daylight, research gaps could basically on the hot areas rather than cold areas. Also standards were not enough.

CHAPTER THREE

MATERIAL AND METHOD

This chapter provides details of the study area, the kinds of information required for the study, sampling techniques, and also the methods that were used for gathering the assorted data together with the tools employed. The chapter also addresses and describes the techniques used to analyze the information that yields to answers the research questions and realize the objectives of the research.

3.1 description of the study area

Robe town was established in 1923 by the Geda Of Abba Bokku Kimo Damboba. In the time there was a serious drought and the ‘Kalus’ (spiritual fathers) pray to god, and then the rain was raining. So that, they said ‘robe Roba Torbani’ which means ‘raining for the seven days. And later the name ‘robe’ was given to the town. The town was get its legality as municipal town in 1955 and considered as reform town in 1996. Now the rank of the town is secondary ‘a’. The town is characterized by informal settlements especially on the periphery until the new development plane was prepared in 2012. Today, robe town has the area of 8024 hectares. And the town is the capital city of bale zone of Oromia since 1985 E.C. (Robe Town profile, 2013 E.C).

The study area, bale zone is geographically located between 5.360 n-8.12 0n and39.210e-42.230e in the south eastern parts of Ethiopia. The region extends over 18 districts. Based on traditional agro-climatic classification which is mainly depends on altitude and mean temperature the study area is classified in to highland, weina dega and quolla. The area is characterized by bimodal rainfall pattern kiremt and belg

The study area is under Indian Ocean influences as southerly fluxes generating rainfall when strong southerly moisture flow and easterly perturbation engulf. This can be also affected by heavy rainfall events coming from north ward advancement and southward retreat of its. There are two cropping seasons in the region ganna (March to June) and bona (July to December); crops which are planted on kiremt season are collected in bega season which is the dry period of the area. During this period feed shortage for livestock occurs.

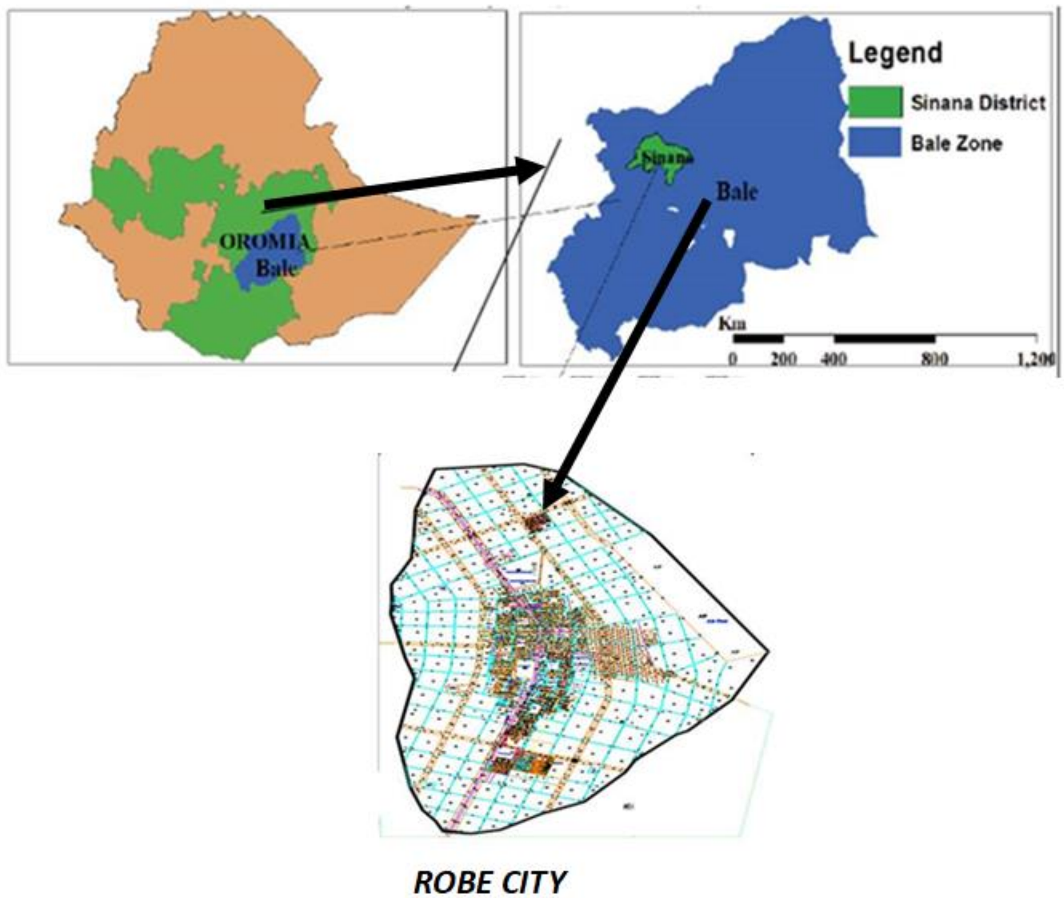

Figure 3.0.1 location map study area

3.1. 2 study area weather conditions

The study area bale zone is characterized by bimodal rainfall pattern kiremt and belg some studies have been carried out in few districts of bale zone which highlighted variability of rainfall and its implication in hindering agricultural activities of the area, additionally the record data on rainfall from 1995 to 2013 showed that there is a slight increasing trend in annual and seasonal (June -September and February-may) rainfall over sinana district. Climate related risks such as meteorological drought, water logging, erratic rainfall, and partial and full crop damage, increased crop disease and pests were observed in one of the district which is the main causes for crop failure .in depth scientific studies on spatial and temporal rainfall variability, distribution, trend detection and the likes is lacking over the study area. Therefore, this study was mainly designed to explore current rainfall variability and trend over the study area.

The analysis of rainfall revealed changes in extreme values during 1984-2016 in the study area. The analysis of historical rainfall variability and trend was conducted after the quality control was done, missed data was filled. The result indicated that rainfall did not show heterogeneity during 1984-2016 at sinana and robe stations. The areas are characterized by a bimodal rainfall pattern with total mean annual rainfall of 905.13 mm and 812.4 mm for sinana and robe respectively. As shown in figure 11. The area has bimodal rainfall distribution i.e. Belg season (short rainy season) in the months of February to May and kiremt (the main rainfall season) extending from June to September.

Additionally, the mann–kendall trend test showed a decreasing trend of start of season, end of season and annual number of rainy days at sinana and end of season and length of growing season at robe stations; however, it is not statistically significant. This method was based on definition of onset and end date which the instat method based on 20 mm of total rainfall was received over three consecutive days that were not followed by greater than 10 days of dry spell length within 30 days from planting was adopted for both locations. For both areas box and whisker plots for observed start of season, end of season and length of growing season for main rainy season was indicated in figure 3.2.

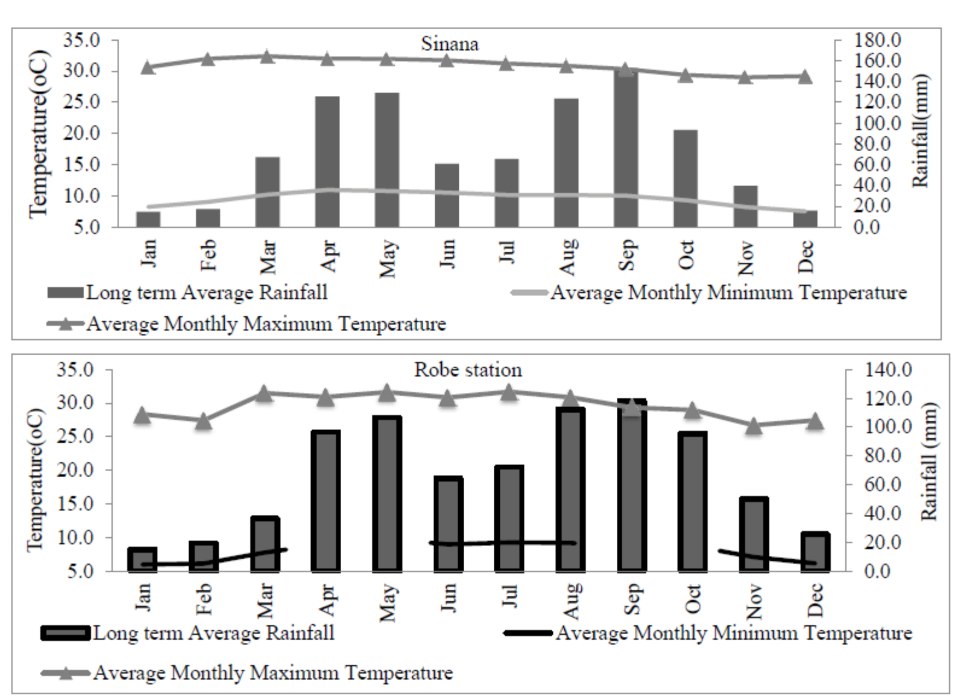

Figure 3.0.2 temperature and rain fall of robe town and sinana

3.2 research design

A research design is the arrangement of conditions for collection and analysis of data in a manner that aims to combine relevance to the research purpose with economy in procedure (Selltiz 1962). It contains a clear statement of the research problem or procedures and techniques to be used for gathering information and methods to be used in processing and analyzing data. It includes a clear statement of the research problem or procedures, techniques for gathering information, and methods for processing and analyzing data. It integrates research methods such as collecting, analyzing, and combining quantitative (literature, secondary data from sectors, physical measurements, simulations) and qualitative (questionnaire survey, interviews, field work) research. This study conducts exploratory research on the effectiveness of day lighting and visual comfort in commercial buildings.

According to a survey sample of occupants in five buildings, selected for an eight-week field study from January to April 2024. Identifying constant and variable parameters is crucial for field study measurements and survey analysis of the effective day lighting and visual comfort of building façades with building orientation. The variables were chosen for software simulation and survey studies to assess daylight and visual comfort in both interior and exterior spaces.

To investigate the impact of sun position on buildings' facade and its effects on indoor and outdoor lighting, a building was examined. Simulations were carried out at various times of the day and days of the month to understand the changing conditions. Clear, intermediate, and overcast skies were considered.

The methodological objective of this research was to pair subjective responses with physical measures of environmental variables to compare subjective outcomes with existing criteria for success or failure. Daylight and visual discomfort conditions in a day lit space are highly variable because of daily and seasonal changes in sun and sky conditions as well as the changing position of shading devices. Investigating the impact of facade on effective day lighting and visual comfort has been performed by various methods.

3.3 source of data

A. Questioner and survey data

The questionnaire survey was organized to achieve specific objectives of the study, using a database to assess visual environments. It included both open-ended and closed-ended questions, with satisfaction responses. Multiple choices responses were also used. Open-ended interviews were conducted with occupants, building designers, building users and related professionals in various fields.

B. Physical data measurements

The study of the environment was conducted through field measurements. In this research, physical data was collected to analyze and quantify the effectiveness of day lighting and visual comfort. Luminous conditions in each space (workspace, table, and computer screen) were quantified using a set of physical measurements. The research specifically gathered physical data to measure the availability of daylight throughout the space, the view to the exterior, and the potential for glare. The illuminance at the working plane (table) was measured using a lux-meter (light-meter), which is a convenient instrument with a sensor. This measurement is typically taken at 0.80 meters above the floor. The level of illumination at the working plane varies with the distance from the façade/glazing at workspaces and with the sky conditions of the day.

C. Simulation tools

Several building simulation software have rapidly developed to improve options that are more flexible and accurate for day lighting and visual comfort, as indicated in a literature review. The simulations were selected for façade design for day lighting and visual comfort in working environments. Currently, simulation tools are crucial for integrating environmental parameters into buildings, as many architects seek to test internal spaces before the construction phase. Familiar simulation tools, such as Ecotect, design builder and relux, were used in this study due to their ease of operation and better accuracy in terms of data analysis and interpretation.

3.4 sampling design

According to Daryle W. Morgan methods, the recommended sample size for a occupants of 64 in Five buildings, a confidence level of 99%, and a margin of error (degree of accuracy) of 3.5%. (Krejcie, 1970). According to purpose research, survey sample of occupants on five buildings was selected to participate. Identifying the constant and the variable parameters is very important to get into field study measurements and survey to analyze the effective day lighting and 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.

3.5 study site selections

The sample buildings were selected in bale robe town in the areas of Adoshe weleshe and Adoshe Zeybala Sub city for the study. These areas were chosen because they contain numerous commercial buildings with fully or partially glazed façades, and the orientation of the buildings has an impact on the level of daylight. The selection of buildings was based on specific criteria obtained from preliminary measurements. In the selected business district areas, buildings with streets oriented to the west and southwest were prioritized. Out of approximately 58 buildings, 15 were chosen based on their height being above g+2 stories. Five buildings with fully or partially glazed exteriors were selected, including Awash Bank Robe mixed-use building, commercial bank of Ethiopia Robe district, Siko Mendo union mixed-use building, Asbarera guest house, and Sena mixed-use building as shown in the figure 3.3 below.

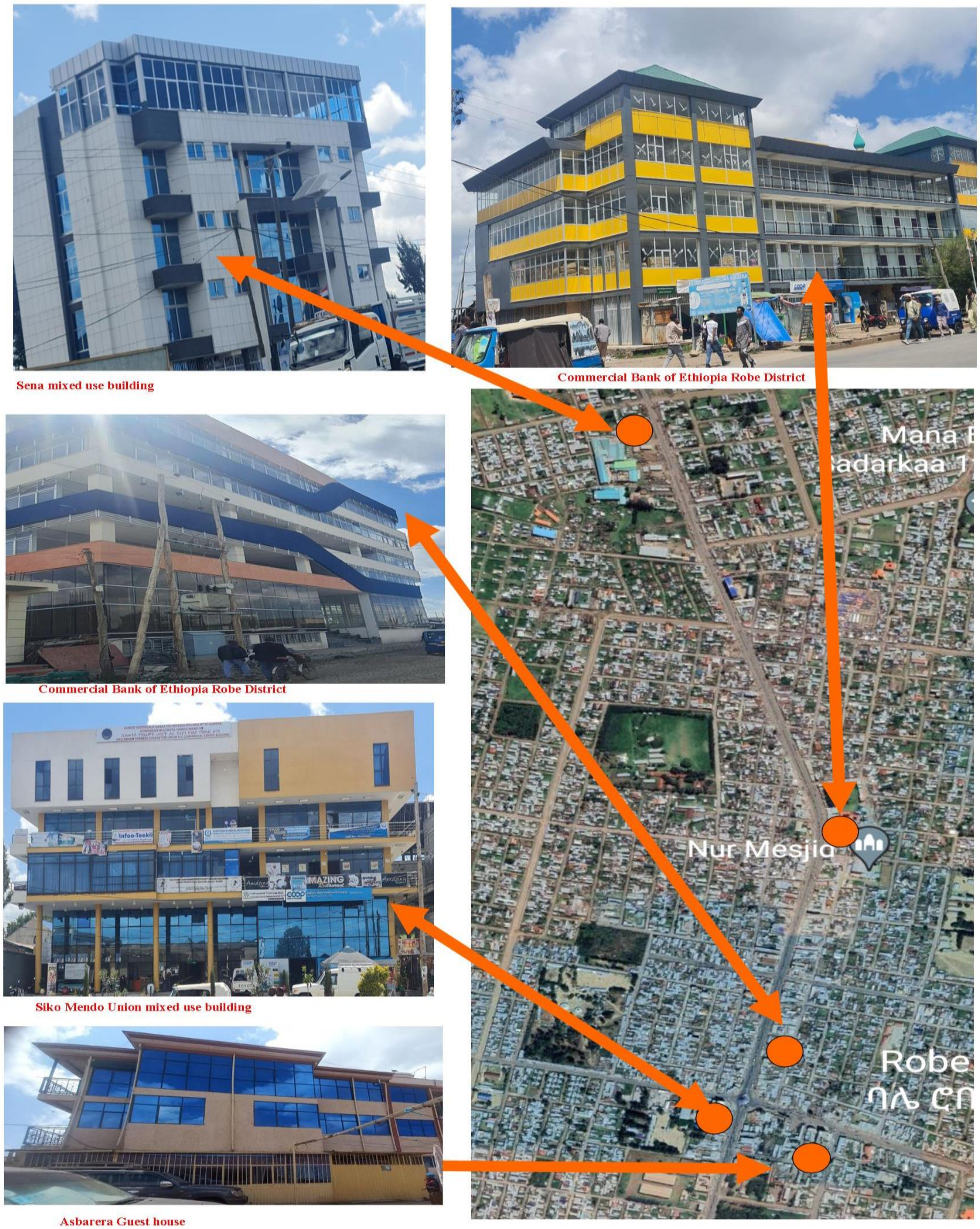

Figure 3.0.3 case building selections

3.6 methods of data collecting

3.6.1 Orientation of the buildings

The orientation of a building is a crucial architectural consideration, especially regarding environmental factors such as temperature, humidity, air flow, and natural light (woods, 2014). The building's orientation dictates the amount of solar radiation it receives and influences its surroundings. Glare typically occurs at lower sun angles, which occur during early morning and late afternoon. Consequently, the sun naturally sets in the west, with lower sun angles beginning in the southwest direction.

3.6.2 Materials of building

Glass is increasingly utilized in building envelopes. In order to save energy and decrease cooling load, facade designers opt for highly reflective glass (ishak et al., 2019). This material is favored for its reflectivity, leading researchers to establish criteria for sample buildings to feature glazed building envelopes.

3.7 data analysis techniques

This is one of the most common methods to analyze qualitative data. It is used to analyze documented information in the form of texts, media, or even physical items. When to use this method depends on the research questions. Content analysis is usually used to analyze responses from interviewees. This analysis particular focused on the first objective.

The analysis phase involves transforming input data into quantitative and qualitative results. All valid responses were coded and exported to SPSS 20 and excel for data analysis. The survey included both quantitative and qualitative variables, which were analyzed accordingly. In this study, a mixed method approach was used to fully understand occupant behavior responses. Quantitative and qualitative data were analyzed separately. The illuminance level of light was measured onsite at workspaces and recorded at 40-minute intervals.

The results were then compared with standard lux levels for commercial building workspaces. Additionally, Microsoft excel sheets were used to analyze the recorded numerical results of actual measurement tools. Day lighting and visual comfort simulations in selected buildings were analyzed using energy plus software. The analysis included climate analysis of the site, sun path diagrams, orientation, sun angles, radiation amounts, and temperature (daily, monthly, annually) using ecotect integrated with related environmental parameters. Energy plus and metronome 7 were used to process climate/meteorology data. The software produced graphical output data and provided minimum, maximum, and average values for several parameters of different cases.

3.8 data collection

The comfort zone described in ASHARE 55 and ISO 7730 standard was compared to the indoor thermal comfort parameters (temperature, airspeed, and humidity) and (daylight illumination) discovered in the locations. Different soft-wares such as ecotect analysis, and excel were used to analyze the data in the form of descriptive statistics analysis. Temperature and humidity data collection the data of indoor and outdoor temperature and humidity was collected using two digital thermometers model astroal380-ca made in china, environmental x-meter made in America and the temperature and humidity was recorded in class room as well as the standard class room in the absence of any kind of mechanical cooling and ventilation system.

Figure 3.8 digital infrared thermometer

3.9. Ethical consideration

For quality output the study has given prior concern on awareness creation on purpose and objectives of the study. Consent from each study participants would be obtained, before data collection. The anonymity and confidentiality of information will be secured. Legal permission will be attained from Robe town commercial buildings. All material used throughout the study will have acknowledged. The measuring equipment will be located in a way that doesn't disturb households. The researcher will be analyzed the data relative to standards without manipulation.

CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1 Introduction

In this section present detailed statistical analyses, measured physical data, a brief review of relevant open indeed responses. These analyses focused and performed to support the overarching research objectives. To establish first a relationship between survey variables as well as the strength and direction of the relationships, two key tests were utilized.

This chapter discusses analyze data the result of the data and results which is collected during the study to ensure the objectives of the research. Subjective and objective approaches were used.

4.2 demographic profile and response rate of respondents

4.2.1 Demographic profile

A. Respondent sex

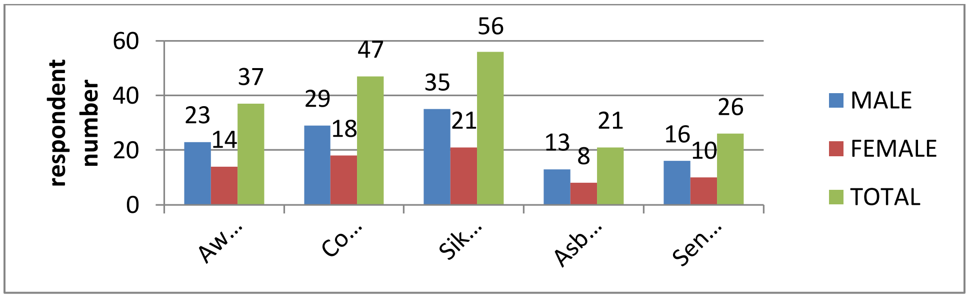

Figure 4.0.1 respondent sex

B. Respondent age

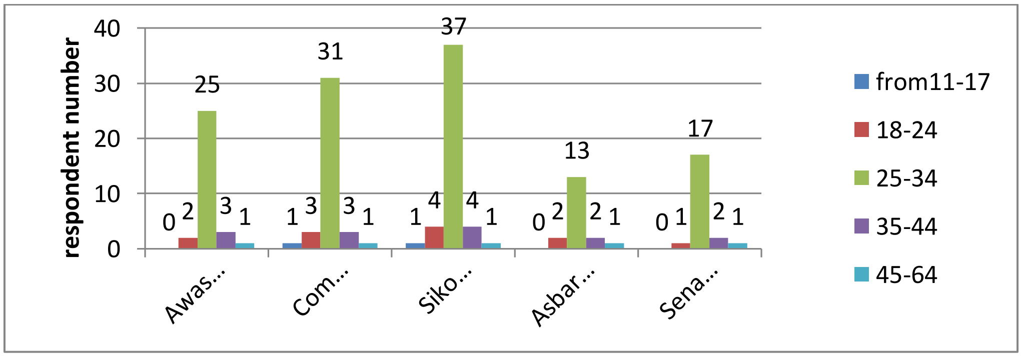

Figure 4.0.2 respondent age

C. educational background

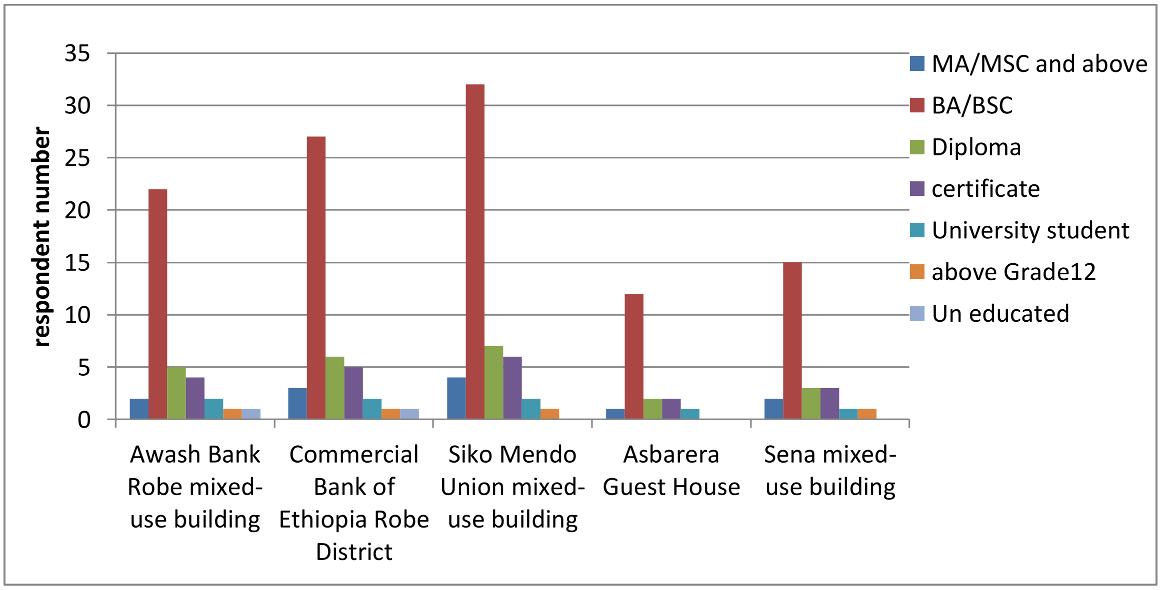

Figure 4 .0.3 educational background

D. Body weight

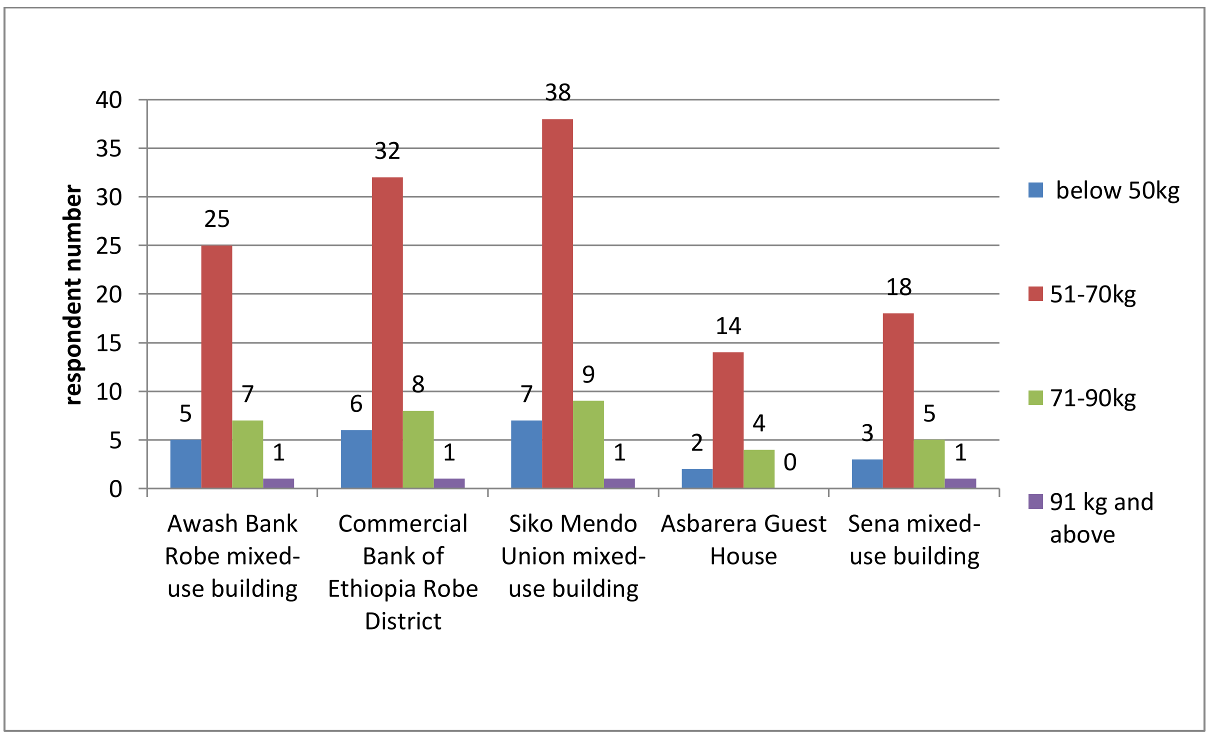

Figure 4.0.4 body weight

E. On work time

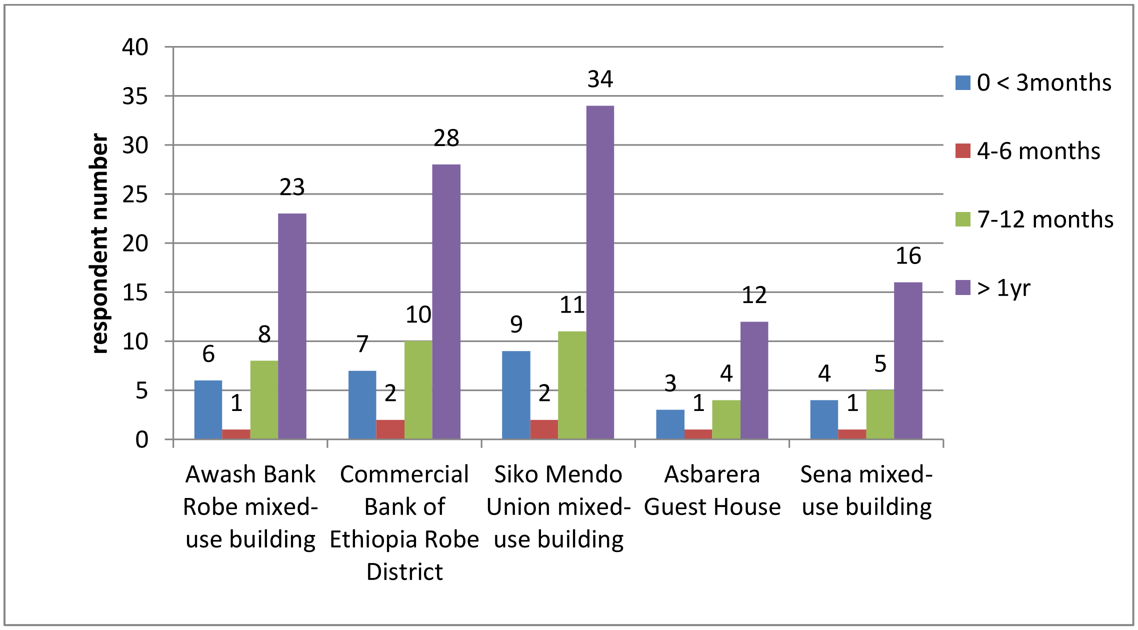

Figure 4.0.5 on work time

F. Working time/ day

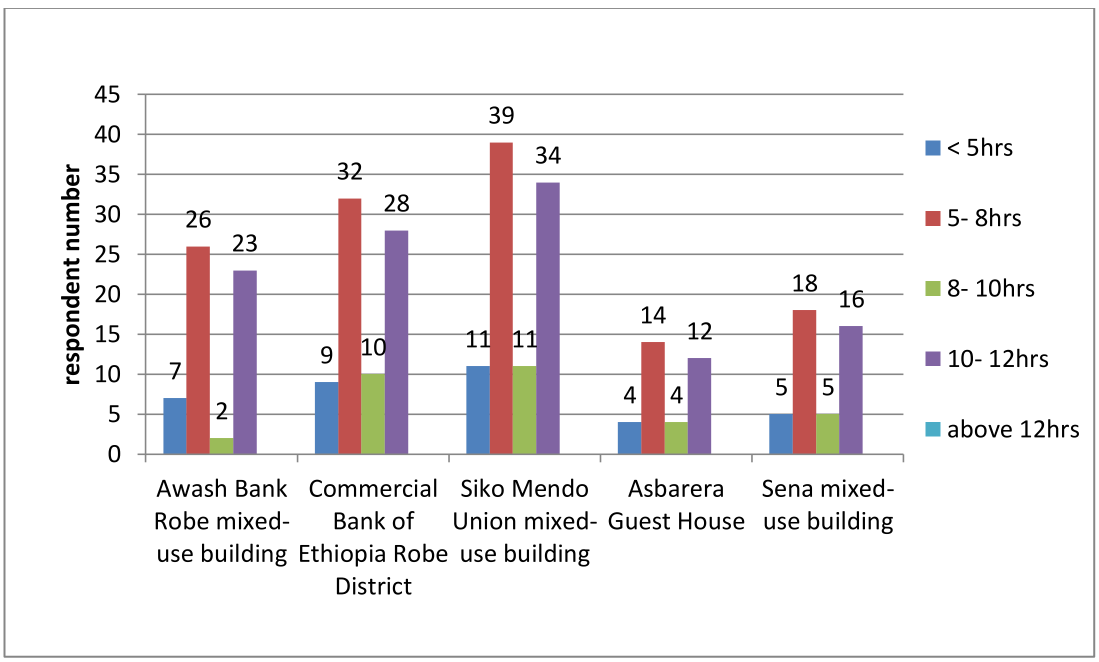

Figure 4.0.6 working time/ day

Based on personal information above from figure 4.1 describe that respondent sex distribution is in building Awash 23 male 14 female totally 37 which is 64.85% are male. In second building Commercial building 29 male 18 female totally 47 which are 61.7% are male. In Siko Mendo building 35 male 21 female totally 56 which are 62.5% are male. In Asbarera building 13 male 8 female totally 21 which are 61.7% are male. In the last building of sena building 16 male 10 female totally 26 which are 61.5% are male. In general in the selected buildings there above 60% are male worker and users are found. The list around from 30% - 40% are female user and workers.

The second personal information is about their age distributions figure 4.2. It indicates that their age distribution is from age 11-17 respondent are 1.2%. From age 18-24 respondent are 7.6%. From age 25 34 respondent are 78.85%. From age 35 – 44 respondent are 8.9%. %. From age 4.4 - 64 respondent are 3.2%. In general in the selected buildings there above 80% the response are above 25 years old and there are responsible for the research topics.

Education background of respondent on figure 24 implies that around 90% of the resonance educational background is above certificate. This shows that they have enough knowledge to the related questioners. Based on above questioner responders personal information about their work time figure 4.5 implies 80% of respondents are working over 7 months. These show us they can adapt and has enough information about their buildings.

Based on above questioner responders personal information about their work time per a day figure 4.67 implies 70% of respondents are working over five hours to eight hours. These indicate us they have well and enough information and knowledge about their selective commercial buildings.

4.2 investigating existing building orientation due to sun effect of study area

In Robe Town there are mainly buildings that are properly positioned take advantage of the temperature, airspeed, solar radiation, and prevailing wind. Most buildings front face are oriented along road which is long side is south west direction and other is south east directions. The descriptive statistics from each of the five buildings were presented on table 4.1.

Table 4. 0-1 existing building orientation

No.	Building name	Orientation
1	Awash bank robe mixed-use building	South west
2	Commercial bank of Ethiopia robe district	South west
3	Siko mendo union mixed-use building	South east
4	Asbarera guest house	South west
5	Sena mixed-use building	South east

According to above table1 selected existing commercial buildings in robe town are south west faced and south east faced which is 60% and 40%). In an east-west orientation, the long face is aligned with the south face. The majority of the doors and windows, as well as the long wall, are oriented to the south. The facades get the most solar radiation, hence the surface area of the building exposed to them should be as little as possible, and windows on these facades should be avoided. Therefore, the longer axis of the structure should lie along the south-north axis. The wide wall facade has a thermal comfort influence on the inner atmosphere on sunny days. During periods of intense sunlight, high solar radiation in the indoor chamber causes pain. Most of the openings face the opposite direction of the wind. On south orientated, windows are good to enable excess natural light and ventilation but using these many windows on every side is not good for room temperature and sunlight prevention. WWR on south faced is the worst ranging between 30 to 70%. Many wide windows penetrate the direct sun according to observation and survey. Particularly south and west windows are penetrating the sunlight and they are the reason of increase room temperature, however, the buildings are not considered the sun direction and sun path. The interaction of outside and interior air is influenced by openings, which has an impact on energy consumption, indoor air quality, and thermal performance. The amount of light available in the rooms is influenced by the size of the windows.

4.2.1 Awash Bank Robe Mixed Use Building

Project name: Awash bank robe mixed use building

Owner: Awash bank

Location: Bale Robe, Ethiopia

Construction ended year: 2014 E.C

Project details: g+4 response and modern architecture. It’s an iconic building that portrays Awash bank’s image on its skin and interprets the flowing nourishing concept across the interior programs. Furthermore, pedestrian accessibility is made possible through porosity creating ease of access but still being well secure. Well zoned programs according to hierarchy with a captivating & entertaining interior marks a modern building approach.

Figure 4.0.7 **Awash bank robe mixed use building**

The southwest facade of the Awash bank robe mixed use building is covered with a glass curtain wall that provides high daylight effectiveness and visual comfort for occupants. The reflected daylight enhances the environment. However, occupants only have exterior views through windows on one facade, and single glazing transfers direct sun heat into the room. There is manual temporary shading on the interior that can be moved to the side. These conditions limit views to one facade and hinder bilateral daylight for occupants, resulting in discomfort in the interior working environments on sunny days.

4.2.2 Commercial bank of Ethiopia robe district

Project name: commercial bank of Ethiopia robe district

Owner: Chombe Seyoum

Location: bale robe, Ethiopia

Construction ended year: 2012 E.C

Commercial bank of Ethiopia Robe district is a five-story building. The building designed for commercial purpose. In ground and first floor there mainly used for district banks. On the second, third and fourth are commercial purpose rooms like shops, supermarket, barberry, and other functional rooms.

Figure 4.0.8 commercial bank of Ethiopia robe district

The building has an approximately rectangular shape, with glazing facing the main asphalt road and the facade facing south, southwest, and west. It primarily utilizes a commercial plan with transparent partitions. Although manager offices and break areas are located at the corners of each floor, occupants near the corners of the building have access to views through two exterior facades (east and north) and some amount of bilateral daylight illuminance. However, there is an additional whiteboard besides the glazing that protects against direct sun heat but obstructs views.

4.2.3 Siko Mendo union mixed use building

Project name: Siko Mendo union mixed use building

Owner: Siko mendo farmers union mixed use building

Location: Bale Robe, Ethiopia

Construction ended year: 2015 E.C

Siko Mendo union mixed use building is a five-story building. The building designed for commercial purpose. In ground has mainly used for bank services and others are some shops. From first to the fourth floor are commercial purpose rooms like shops, supermarket, barberry, and other functional rooms. And fifth floor there is meeting hall and gym purpose.

Figure 4.0.9 Siko Mendo union mixed use building

Its footprint is approximately rectangle with wide atrium at entrance and its facade face south, southwest and, west. The buildings mostly features open plan and most occupants have unobstructed views to the exterior. The second floor was selected for survey, computer simulations and physical data measurements.

During sunny days, the large glazed façade at south and southwest causes glare effect to the interior and outside environment. High differences in internal illuminance on working spaces during the time of intensive sunshine cause discomfort at working environments. The computer simulation output is compared with some of the findings of observations and questionnaire survey inputs.

4.2.4 Asbarera guest house

Project name: Asbarera guest house

Owner: Taklu Eshetu

Location: Bale Robe, Ethiopia

Construction ended year: 2009 E.C.

Asbarera guest house is found in robe town Adoshe Welashe Sub city around G/Wako Gutu round about to east direction 0.5km far. The guest house was g+2 which compose bar and restaurant on the ground, from first floor and second floor it has different size and type bed rooms.

Figure4.0.10 Asbarera guest house

The building has rectangular shape, with glazing facing the main road facing south, southwest, and west. In the building there is of bed rooms primarily utilizes a commercial plan with transparent partitions. Although manager offices and break areas are located at the corners of each floor, occupants near the corners of the building have access to views through two exterior facades (east and north) and some amount of bilateral daylight illuminance.

4.2.5 Sena mixed use building.

Project name: Sena mixed use building.

Owner: Mohamed Desta

Location: bale robe, Ethiopia

Construction ended year: 2015 E.C

Figure4.0.11 **Sena mixed use building.**

The north east facade sena mixed use building has rectangular shape covered with a highly occupants near the corners of the building have access to views through two exterior facades (east and north) and some amount of bilateral daylight illuminance. However, there are additional white board at side of glazing that protects direct sun heat but obstructs views.

4.2.2 General working environments assessment

A. At which time of the day did discomfort was occurred?

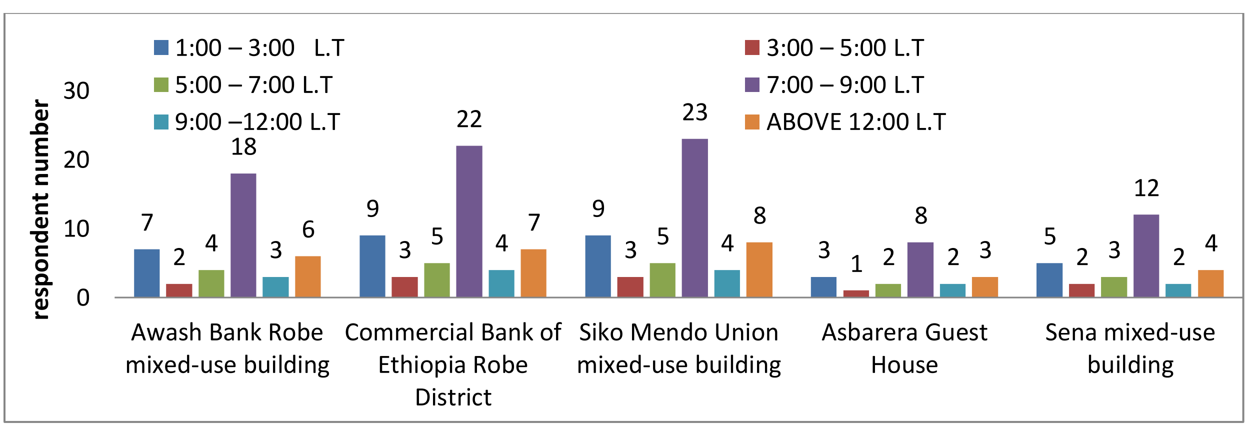

Figure 4.0.12 time of the day discomfort was occurred

From above Figure 4.12 summarizes responses to overall discomfort survey which includes from 1:00- 3:00 o'clock L.T all five buildings are discomforted time. From 5:00- 7:00 o'clock L.T and 9:00- 12:00 o'clock L.T buildings are medium time. From 7:00- 9:00 o'clock L.T all building this time the highest discomfort time. The buildings did not comfortable. In all building this time the highest discomfort time. From above 12:00 o'clock L.T the buildings did not comfortable for respondents.

B. How satisfied are you with your level of visual comfort of lighting in your workspace?

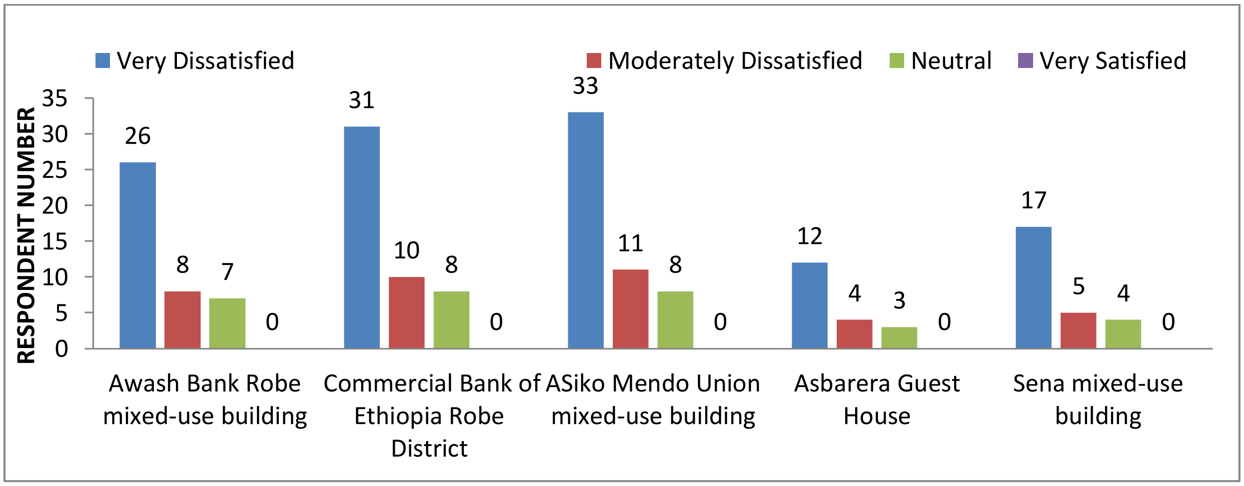

Figure 4.0.13 level of visual comfort of lighting in workspace

From above figure 4.13 summarizes responses to overall are visual comfort of lighting in your workspace are not satisfied. In all five commercial buildings the highest number of response is very dissatisfied. Based on above questioner responders implies 80% of respondents are dissatisfied. Only 10% are neutral and moderately dissatisfied. O % of the respondents is satisfied. This questioner response implies visual comfort of lighting in your workspace not well and need to change.

C. What is closest cardinal direction of the nearest exterior window?

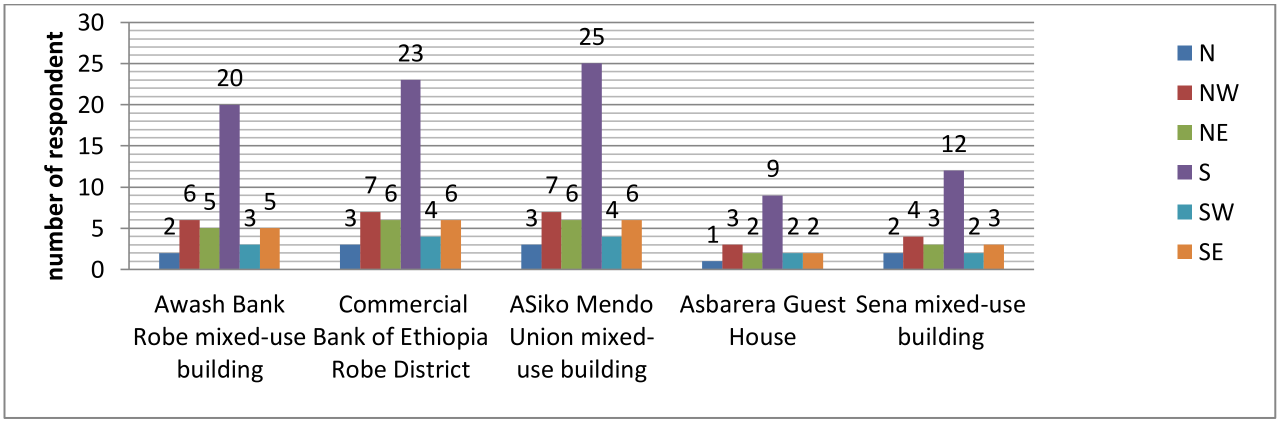

Figure 4.0.14 direction of the nearest exterior window

From above figure 4.14 summarizes responses to overall closest cardinal direction of the nearest exterior window. From five commercial buildings the highest number of response is in all buildings the responses are nearest to south direction. Based on above questioner responders implies other of respondents are closest cardinal direction of the nearest exterior windows. From selected five buildings Awash Bank Robe mixed-use building, commercial bank of Ethiopia Robe district, Siko Mendo union mixed-use building are mostly affected on the south closest cardinal direction of the nearest exterior window. Also both Asbarera guest house and Sena mixed-use building mostly related south west and south east closest cardinal direction of the nearest exterior window.

D. Please indicate the source of visual discomfort most in your work space?

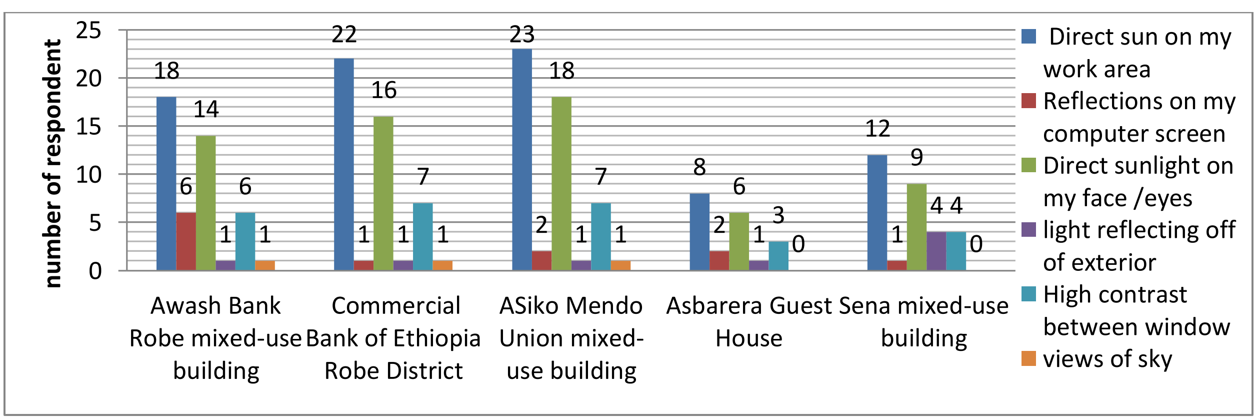

Figure 4.0.15 source of visual discomfort

Source of visual discomfort most in your work space of respondent on figure 4.15 implies that around 90% of the resonance is from outside direct sun to work area and direct sun from to face. This show as the outside sun has affected the interior working spaces. View from the sky and light reflecting of exterior has not much effect. Reflections from computer have created some visual discomfort.

E. Which of the following devices do you use to control direct sun light penetration?

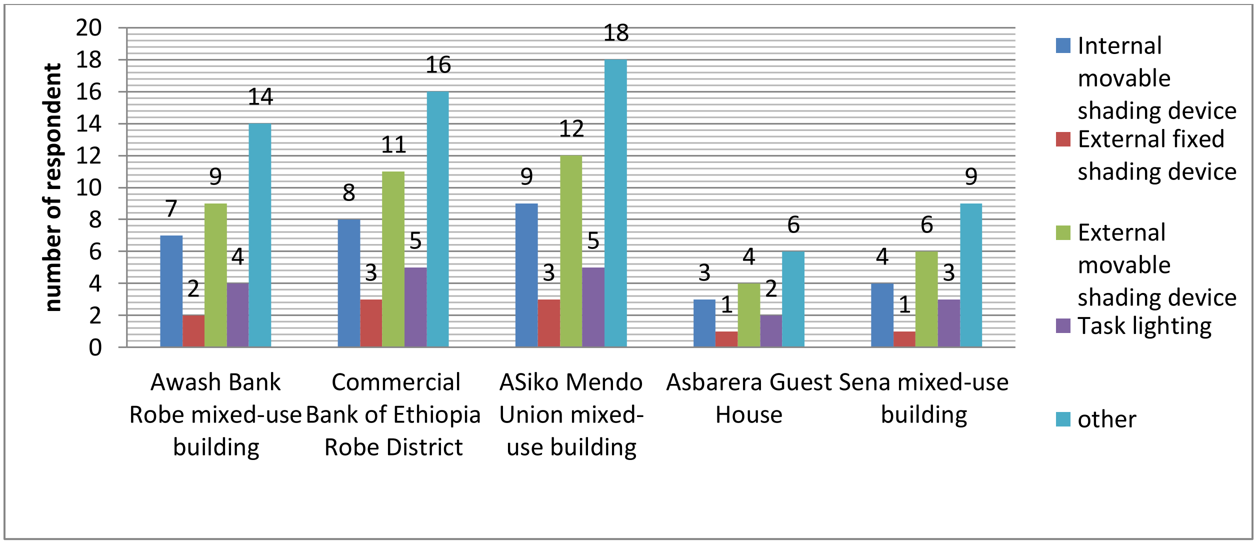

Figure4.0.16 devices used to control direct sun light penetration

From above figure 4.16 summarizes responses to overall devices do you use to control direct sun light penetration. All selected five commercial buildings internal movable shading device and external movable shading device has 40% together. In all selected five commercial buildings the respondents using curtain in the interior. All selected five buildings Awash Bank Robe mixed-use building, commercial bank of Ethiopia Robe district, Siko Mendo union mixed-use building Asbarera guest house and Sena mixed-use building has the same devices control direct sun light penetration.

F. What are the measures you use to regulate your rooms and protect solar intensity?

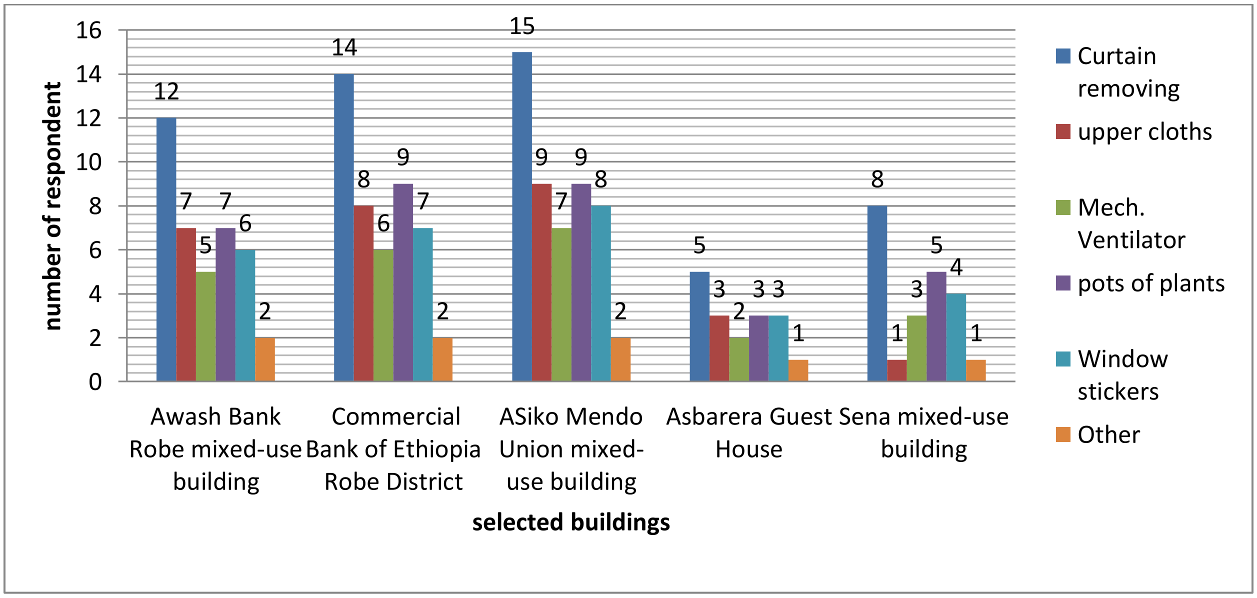

Figure4.0.17 measures to regulate rooms and protect solar intensity

According to above figure 4.17 summarizes responses to measures you use to regulate your rooms and protect solar intensity are using stickers which can used as promotion on outer parts. Curtain removing has the highest which is 30 %. Pot of plants is one of respondent answer around 18 % of the resonance. Using mechanical ventilator also mechanisms of the respondent which has 16% of total respondents. Others response can away from their works take a nap those times. Based on the building function, capacity and function from selected five buildings Awash Bank Robe mixed-use building, commercial bank of Ethiopia Robe district, Siko Mendo union mixed-use building is highly using curtain, pots of plant and mechanical ventilator. Also both Asbarera guest house and Sena mixed-use building are also upper clothes and use window stickers.

4.3 level of day light in selected buildings

4.3.1 Lighting and general indoor environmental quality assessment

A. Satisfaction with the work spaces design of the building services

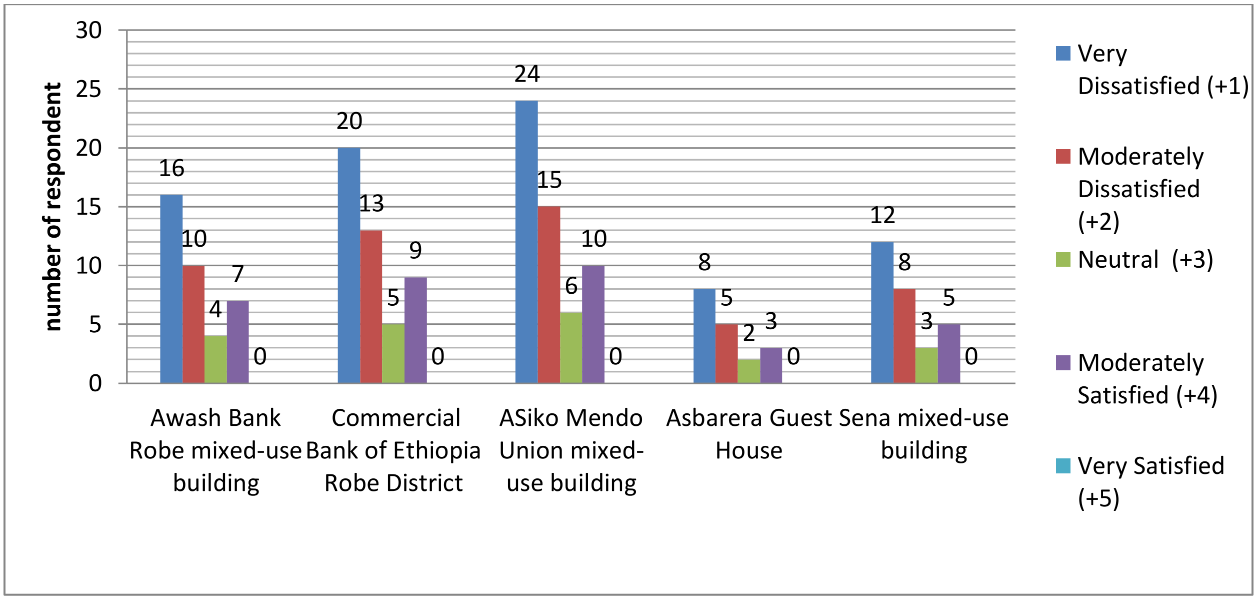

Figure 4.0.18 satisfaction with the work spaces design of the building services

B. Satisfaction with the lighting conditions in the work space where you spend the most time

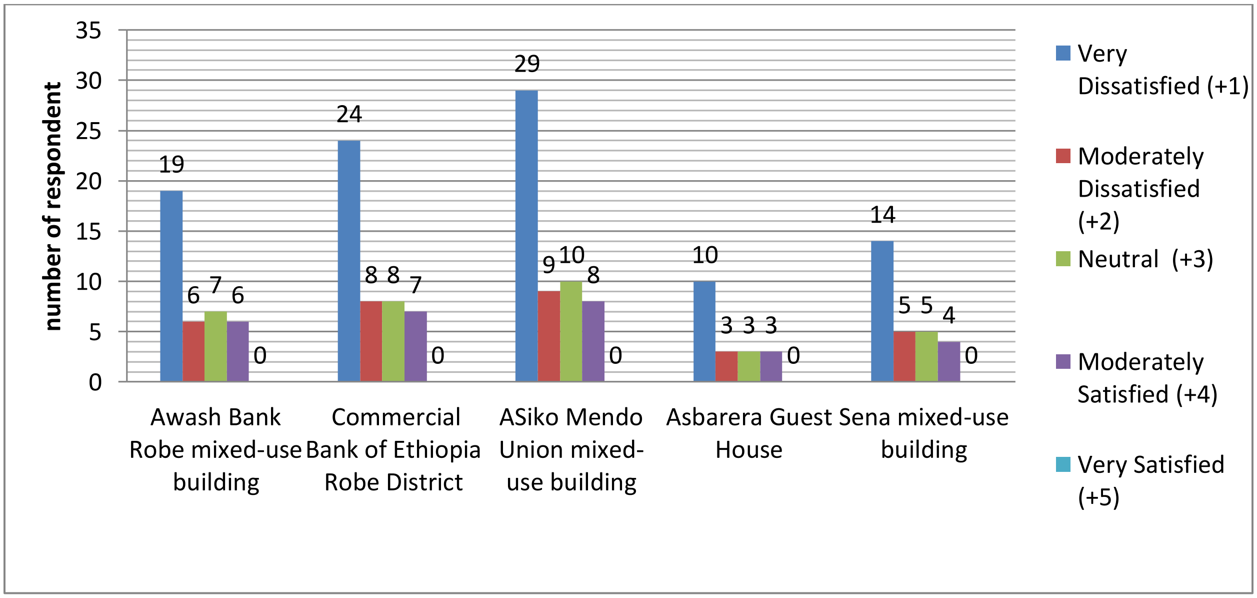

Figure4.0.19 satisfaction with the lighting conditions in the work space

C. Satisfaction with the view

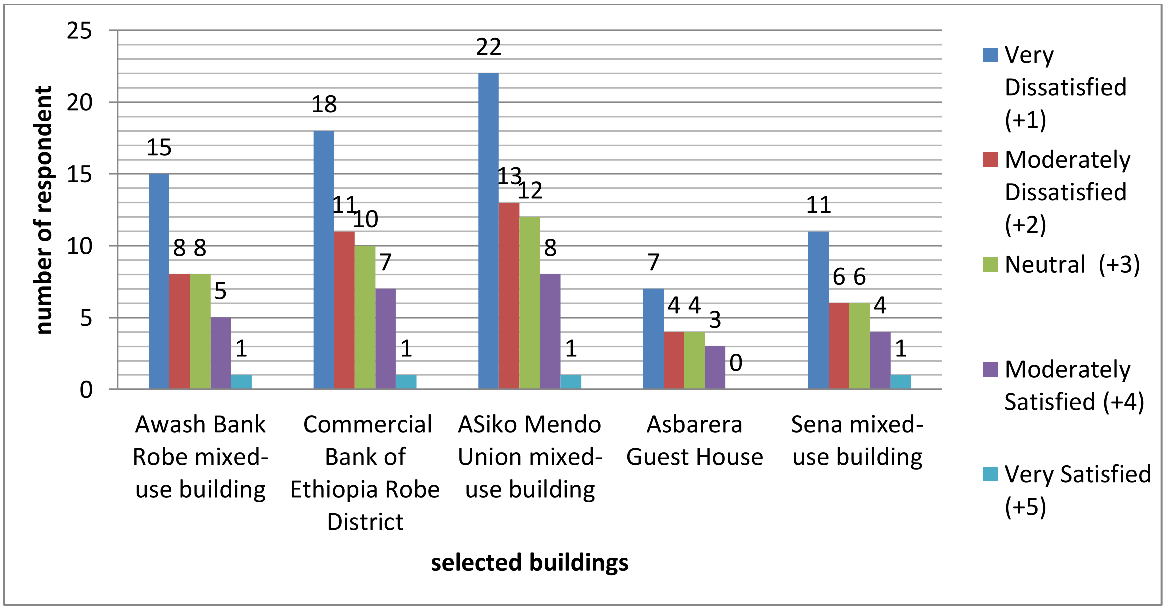

Figure 4.0.20 satisfaction with the view

D. Access to natural/day light

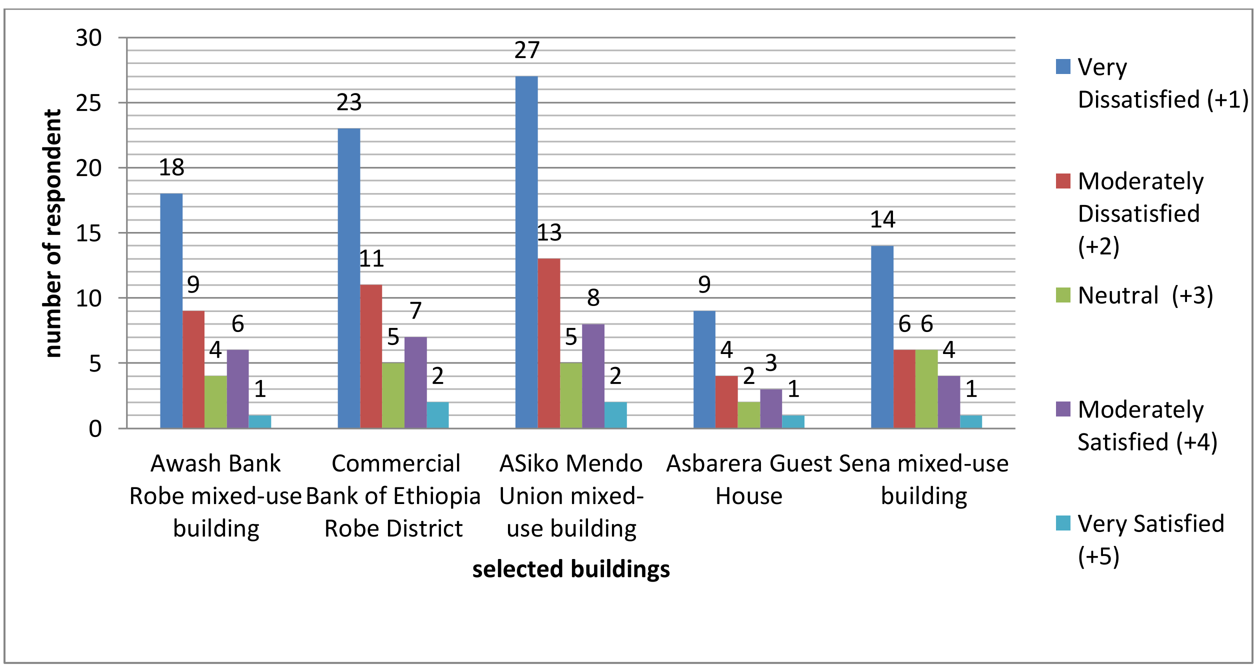

Figure 4. 0.21 access to natural/day light

E. Artificial/electric light

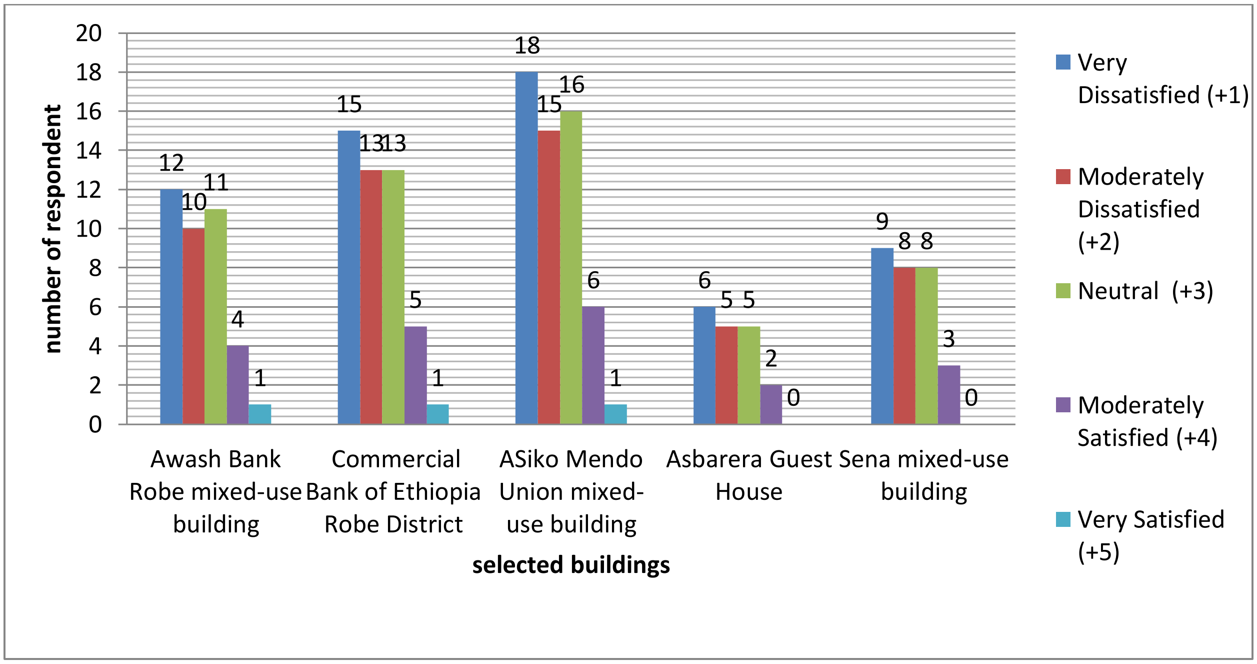

Figure 4.0.22 artificial/electric light

F. Satisfaction with amount day light

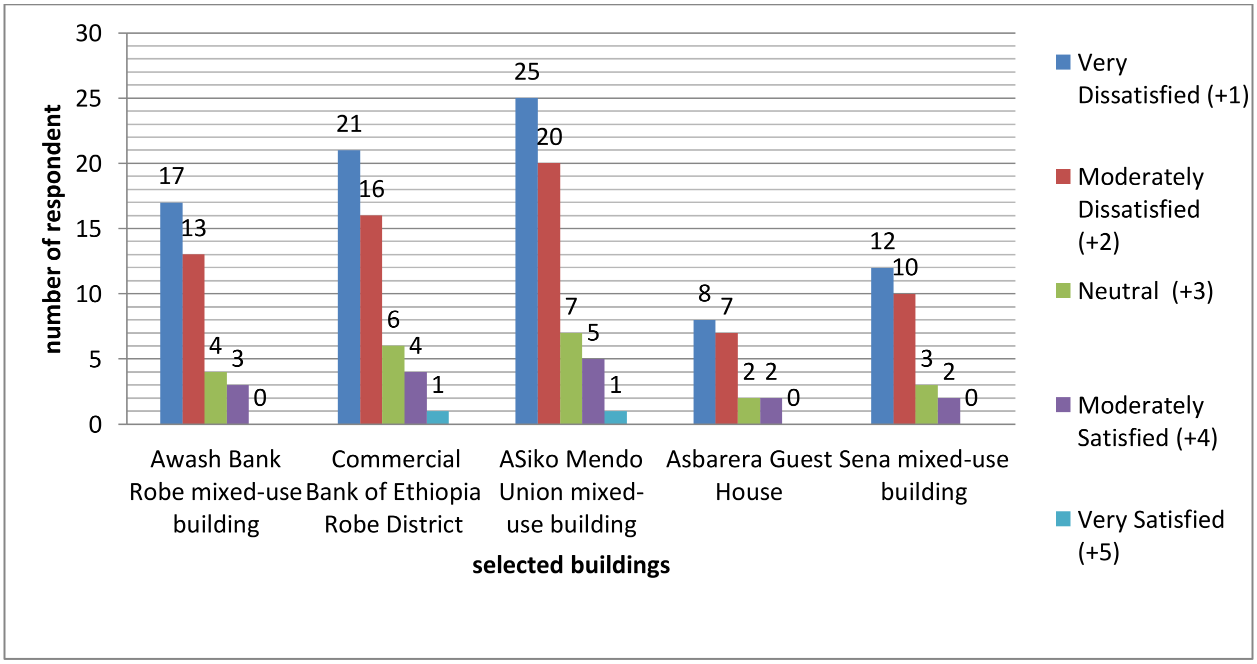

Figure4 .0.23 satisfaction with amount day light satisfaction with overall building services, overall lighting, satisfaction with quality of light, access to daylight, electric light, shading devices, satisfaction with amount of light, view and effects of light on productivity. Satisfaction level of occupants with the visual environment in the buildings of study showed participants were dissatisfied with the workspaces, shading devices and amount of light at their work places. General the satisfaction result showed a satisfaction with workspace is dissatisfied in building all buildings. Overall lighting and access to day lighting is moderately satisfied in all buildings.

Based on Lighting and general indoor environmental quality assessment describe that respondent Satisfaction with the work spaces design of the building services which is 42.78 % are very dissatisfied. 27.27 % of respondents are moderated dissatisfied. 10.69 % of respondents are neutral. 18.18 % of respondents are moderated satisfied. 10.69 % of respondents are very satisfied. Satisfactions with the lighting conditions in the work space where you spend the most time which is 51.63 % are very dissatisfied. 16.48 % of respondents are moderated dissatisfied. 17.55 % of respondents are neutral. 14.89 % of respondents are moderated satisfied. 0 % of respondents are very satisfied.

Satisfaction with the view which is 39.24 % are very dissatisfied. 22.58 % of respondents are moderated dissatisfied. 21.50 % of respondents are neutral. 14.51 % of respondents are moderated satisfied. 2.1% of respondents are very satisfied. Access to natural/day light which is 47.64 % are very dissatisfied. 22.5 % of respondents are moderated dissatisfied. 11.51 % of respondents are neutral. 14.65 % of respondents are moderated satisfied. 3.6% of respondents are very satisfied. Artificial/electric light which is 32.08 % are very dissatisfied. 27.27 % of respondents are moderated dissatisfied. 28.34% of respondents are neutral. 10.69 % of respondents are moderated satisfied. 1.6% of respondents are very satisfied.

4.3.2 Physical data measurements

Known that this was a field study in operational buildings, the author was limited to conduct thorough assessments of true /real lighting conditions. To assess daylight availability, this study focused on measuring daylight illuminance using lux meter on selected office spaces and maintained as best as possible to obtain measurements.

The measurements of daylight illuminance on clear-sky and intermediate days at two interior locations (distance <3m from window and >3m form window) in each of the three buildings. Lux meter measured the amount of light on table within 45 minutes interval and it was checked on screen, the graphs showed the values with time interval.

The measurements indicate that there is access to daylight and views even, as far as 10 meter form the window within each building. However, that as one moves deeper into each space, the amount is insufficient for illumination to be provided by daylight.

Daylight factor (df) is a daylight availability metric that expresses – as a percentage – the amount of daylight available inside a room (on a work plane) compared to the amount of unobstructed daylight available outside under overcast sky conditions. It is the ratio of interior illuminance (ei) to available outdoor illuminance (eh) under overcast skies. 500lux would be sufficient for a well-lit.

A. Distance <3m from window

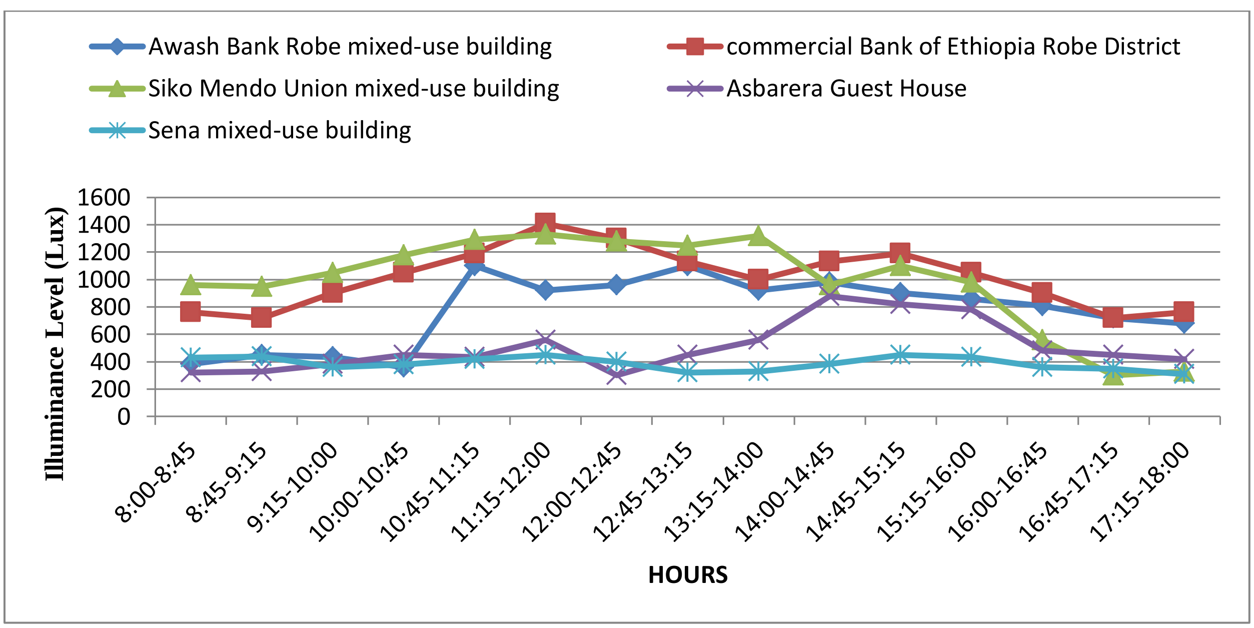

Figure 4.0.24 measurement distance <3m from window

Figure 4.23

B. Depth 3m & above from window

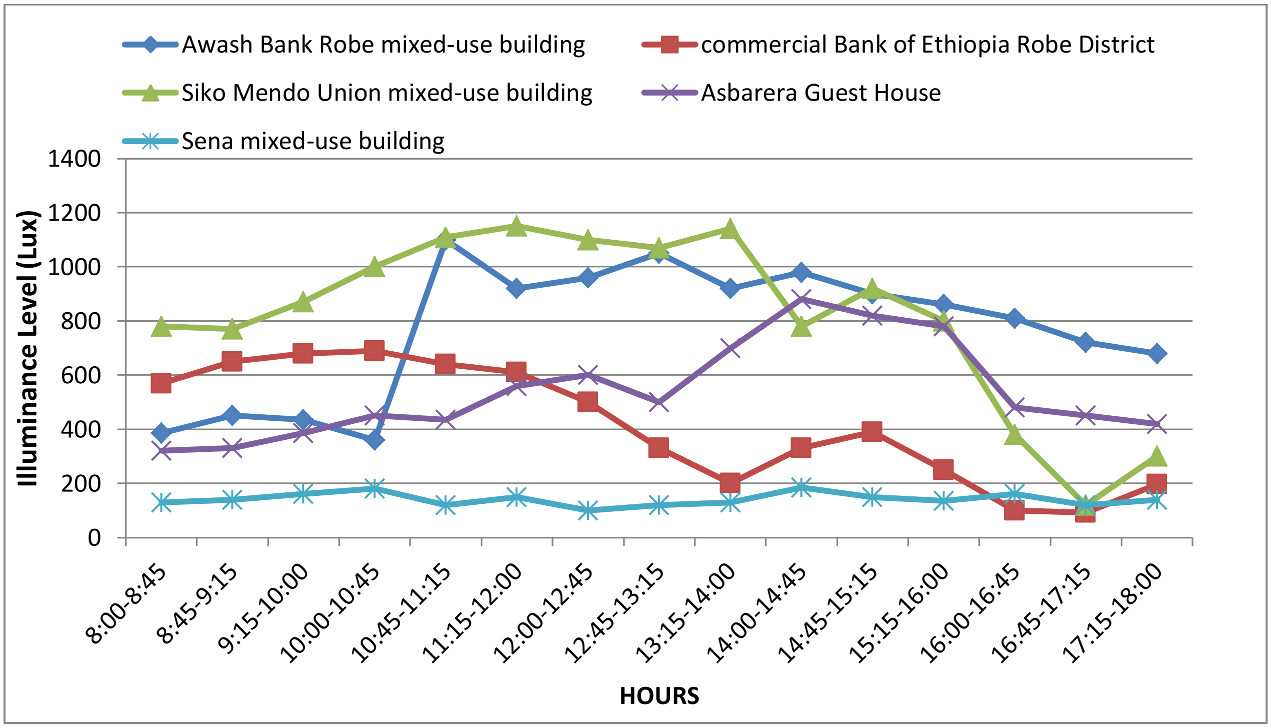

Figure 4.0.25 measurement depth 3m & above from window

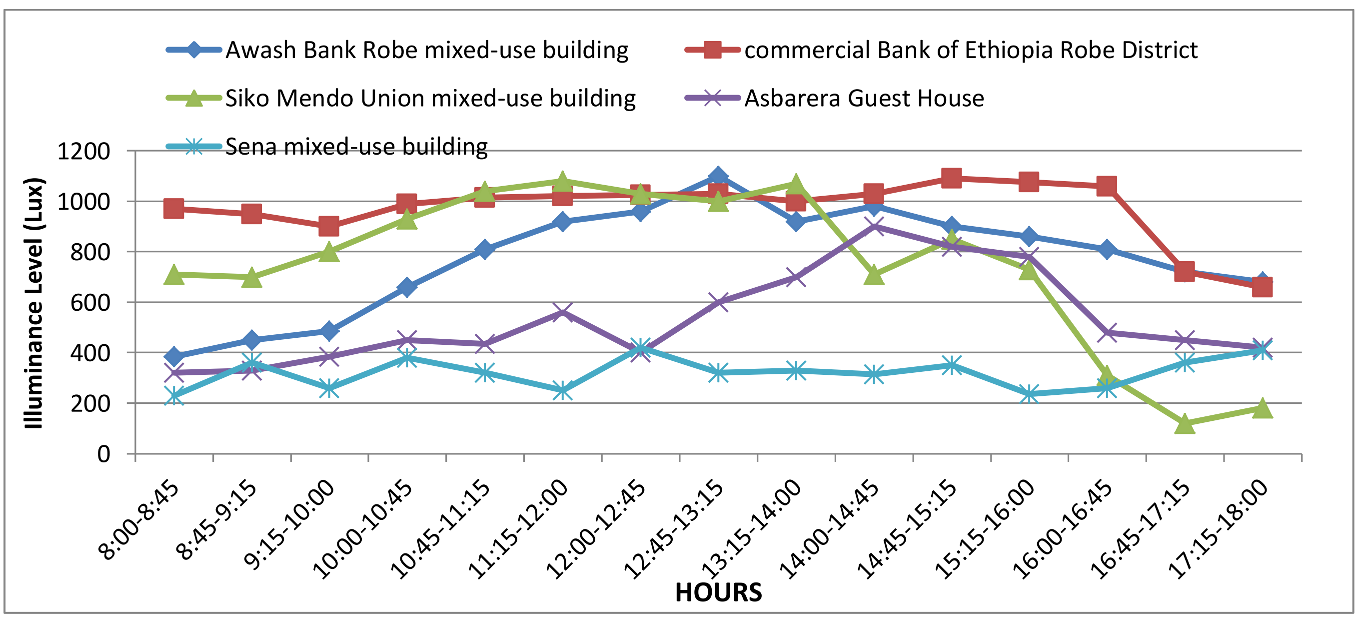

Figure 4.0.26 measurement depth up to 3m from window

C. Depth 3m & above from window

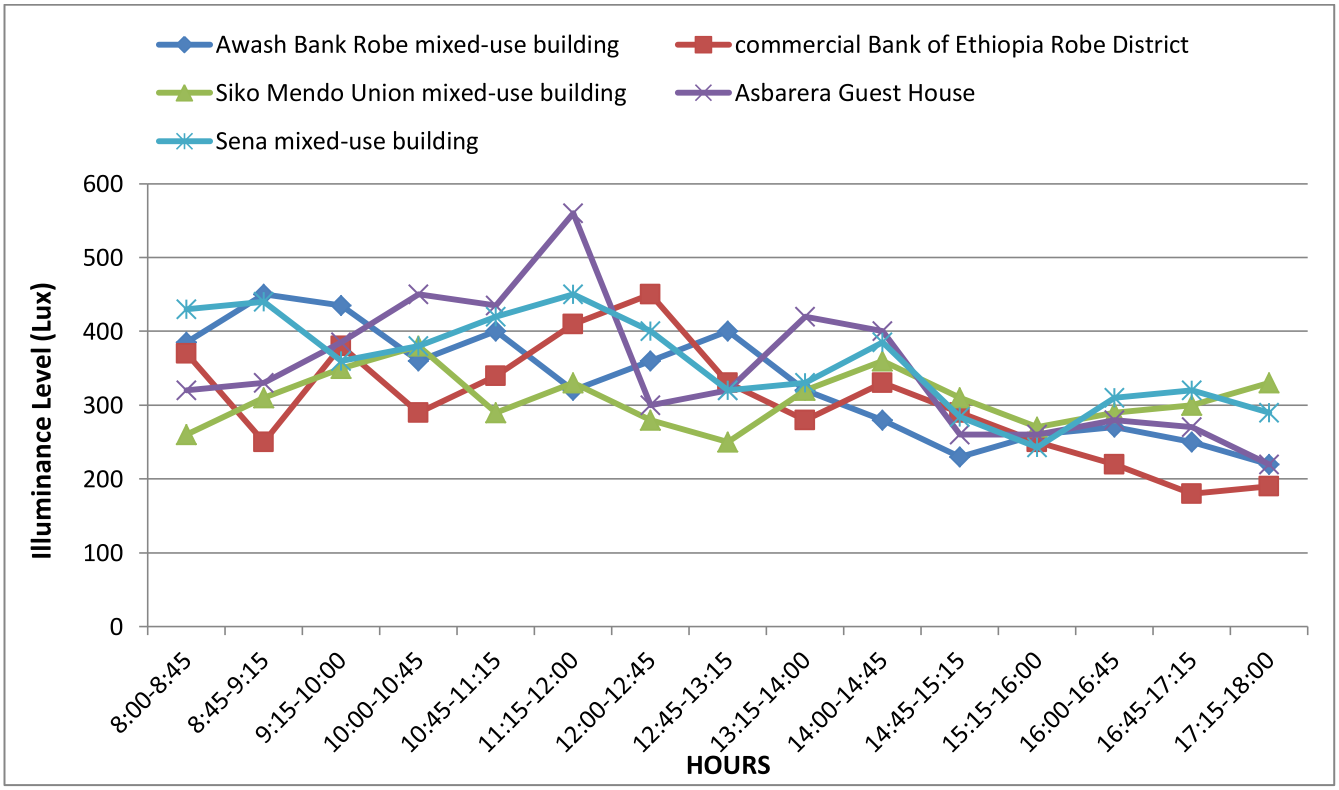

Figure4.0.27 depth 3m & above from window

Based on measurement assessment information above from figure 4.24 to figure 4.27 describe that In this field study of operational buildings, the author's ability to thoroughly assess actual lighting conditions was constrained. The study primarily focused on using a lux meter to measure daylight illuminance in selected office spaces. The objective was to gather measurements as accurately as possible. Daylight illuminance was measured in two interior locations within each of the five buildings - one location less than 3m away from a window and the other more than 3m away. The lux meter recorded the light levels on a table at 45-minute intervals, displaying the data graphically on a screen. Interestingly, the measurements indicated that the light values were higher. The amount of light, measured in lux, varies in different buildings, at different depths from windows, and under different sky conditions. This variation is influenced by factors such as window size, position, orientation, and the visual transmittance properties of the window.

4.3.3 Simulation analysis

The quantitative lighting data of interior workspace is measured by using simulations, energy plus. Indoor environmental parameters needed to be assessed in addition to subjective data to prove the study spaces have potential impacts on occupants comfort with visual environment and to compare the results. Inputs for analysis includes weather data, window size and properties, orientations, floor plan and outputs were sun path diagram, orientation, solar radiation amount, and temperature using design builder. The analysis conducted on intermediate sky conditions.

This result of simulations was compared with survey and physical data measurements.

The glazing facade of the buildings, namely, building 2/ commercial bank of Ethiopia Robe district have 75% glazed on east & n-west and building 1 awash bank robe mixed-use building, have more than 85% glazed on their south and west facade. Whereas, building 3, siko mendo union mixed-use building is 70% glazed which somehow reduced the amount of direct radiation through east orientations and overhang slab. Building 4 asbarera guest house, and sena mixed-use building 70% glazed which somehow reduced the amount of direct radiation through east orientations. 60% of the buildings use internal shading which is made of plastic fibers

Selected building models

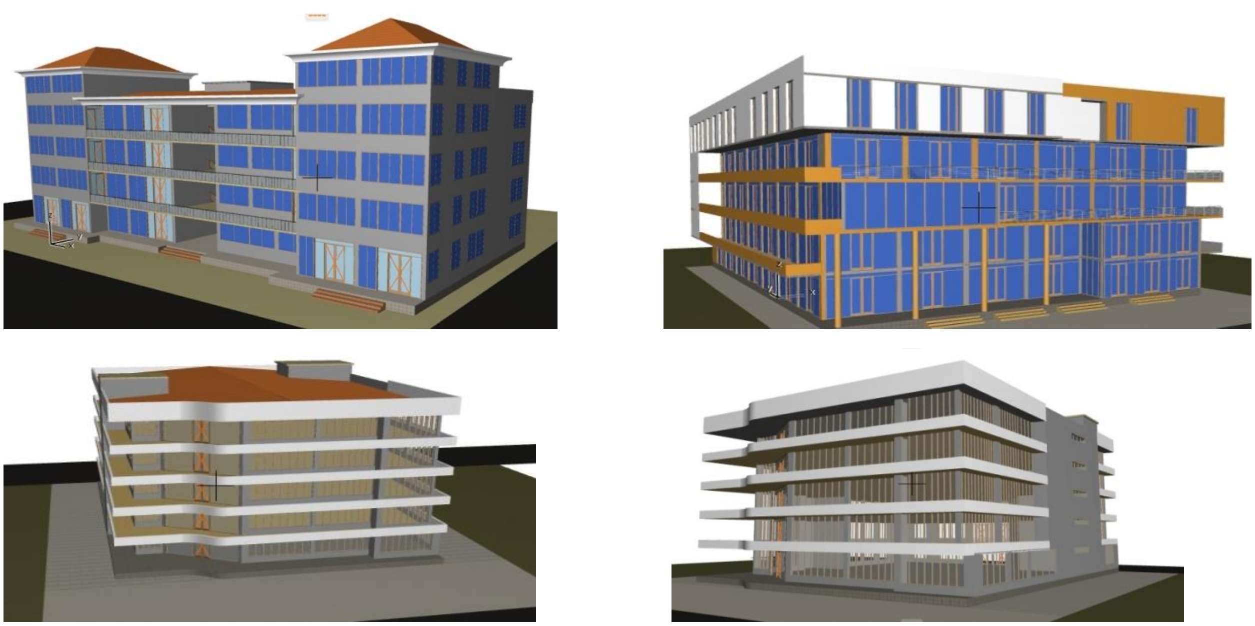

Figure4.0.28 Selected building models

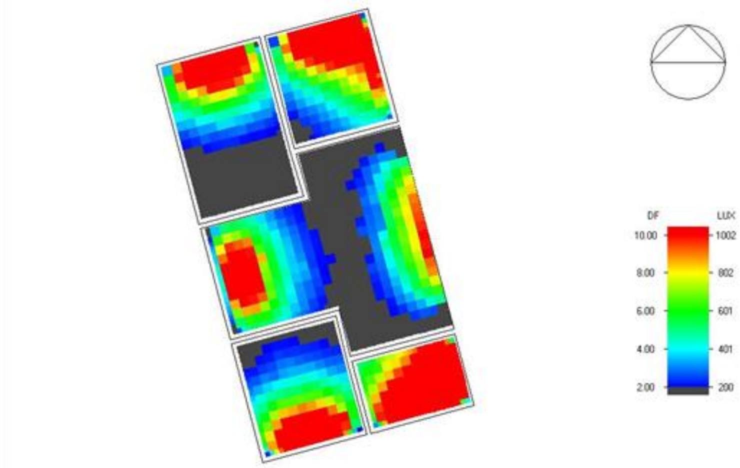

Figure 4.0.29 Day light simulation result 1

The World Health Organization (WHO) does not provide specific temperature recommendations. In the simulation, the average temperature is 25°C, exceeding the optimal range of 15.6-20°C. A minimum illuminance of 0.9 lux and a maximum of 4.9 lux were chosen, falling short of the required 400 lux-500 lux, indicating insufficient lighting. These illuminance levels are inadequate for the necessary 300 lux for tasks, requiring additional lighting installation or an upgrade to the existing system.

Elevated temperatures can lead to player discomfort and fatigue, hindering optimal performance. Exceeding the recommended range increases the risk of heatstroke, a severe condition resulting from prolonged exposure to high temperatures.

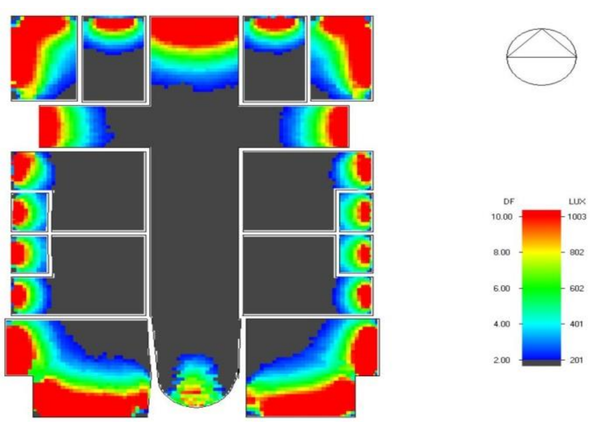

Figure 4.0.30 Day light simulation result 2

Table 4. 0-1. Simulation results

Block	Floor Area (m2)	Minimum Daylight Factor (%)	Maximum Daylight Factor (%)	Min Illuminance	Max Illuminance
Zone 2	4.372	0.01	0.04	0.53	4.02
Zone 19	18.949	0.01	14.59	1.33	1461.49
Zone 3	3.242	0	0.05	0.49	4.82
Zone 7	11.741	0.03	9.82	2.51	981.79
Zone 8	3.125	0	0.05	0.4	4.89
Zone 10	12.317	0.03	11.08	2.98	1109.2
Zone 9	2.805	0	0.02	0.18	2.36
Zone 11	11.834	0.03	10.56	3.04	1056.08
Zone 12	13.97	0.02	14.84	1.63	1485.84
Zone 6	12.491	0.03	9.65	2.57	966.69
Zone 18	57.681	0	15.22	0.21	1523.61
Zone 4	18.596	0.05	15.82	5.29	1585.05
Zone 16	12.532	0.03	10.35	2.91	1035.16
Zone 17	11.777	0.03	9.85	2.76	986.39
Zone 13	3.098	0	0.03	0.2	3.43
Zone 14	3.137	0	0.03	0.21	2.67
Zone 15	3.138	0.01	0.07	1.31	7.21
Zone 1	2.988	0.39	8.13	39.11	814.06
Zone 5	2.979	0	0.03	0.36	3.02
Total	210.771	0	15.82	0.18	1585.05

4.4 strategies enhance building orientation and level of day light study area.

4.4.1 Fenestration

This orientation minimizes cooling loads by protecting the bed rooms from the harsh south, east, and west sun exposure. The north facade's WWR of 70% takes advantage of the available daylight and provides excellent views to the outside. The facade at the second and third levels is a two-story curtain wall with clear and colored glazing. At the ground level is a brick cavity wall with metal framing, punctuated by a series of long strip windows.

4.4.2 Material assembly

The concrete provides durability and the desired finished look of the facade. The steel studs provide the structural support for the thin shell precast concrete panels. The resulting panels are low in weight compared with standard precast panels, reducing structural frame. Finishes are used for the panel’s smooth finish to match the structural columns and board formed texture on the ground level facade. To improve the thermal performance of the facade, foam insulation is embedded within the thin shell concrete precast panels.

4.4.3 Façade design

Large-volume instructional spaces and other program spaces that require maximum natural light are located along the south facade. The WWR for this facade is 30%. Several exterior wall systems are used—brick cavity wall with metal framing, metal panels, aluminum curtain wall, storefront facade, and punched windows. A deep roof overhang shades the facade from the south sun. The east and west facades consist primarily of brick cavity wall. The openings in these facades are kept to a minimum, with a 0% WWR on the east facade and a 10% WWR on the west facade.

4.4.4 Shading devices

The investigation of the shading devices for their respective orientation has revealed that the average shading performance is above 50% in all external permanent shading devices. With the highest shading performance recorded at 93%. The highest shading performance is achieved by horizontal louvers on a vertical plane that covers the entire elevation of the glazing. On the other hand, the lowest performance is achieved by vertical fines used in the eastern and western elevations.

Figure 4.31 vertical shading

This external shading device is perforated aluminum retrofitted on a preexisting full-glazed façade. The higher performance of this shading is a product of the shading type. Despite being oriented toward the south, the shading device achieved around 90% of shading. The installed shading is mostly opaque with small perforations which do not allow the penetration of direct solar radiation.

Through studies, the project optimizes its performance according to the local climate to offer proper light conditions and visual comfort, environmental impact reduction and cost efficiency through the development. Optimization process: The following data is investigated using day lighting simulations and according to the findings of the study and literature reviews concerned within this study.

Shading coefficient determines the thermal performance of a glass building. The value indicates how the glass is thermally insulating (shading) the interior when there is direct sunlight on the panel or window. Provide total glazing areas per elevation within the following optimum percentages. The proper window wall ratio, taken from some literature studies, is also set according to the orientation of local climate;-South orientation: 40% - 60% window to wall ratio (WWR), North orientation: 60% - 70%, West orientation: 35% – 45%, East orientation: 55% - 75% These percentage is roughly calculated based on daily and annually solar exposure of a model building facade. The glazing percentage values differ due to various use of shading devices geometry and different performances.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This study was designed to Investigating Building Orientation and Level of Day Light of Commercial Buildings in Bale Robe Town. According to the existing internal solar controls failed to provide comfortable lighting environments for most of the occupants. The average illumination in the south oriented is higher than the north oriented. The average illumination in the west oriented is higher than the east oriented. Not only the orientation of opening highly affect day lighting system of an indoor environment but also the size and indoor reflecting materials have a great effect on the distribution.

The optimal orientation would increase the thermal comfort of the building as well as its urban environment. Orientation of untreated building envelope directly affects the comfort of the indoor temperatures, while buildings with lengthy facades facing S-N had better performance. During daylight afternoons, south-facing rooms are hotter than north-facing rooms due to the effects of the window-to-wall ratio and room orientation on hourly interior air temperature and daylight illumination.

Too much light contrast is observed towards the perimeter whereas the interior zone showed up too dark. The interior occupants far from window did not receive enough daylight when the windows darkened and were ultimately displeased with their workspaces. This finding was in parallel with previous study that showed, day lighting can also have negative effects on occupants and poor working productivity.

Human performances in workspace were mostly influenced by access to daylight. This finding declares the substantial benefits of daylights with control and natural views to have impacts on comfortable interior environments for occupants' wellbeing, health and productivity. Buildings should be designed with occupants in mind it is crucial that designers understand day lighting strategies, shading, and corresponding human perceptions of comfort.

5.2 Recommendation

This study of Investigating Building Orientation and Level of Day Light of Commercial Buildings in Bale Robe proposes recommendations for further studies, The implication of this study is multidimensional regarding the findings and the methodology adopted. Hence it is recommended that a better understanding be established while implementing such design decisions.

For the municipal organizations, they should incorporate the regulations and monitoring systems regarding building orientation. Keep the building's longer sides away from direct sun radiation. Consider the visual properties of exterior shading devices and avoid highly reflective, trans missive, or specular materials for surfaces that will be in view from occupant workspaces. *Visual e*nvironments with day lighting in workspace should be evaluated through glass types, shading devices and effective angles for different orientations, which evaluate upcoming facade designs in the town before construction permit.

Future experiments and investigations for effective shading devices, indoor environments, more advanced analysis will be performed with the qualitative data coding, to further compare survey results with the measured physical data, and real simulation tools plug in buildings. Climatic analysis and interpretation shall be integrated in the design and fabrication process. . Designers and researchers, it is recommended to be engaged in comprehensive study of the environment before decisions of major facade elements design.

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Appendix- i Questioner

Adama Science and Technology University Office of graduate studies

Department of Environmental Architecture

Dear respondents,

Thank you for taking the time to fill out this questionnaire. These survey questions are a research instrument for the fulfillment of my MSc program in the field of Environmental Architecture at Adama Science and Technology University, the study is focused on **Investigating building orientation and level of day light of commercial building in Bale Robe** Town. Your response will be completely anonymous and confidential, and will not be identified by an individual. All responses will be compiled together and analyzed as a group.

Dear respondent, please do not hesitate to contact me for any difficulty and /or clarification while you are filling out this questionnaire. Direction;

- You are requested to put mark in the box provided in front of each question.
- For questions you are required additional answers, write only on space provided.

Part one: personal information

a. Age; 11-17 ☐ 18-24 ☐ 25-34 ☐ 5-34 ☐ 45-44 ☐ 55-64 ☐ .>65 ☐

b. Sex; male ☐ female ☐

c. Educational background;

MA/MSC and above ☐ BA/BSC ☐ Diploma ☐ certificate ☐

University student ☐ < Grade12 ☐ Un educated ☐

d. Body weight; below 50kg ☐ 51-70kg ☐ 71-90kg ☐ 91 kg and above ☐

e. How many years have you worked in this current building?

0 < 3months ☐ 4-6 months ☐ 7-12 months ☐ > 1yr ☐

f. How long have you been working at your present workspace?

< 5hrs ☐ 5- 8hrs ☐ 8- 10hrs ☐ 10- 12hrs ☐ above 12hrs ☐

Part two: General working environments Assessment

a. At which time of the day did discomfort was occurred?

1:00 – 3:00 L.T ☐ 3:00 – 5:00 L.T ☐

5:00 – 7:00 L.T ☐ 7:00 – 9:00 L.T ☐

9:00 –12:00 L.T ☐ ABOVE 12:00 L.T ☐

b. Overall, how satisfied are you with your level of VISUAL COMFORT of lighting in your workspace?

Very Dissatisfied ☐ Moderately Dissatisfied ☐

Neutral ☐ Very Satisfied ☐

c. What is closest cardinal direction of the nearest exterior window?

N ☐ NW ☐ NE ☐ S ☐ SW ☐ SE ☐ E ☐

d. Please indicate the SOURCE of visual discomfort you find most in your work space?

Direct sun on my work area ☐ Reflections on my computer screen ☐

Direct sunlight on my face /eyes ☐ light reflecting off of exterior ☐

High contrast between window ☐ views of sky ☐

e. Please indicate amount of light penetration in your work space?

Intolerable (impossible to see) ☐ Disturbing (bearable for 15–30 min) ☐

Perceptible, slightly Uncomfortable ☐ Comfortable/ imperceptible ☐

f. Which of the following devices do you use to CONTROL direct sun light penetration?

Internal movable shading device ☐ External fixed shading device ☐

Internal fixed shading device ☐ External movable shading device ☐

g. What are the measures you use to regulate your rooms and protect solar intensity?

Curtain removing ☐ upper cloths ☐ Mech. Ventilator ☐

Few pots of plants ☐ Window stickers ☐ Other_______________

Part three: Lighting and General Indoor Environmental Quality (IEQ) assessment

Please rate the degree of satisfaction with lighting at your workspaces with these parameters on scale of 1-5.

No.	How you asses lighting on your office in your commercial with in terms of these variables?	Very Dissati sfied (+1)	Moderately Dissatisfied (+2)	Neutral (+3)	Moderately Satisfied (+4)	Very Satisfied (+5)
1	satisfaction with the work spaces (design of the building services					
2	satisfaction with the Lighting Conditions in the work space where I spend the most time					
3	Satisfaction with the VIEW					
4	ACCESS to natural /day light					
5	ARTIFICIAL/ELECTRIC LIGHT					
6	Satisfaction with AMOUNT day light					

Please add any comment or concerns on this thesis entitled 'Investigating building orientation and level of day light of commercial building in Bale Robe' ______________________________

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Appendix- ii Questioner Results

No.	Personal information’s			1 0.2	2 .25	3 .3	4 .11	5 .14
1	Sex	Male	116	23	29	35	13	16
		Female	71	14	18	21	8	10
2	Age	11-17	2	0	1	1	0	0
		18-24	12	2	3	4	2	1
		25-34	123	25	31	37	13	17
		35-44	31	6	8	9	3	4
		45-64	14	3	3	4	2	2
		Above65	5	1	1	1	1	1
3	Education	Ma/msc and above	12	2	3	4	1	2
		Ba/bsc	108	22	27	32	12	15
		Diploma	23	4	6	7	2	3
		Certificate	20	4	5	6	2	3
		University student	8	2	2	2	1	1
		Above grade12	4	1	1	1	0	1
		Un educated	2	1	1	0	0	0
4	Body weight	below 50kg	23	5	6	7	2	3
		51-70kg	127	25	32	38	14	18
		71-90kg	33	7	8	9	4	5
		91 kg and above	4	1	1	1	0	1
5	On work time	0 < 3months	29	6	7	9	3	4
		4-6 months	7	1	2	2	1	1
		7-12 months	38	8	10	11	4	5
		> 1yr	113	23	28	34	12	16
6	Working time/day	< 5hrs	36	7	9	11	4	5
		5- 8hrs	129	26	32	39	14	18
		8- 10hrs	12	2	3	4	1	2
		10- 12hrs	6	1	1	2	1	1
		Above 12hrs	4	1	1	1	0	1

No.	General working environments assessment		No.	1	2	3	4	5
1	At which time of the day did discomfort was occurred?	1:00 – 3:00 l.t	33	7	9	9	3	5
		3:00 – 5:00 l.t	11	2	3	3	1	2
		5:00 – 7:00 l.t	18	4	5	5	2	3
		7:00 – 9:00 l.t	83	18	22	23	8	12
		9:00 –12:00 l.t	15	3	4	4	2	2
		Above 12:00 l.t	27	6	7	8	3	4
2	Overall, how satisfied are you with your level of visual comfort of lighting in your workspace?	Very dissatisfied	119	26	31	33	12	17
		Moderately dissatisfied	38	8	10	11	4	5
		Neutral	30	7	8	8	3	4
		Very satisfied	0	0	0	0	0	0
3	What is closest cardinal direction of the nearest exterior window?	N	11	2	3	3	1	2
		Nw	26	6	7	7	3	4
		Ne	23	5	6	6	2	3
		S	89	20	23	25	9	12
		Sw	15	3	4	4	2	2
		Se	23	5	6	6	2	3
4	Please indicate the source of visual discomfort or glare you find most in your work space?	direct sun on my work area	83	18	22	23	8	12
		Reflections on my computer screen	6	1	2	2	1	1
		Direct sunlight on my face /eyes	25	6	7	7	3	4
		Light reflecting off of exterior	4	1	1	1	0	1
		High contrast between window	63	14	16	18	6	9
		Views of sky	3	1	1	1	0	0
5	Which of the following devices do you use to control direct sun light	Internal movable shading device	31	7	8	9	3	4
		External fixed shading device	10	2	3	3	1	1
		External movable shading device	43	9	11	12	4	6

	penetration?	Task lighting	18	4	5	5	2	3
		Other	63	14	16	18	6	9
6	What are the measures you use to regulate your rooms and protect solar intensity?	Curtain removing	28	6	7	8	3	4
		Upper cloths	32	7	8	9	3	4
		Mech. Ventilator	24	5	6	7	2	3
		Pots of plants	33	7	9	9	3	5
		Window stickers	54	12	14	15	5	8
		Other	8	2	2	2	1	1

No.	Lighting and general indoor environmental quality (ieq) assessment			1	2	3	4	5
1	Satisfaction with the work spaces design of the building services	Very dissatisfied (+1)	81	16	20	24	8	12
		Moderately dissatisfied (+2)	51	10	13	15	5	8
		Neutral (+3)	21	4	5	6	2	3
		Moderately satisfied (+4)	34	7	9	10	3	5
		Very satisfied (+5)	0	0	0	0	0	0
2	Satisfaction with the lighting conditions in the work space where i spend the most time	Very dissatisfied (+1)	96	19	24	29	10	14
		Moderately dissatisfied (+2)	30	6	8	9	3	5
		Neutral (+3)	33	7	8	10	3	5
		Moderately satisfied (+4)	28	6	7	8	3	4
		Very satisfied (+5)	0	0	0	0	0	0
3	Satisfaction with the view	Very dissatisfied (+1)	73	15	18	22	7	11
		Moderately dissatisfied (+2)	42	8	11	13	4	6
		Neutral (+3)	41	8	10	12	4	6
		Moderately satisfied (+4)	27	5	7	8	3	4
		Very satisfied (+5)	4	1	1	1	0	1
4	Access to natural/day light	Very dissatisfied (+1)	91	18	23	27	9	14
		Moderately dissatisfied (+2)	43	9	11	13	4	6
		Neutral (+3)	18	4	5	5	2	3
		Moderately satisfied (+4)	28	6	7	8	3	4

		Very satisfied (+5)	7	1	2	2	1	1
5	Artificial/electric light	Very dissatisfied (+1)	61	12	15	18	6	9
		Moderately dissatisfied (+2)	50	10	13	15	5	8
		Neutral (+3)	53	11	13	16	5	8
		Moderately satisfied (+4)	20	4	5	6	2	3
		Very satisfied (+5)	3	1	1	1	0	0
6	Satisfaction with amount day light	Very dissatisfied (+1)	83	17	21	25	8	12
		Moderately dissatisfied (+2)	65	13	16	20	7	10
		Neutral (+3)	22	4	6	7	2	3
		Moderately satisfied (+4)	15	3	4	5	2	2
		Very satisfied (+5)	2	0	1	1	0	0

Appendix- iii Physical Data Measurements

Distance <3m from window

No.	Time	Building 1 Awash bank robe mixed-use building	Building 2 Commercial bank of ethiopia robe district	Building 3 Siko mendo union mixed-use building	Building 4 Asbarera guest house	Building 5 Sena mixed-use building
1	8:00-8:45	385	1570	960	320	430
2	8:45-9:15	450	1650	950	330	440
3	9:15-10:00	435	1680	1050	385	360
4	10:00-10:45	360	1690	1180	450	380
5	10:45-11:15	1100	1640	1290	435	420
6	11:15-12:00	920	1610	1330	560	450
7	12:00-12:45	960	1500	1280	300	400
8	12:45-13:15	1100	1330	1250	1120	320
9	13:15-14:00	920	1200	1320	1200	330
10	14:00-14:45	980	1330	960	900	385
11	14:45-15:15	900	1390	1100	820	450
12	15:15-16:00	860	1250	980	780	435
13	16:00-16:45	810	1100	560	480	360
14	16:45-17:15	720	920	300	450	350
15	17:15-18:00	680	960	330	420	310

Depth 3m & above from window

No.	Time	Building 1 Awash bank robe mixed-use building	Building 2 Commercial bank of ethiopia robe district	Building 3 Siko mendo union mixed-use building	Building 4 Asbarera guest house	Building 5 Sena mixed-use building
1	8:00-8:45	385	570	960	320	130
2	8:45-9:15	450	650	950	330	140
3	9:15-10:00	435	680	1050	385	160
4	10:00-10:45	360	690	1180	450	180
5	10:45-11:15	1100	640	1290	435	120
6	11:15-12:00	920	610	1330	560	150
7	12:00-12:45	960	500	1280	300	100
8	12:45-13:15	1050	330	1250	1120	120
9	13:15-14:00	920	200	1320	1200	130
10	14:00-14:45	980	330	960	900	185
11	14:45-15:15	900	390	1100	820	150
12	15:15-16:00	860	250	980	780	135
13	16:00-16:45	810	100	560	480	160
14	16:45-17:15	720	92	300	450	50
15	17:15-18:00	680	96	330	420	60

Depth up to 3m from window

No.	Time	Building 1 Awash bank robe mixed-use building	Building 2 Commercial bank of ethiopia robe district	Building 3 Siko mendo union mixed-use building	Building 4 Asbarera guest house	Building 5 Sena mixed-use building
1	8:00-8:45	385	1170	960	320	230
2	8:45-9:15	450	1150	950	330	360
3	9:15-10:00	485	1100	1050	385	260
4	10:00-10:45	660	1190	1180	450	380
5	10:45-11:15	810	1215	1290	435	320
6	11:15-12:00	920	1220	1330	560	250
7	12:00-12:45	960	1226	1280	300	420
8	12:45-13:15	1100	1230	1250	1120	320
9	13:15-14:00	920	1200	1320	1200	330
10	14:00-14:45	980	1230	960	900	315
11	14:45-15:15	900	1290	1100	820	350
12	15:15-16:00	860	1275	980	780	235
13	16:00-16:45	810	1260	560	480	260
14	16:45-17:15	720	920	300	450	360
15	17:15-18:00	680	860	330	420	410

Depth 3m & above from window

No.	Time	Building 1 Awash bank robe mixed-use building	Building 2 Commercial bank of ethiopia robe district	Building 3 Siko mendo union mixed-use building	Building 4 Asbarera guest house	Building 5 Sena mixed-use building
1	8:00-8:45	385	370	260	320	430
2	8:45-9:15	450	250	310	330	440
3	9:15-10:00	435	380	350	385	360
4	10:00-10:45	360	290	380	450	380
5	10:45-11:15	400	340	290	435	420
6	11:15-12:00	320	410	330	560	450
7	12:00-12:45	360	450	280	300	400
8	12:45-13:15	400	330	250	320	320
9	13:15-14:00	320	280	320	420	330
10	14:00-14:45	280	330	360	400	385
11	14:45-15:15	230	290	310	260	284
12	15:15-16:00	260	250	270	260	243
13	16:00-16:45	700	810	560	480	360
14	16:45-17:15	720	920	300	450	350
15	17:15-18:00	680	960	330	420	310