THE RELATIONSHIP OF STUDENT VISUAL COMFORT AND LEVEL OF DAYLIGHT AT ELEMENTARY SCHOOL IN ADAMA, ETHIOPIA

By

Afomia Million Ketsela

A Thesis submitted to

The Department of Architecture

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master of science in Environmental Architecture

Office of Graduate Studies

Adama Science and Technology University

Adama, Ethiopia

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APPROVAL SHEET

Adama Science and Technology University School of Civil Engineering and Architecture Department of Architecture and Urban Planning

This is to certify that the thesis prepared by Afomia Million, entitled: The Relationship Of Student Performance And Level Of Daylight At Elementary School Classrooms In Adama, Ethiopia and submitted in partial fulfillment of the requirements for the Masters of Science degree in Environmental Architecture complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

Signed by the Examining Committee

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External examiner

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Post Graduate Dean

DECLARATION

I, the undersigned, declare that this thesis is my own and original work and has not been presented for a degree or diploma in any other institution or university and that all sources of material used for the thesis have been duly acknowledged, following the scientific guidelines of the university.

Afomia Million Ketsela

Signature ____________________

Date ________________________

Confirmation

This MSc Thesis has been submitted for examination with my approval as thesis advisor.

Advisor's Name: Tibebe Assefa (PHD)

Signature ____________________

Date ____________________

ADVISOR'S APPROVAL SHEET

To: Architecture department

Subject: Thesis Submission

This is to certify that the thesis entitled "The relationship of student visual comfort and level of daylight at elementary school in Adama, Ethiopia" submitted in partial fulfillment of the requirements for the degree of Master of Science in Environmental Architecture, the Graduate Program of the Department of Architecture, and has been carried out by Afomia Million ID. No PGR/18030/11, under my supervision. Therefore, I recommend that the student has fulfilled the requirements and hence hereby she can submit the thesis to the department.

Tibebe Asefa (Ph.D.)	____________	_____________
Name of major Advisor	Signature	Date

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Thank you all those who put their handprint either directly or indirectly for making this thesis possible

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ACRONYM AND ABBREVIATION

BREEAM	Building Research Establishment Environmental Assessment Methodology
CASBEE	Comprehensive Assessment System for Built Environment Efficiency
CCT	Correlated color temperature
CLA	Circadian light
CRI	Color rendering index
CS	Circadian Stimulus
EBCS 12	Ethiopian building code standards 12
GBTool	Green Building Tool
GSS	Global sensitivity score
IESNA	Illuminating Engineering Society of North America
LEED	Leadership in Energy and Environmental Design
NIF	Non-Image Forming
SBTool5	Sustainable Building Tool
SCN	Suprachiasmatic Nucleus
SPD	spectral power distribution
USGBC	U.S. Green Building Council

ABSTRACT

Daylight in classrooms is the most important for indoor environmental comfort when designing school building, in terms of its impact on student's visual comfort. Visual comfort at classrooms has often been considered in terms of task visibility and discomfort glare. Besides visual effects, the lighting environment has also impact on human non visual effect. "The light quality of indoor environment also plays a significant role in regulating Non-Image Forming (NIF) functions" such as circadian rhythms, which contain human psychology like alertness, well-being and mood. The main focus of this study is about the relation of student visual comfort and level of daylighting in Adama Elementary schools classrooms. There wasn't any study done in Adama, Ethiopia on the daylight level assessment in school compound. In this study, daylight is being measured and analyzed to determine its level of distribution and functionality in the indoor classroom spaces then compared with student perception towards visual comfort. Lux meter was used to measure daylight level at the task area then simulate the data by using Ecotect software. The student perception data was analyzed using MS Excel charts and graphs. The result of the analysis had shown classes with a deficiency of day light. Up to 76.6% of the working planes get daylight less than 200 lux which is not enough for teaching and learning process. Although some classrooms (68.7%) get daylight greater than 500 lux, it is not comfortable for different tasks in the classroom. Maximizing or minimizing window size, using different shading devices which consider the orientation and by improving surface reflectance which avoids glare are some of the remedies suggested for existing classrooms.

Key words: - alertness, circadian rhythms, classroom, Daylight, non-image forming effects, surface reflectance, task visibility and visual comfort,

CHAPTER ONE

INTRODUCTION

This section includes the background information of the study, statement of the problem, objectives, research questions, scope, limitations and significance of the study.

The study aimed at analyzing the relationship of student visual comfort to level of daylight at elementary school in Adama city. Visual comfort is one of the criteria in sustainable buildings of indoor environment. The main motivation of doing this research was seeing the gap when doing class project on the previous semesters. The distribution of light in different classrooms was different and also the student's level of visual comfort was different in Adama science and Technology University. It is observed that affect the teaching and learning process and also the performance of the students. Most of the time student performance built at the early stage of school (elementary school). That is why this study was doing on the elementary school.

1.1. Background

History of daylighting and the history of architecture were one. From the Roman groin vault to the Crystal Palace of the nineteenth century, the major structural changes in buildings reflected the goal of increasing the amount of light that was collected(Ma et al., 2017). Gothic architecture was primarily a result of the quest for maximum window area. Only small windows were possible when a barrel vault rested on a bearing wall. Large and numerous windows were a dominant characteristic of Renaissance architecture. Windows dominated the facade, especially in regions with cloudy climates, such as England. The masters of twentieth-century architecture continued to use daylight for both functional and dramatic purposes(Giarma et al., 2017).

Daylight is a light that is transmitted via sunlight which is then reflected on a surface before illuminating into a space or an area (Dass et al., 2014). Nowadays different studies has revealed not only its significant impact daylight on human visual system, but also its role on psychological health, improved productivity and performance of the occupant. Daylighting is a visual element of an indoor environment (Zomorodian et al., 2016). The main intention in choosing daylights is because of the quality of light is better than any electrical lighting to do different tasks and also light effects not only vision, but also non-visual effects such as regulating the circadian system (Dass et al., 2014).

The aim of this research is to analyze the daylight level distribution of the existing classroom design and its relation with the visual comfort of the students. By using lux meter for light level measurement then the data was simulated using simulation software.

Daylight has played a crucial role in the design of educational spaces. Studies such as daylighting and visual comfort in Buildings by Aravantinos, D. (2017), Evaluating daylight performance of light shelves by Meresi, A. (2016) have shown that good daylight in schools is able to create a pleasant environment by creating visual comfort to the students The lack of a sufficient light can disrupt the circadian system, such as poor sleep, reduced alertness, and cardiovascular (Zelinski et al. 2014).Good daylighting has also been proven to provide healthier environments (Li et al., 2003). Natural school environments have an important role in improving the psychological health of students (Mirrahimi et al., 2011).

1.2. Statement of the problem

Light levels and lighting distribution in school buildings especially in classrooms have strongly influenced visual performance of an individual to do a given task. The existing class rooms at Adama elementary schools has too many daylighting problems. Some classrooms has insufficient daylight that the window size is not enough for lighting the class, so the students use artificial lighting at the day time. The others have sufficient window size but on the wrong orientation. Therefore, harsh sun glare passing tough the window that disturb the teaching learning process. The rest have right window size and orientation but the distribution of light is not smooth since interior paints are not considered the lighting system.

Therefore, these existing daylighting problems affect the student's visual comfort. Lighting influences not only the visual system, but also many non-visual effects on a wide range of biological functions such as circadian system. The lack of a sufficient light can disrupt the circadian system, which lead to negative health outcomes, such as poor sleep, reduced alertness, and increased risk of cardiovascular disease and cancer.

In the case of Ethiopian building code standards there is considerations only window size that is also not considering the specific task. Especially, school designs need daylight detail design considerations to improve learning environment.

1.3. Objective

General objective:

The general objective of the study is to identify the relationship of student visual comfort to level of daylight at elementary school classrooms in Adama, Ethiopia

Specific objectives:

1. To evaluate the day light level distribution of typical classrooms in Adama elementary schools.
2. To explore student perception towards the existing daylight distribution in the class room.
3. To identify the relation between daylight and learning environment in Adama elementary school.

1.4 Research Question

Main Question

What is the relation between student visual comfort and level of daylight at elementary school classrooms in Adama, Ethiopia?

Specific Question

1. What is the level of daylight distribution in Adama Elementary school classroom?
2. What is the student perception towards the existing daylight distribution in the class room?
3. What is the relation between natural light and learning environment in Adama elementary classroom?

1.5. Scope

Spatially this study limited to elementary school classroom in Adama, where the student performance built most of the time at this early stage. From the Adama city elementary school only governmental are taken as a full sample size. Only four cardinal direction's (north, south, east and west) oriented class rooms are considered in this study. The data was planned to collect from January to May 2020 for five months because of the occurrence of COVID19 the live measuring data was collected for one month. The rest of the months are taken from Ecotect by uploading the weathering data of Adama city.

Therefore, the whole year data is analyzed. Thematically the study will focus on assessing the relationship between student visual comfort and daylight level in classroom. The student's perception towards daylighting in the classrooms also analyzed.

1.6. Significance

After analyzing the important relationship of student visual comfort and level of daylight at elementary school classrooms, the study will be very important for the improvement of visual comfort in school. The research has a great significance for students healthy and comfortable learning environments, improve academic performance by creating visually comfortable classrooms. It has its own significance for the Ethiopian building code standards policymaker, to have its own standards that consider level of daylight distribution in a building special function like school designs and modification strategy for the existing class. For Researcher/ Academics, it introduces Ethiopian classroom daylighting practice and different methods of investigating visual comfort to indicate anew area of references for next.

1.7 Limitation

Due to COVID19 pandemic the data collection was not conducted as planed since schools were closed. Therefore, only the actual measured data was collected for one month. The rest was taped using Ecotect based on the weather of Adama city.

1.8 Description of the study Area

Adama city is a Special Zone of Oromia National regional state of Ethiopia. The city is located about 100 km southeast of the national capital Addis Ababa. It is located at8.54°N 39.27°E at an elevation of 1712 meters. It has a tropical wet-dry climate according to Köppen climate classification. Its average annual temperature and precipitation are 20.5 °C and 808 mm respectively. Figure 4 Show the location of Adama, the study area.

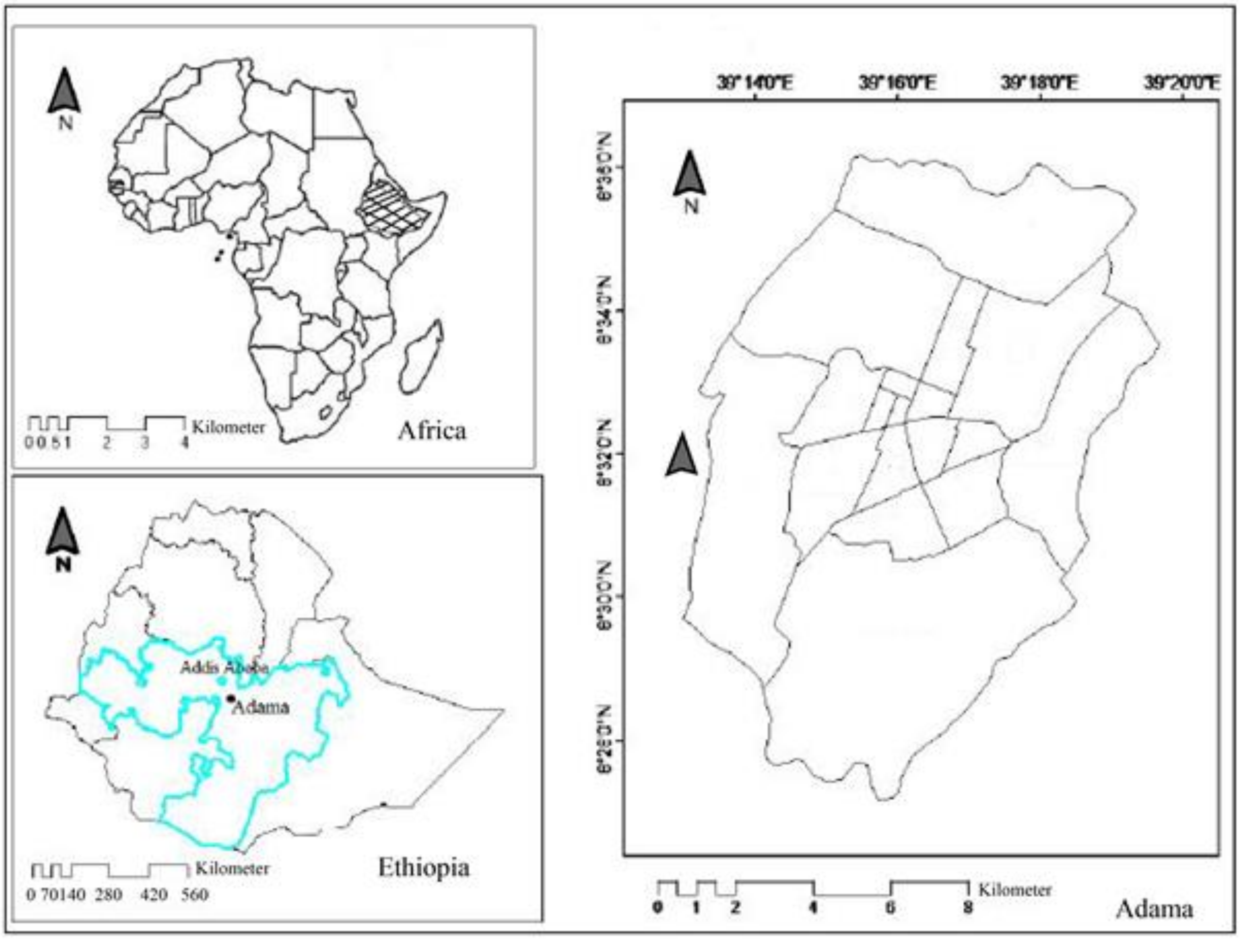


Figure 1 Location map

CHAPTER TWO
LITERATURE REVIEW

2.1. Theoretical review

2.1.1 Daylight and daylighting

Daylight is the combination of all direct and indirect light originating from the sun during daytime (Yacan, 2014) shown on the (figure 2). The light from each source varies not only in quantity but also in such qualities as color, diffuseness, and efficacy. Recent research has proved that daylight provides an array of health and comfort benefits that make it essential for buildings' occupant (Silvester, n.d.).

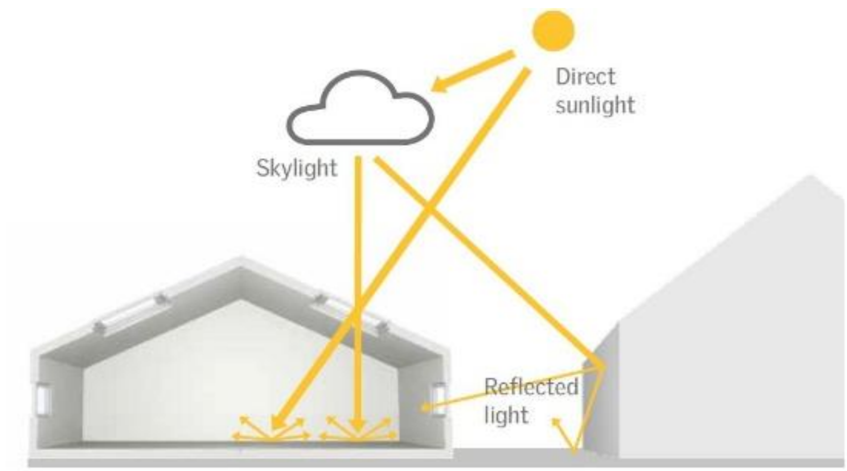


Figure 2 The component of daylight(Design et al., n.d.)

Daylighting describes the controlled use of natural light in and around buildings (Reinhart, 2014). It is the practice of placing windows, or other transparent media and reflective surfaces so that natural light provides effective internal illumination during the day (Erlendsson et al., 2014).Daylight is intrinsically more efficient than any electric source because it provides more lumens per unit of heat content (Heschong, 2002). Daylight in buildings is composed of a mix – direct sunlight (100, 000 lux), diffuse skylight (10 000 lux), and light reflected from the ground and surrounding elements. Daylighting design needs to consider orientation and building site characteristics, facade and roof characteristics, size and placement of window openings, glazing and shading systems, and geometry and reflectance of interior surfaces (Silvester, n.d.).

2.1.2 Visual comfort

Visual comfort is the main determinant of lighting requirements. Good lighting will provide a suitable intensity and direction of illumination on the task area (Action, n.d.). The balance of daylight transmission with the avoidance of glare is a central performance objective for effective daylighting. However, glare is rarely studied during the design process(Practices, n.d.).

For leveling daylighting, good lighting should be comfortable for all building users. With the modern technology designing a lighting system to meet all requirements of an environment is possible(Samani, 2012). A good daylighting design will provide large amounts of glare-free light; a poor daylighting (Dai et al., 2018)design, on the other hand, will provide either insufficient amounts of light - so that electric lighting has to be used recurrently - or large amounts of light, together with glare(Silvester, n.d.). Daylight may cause problems with glare on workplaces or other places in the visual environment(Nielsen et al., 2003). Glare from daylight may be caused by several potential sources such as the sun, bright sky and clouds, and surfaces reflecting the sun. There are three main types of glare:

Disability glare: - is the effect of scattered light in the eye whereby visibility and visual performance are reduced. This occurs when glare sources of high luminance (e.g. sun or specular reflection of the sun) are in the field of view. In day lit interiors, it is often found that discomfort glare is reported before disability glare becomes an issue.

Discomfort glare: - defined as an irritating or distracting, but not necessarily impairing, effect. So in most cases, the perceived magnitude of discomfort glare is lower than for disability glare. Discomfort glare indoors is influenced by the full visual environment, including windows, reflections (especially specular), external surroundings and/or interior surfaces(Boyce et al., 2003). Discomfort glare may cause later side- or after effects in the form of headaches or fatigue.

Reflections or veiling glare: - is reflections on display screens or other task materials reduce the contrast between background and foreground for the visual task and thus reduce readability(Hirning et al., 2017). Reflections occur when bright light sources are in the reflected field of view of the screen (Ma et al., 2017).

The lack of a sufficient light can disrupt the circadian system. Lighting's circadian effect depends on not only corneal illuminance, but also other factors such as spectral power distribution (SPD), timing, duration, and prior lighting exposure history.

Among the lighting factors that affect circadian stimulation, SPD and corneal illuminance are two "static" factors that are typically decided by lighting designers, while the "non-static" factors, such as timing, duration, and prior lighting exposure history, are usually up to the end-users to decide(Dai et al., 2017). Studies show that daylight spectrum is relatively efficient in providing circadian stimulus: based on the CIE D65 spectrum, a corneal illuminance of 233 lx corresponds to a CS value of 0.35; however, artificial light sources that are typically used in indoor applications can be much less effective in delivering CS: for the same CS target of 0.35, the corresponding corneal illuminance needed for a 4000 K FL11 fluorescent lamp is 575 lx. LED spectral optimization is currently an active research area which aims to maximize the tunability range of circadian effect under the constraints of general lighting requirements, such as white color, a high color rendering index (CRI), and a suitable range of correlated color temperature (CCT)(Cai et al., 2018).

2.1.3 Non-Image Forming (NIF) effects of light

The ocular lighting influences not only the visual system, but also many non-visual effects on a wide range of biological functions, such as physiology, mood and behavior. These effects are called "Non-Image Forming" (NIF) functions. Figure 3 schematically illustrates the pathways of visual and NIF effects in the brain.

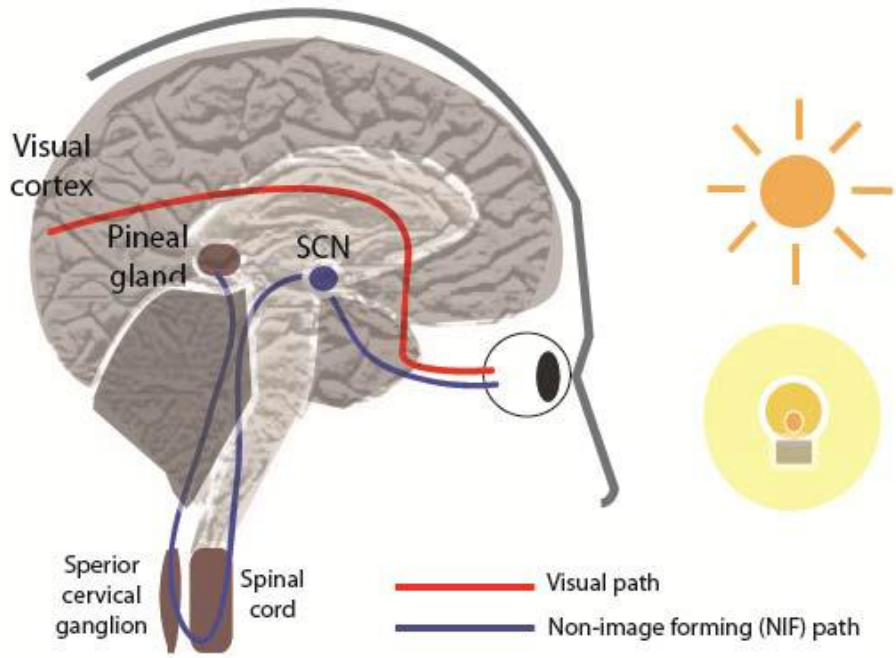


Figure 3 Schematic overview of visual (red) and NIF (blue) pathways in the human brain (Construit et al., 2013)

2.1.4 Circadian rhythms

The circadian system with its master clock in the Suprachiasmatic Nucleus (SCN) governs our daily rhythms such as body temperature, sleep and alertness level, mood secretion, and most other physiological functions(Practices, n.d.). Endogenous concentration changes of two hormones, melatonin and cortisol are often used as circadian ’phase markers’ in humans. Melatonin, also referred to as a “dark hormone”, is secreted by the pineal gland during nighttime. It relates to several physiological processes including circadian entrainment, retinal physiology and seasonal reproduction(Dai et al., 2017).

The lack of a sufficient light stimulus at the appropriate time can disrupt the circadian system, which can in turn lead to a range of negative health outcomes, such as poor sleep, reduced alertness, and increased risk of a range of health problems including diabetes, obesity, cardiovascular disease and cancer (Zelinski et al. 2014). Daylight is an attractive alternative to electrical lighting for maintaining human circadian entrainment indoors due to its spectrum intensity, general availability, and potential to be introduced into spaces via windows and skylights(Cai et al., 2018).

2.1.5 Daylight perception

Daylight perception is a significant factor in indoor environmental quality. Occupants' acceptable light levels should be provided to guarantee comfortable and productive spaces (Chraibi et al., 2016). Daylight not only improves health, awareness and productivity, but also create sense of comfort.

Among daylight and visual comfort studies, a group has focused on subjective evaluations via field and lab experiments to acquire information on occupants' visual preferences (Velds, 2002), investigating the following issues

- Effective parameters on daylight perception
- Visual comfort issues
- Development of new metrics for predicting occupants' visual comfort

Researchers found that not all the existing methods can accurately evaluate visual comfort, which resulted in poor consistency between laboratory-derived measures and occupants' experience in buildings (Jakubiec and Reinhart, 2016). Moreover, satisfying light conditions differ significantly between individuals (Chraibi et al., 2016) due to the known inherent variability between occupants concerning visual comfort perception, preference, and acceptance (Van Den Wymelenberg, 2014). Therefore, there is no consensus yet as to what metric can accurately predict visual comfort, and it is necessary to understand the relationship between metric assessments relative to human evaluations through field studies (Nezamdoost and Van Den Wymelenberg, 2017b).

2.1.6 Effect of Color on Daylighting

Use light colors both indoors and outdoors to reflect more light into the building and farther into the interior. Light-colored interiors will not only reflect light farther into the building but also diffuse it to reduce dark shadows, glare, and excessive brightness ratios. The ceiling should have the highest reflectance factor possible. The floor and small pieces of furniture are the least critical reflectors and, therefore, might have fairly low reflectance factors (dark finishes). The most important for glare control is the wall around the window (Construit et al., 2013). Table 1 shows

Table 1 Typical Reflectance factors

Surface description	Reflectance Material (Percent)
Concrete	30—50
Glass	
Clear or tinted	7
Reflective	20—40
Paint	
Black	4
White	70—90
Wood	5—40

(Source: Cai et al., 2018. The impact of room surface reflectance on corneal illuminance and rule-of-thumb equations for circadian lighting design)

2.1.7 Daylighting and Student Performance

Good daylighting can improve classroom conditions promote students learning, and reduce the rate of absenteeism in classrooms. United States Researchers indicated that adequate natural lighting promotes student performance (Dahlan et al., 2015). Daylight provides high illuminance and permits excellent color discrimination and color rendering. These two properties mean that daylight provides the condition for good vision(Agency et al., n.d.). Students are required to read off of many different surfaces, including paper on the surface of a desk to vertical computer monitors (Pulay, 2010).

Heschong et. al (2002) examined 8000 students in 450 classrooms and results showed that natural light directly affects children performancoe. He concluded that children in daylight classrooms promoted by 20 % compared with children in non-daylight classrooms. According to Heschong et. al (1999), more than 21,000 students' test scores about reading and math were analyzed, and found that the California students 20% to 26% increase in academic performance, while children in Seattle and Fort Collins showed about 7% to 18% developments. When compared with maximum daylight classrooms to with minimum daylight classrooms, students in maximum daylight classrooms improved math by 20% and reading by 26%.Their scores were between 5% and 14% in reading and math.

2.1.8 Design Principles for Daylight in Schools

Good daylighting design should contribute to a comfortable, productive, healthy, environmentally responsive, and cost-effective school. Designer's goals described on following nine design principles:

1. Elongate the wings of the school on an east-west axis to avoid glare and excessive solar heat gain.
2. Bring the light in high. Windows high on the wall will allow the light to penetrate further into the space.
3. Use skylights and roof monitors to daylight areas without easy access to windows.
4. Let daylight in from more than one side of the room when possible.
5. Provide views where appropriate, hut diffuse or block direct sun
6. Use light-colored interior surfaces to reduce luminance contrast and improve coverage.
7. Control first costs by avoiding excessive glazing areas and oversized cooling systems.
8. Create a daylighting culture in the school. Educate teachers and students to open blinds and turn off electric lights when daylight is sufficient.
9. Dim or switch off electric lights when there is sufficient daylight(Leslie et al., n.d.)

Window configurations

Penetration of natural lighting into a classroom depends on many parameters of design, which includes ceiling height, internal reflectance's, depth of room, shape and size of glazing area. (Zomorodian et al., 2016). Configuration of opening can modify the intensity and distribution of daylight to create appropriate luminous environments.

Window location; the intensity and distribution of daylight improves with higher glazing positions. Window to wall ratio the daylight distribution is also affected by greater areas of openings, extending daylight zone. Window glazing; the importance of window glazing on energy and daylighting performance of buildings.

Light shelves; another strategy to maximize daylight distribution is to incorporate light-shelves to bounce daylight back into the interior (figure 4) while protecting the front part of the room from harmful visual effects of direct sunlight (Zomorodian et al., 2016).

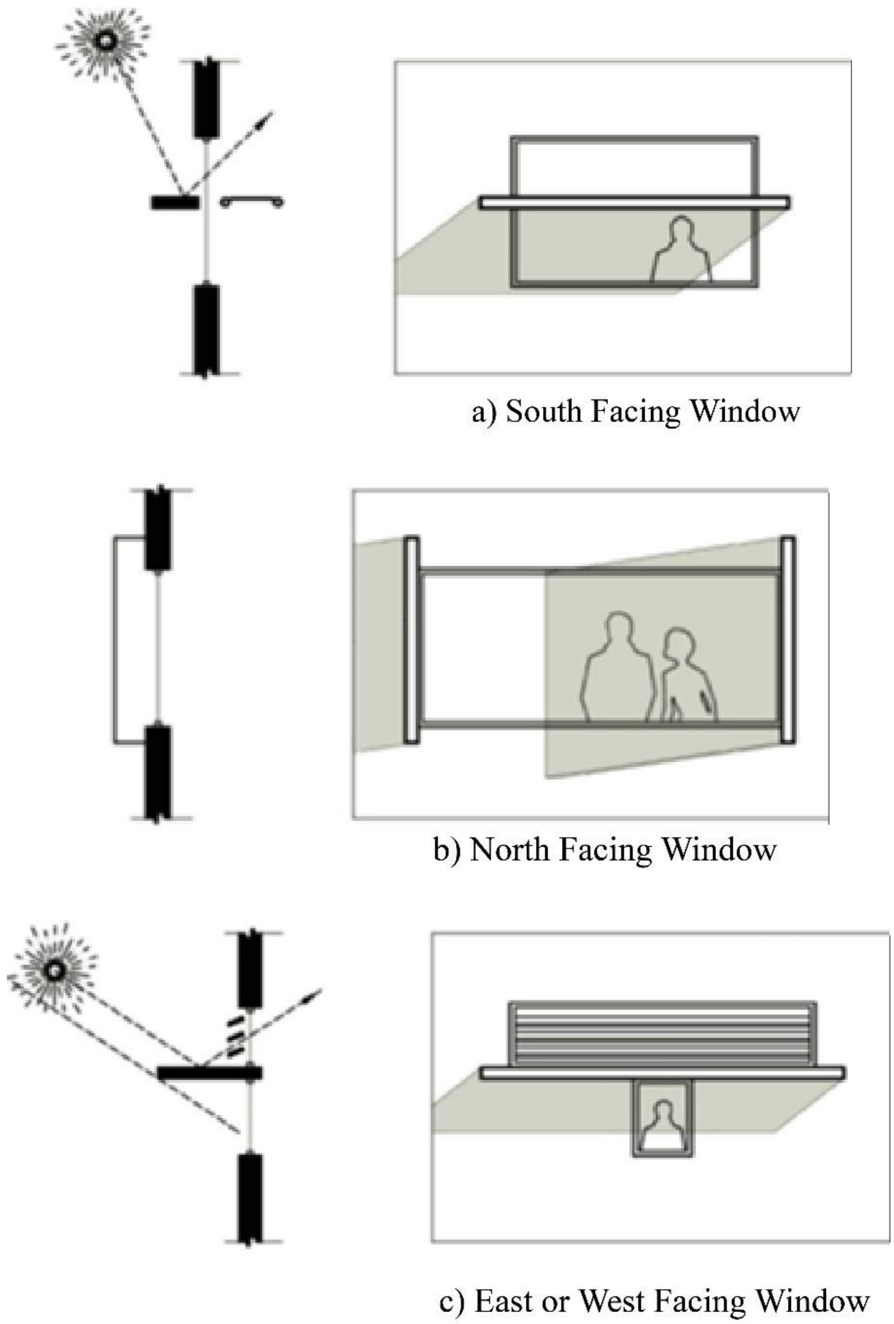


Figure 4 Each orientation having a different window design.

Each orientation should have a different window design. Light shelves work very well on south windows, but not on north windows, where they block more daylight than they collect. North windows, however, need fins to shade the early morning and late afternoon sun. On the difficult east and west facades, use short and wide daylight windows with deep light shelves. View windows should be few and small.

2.1.9 Visual Comfort Parameters In Buildings' Environmental Performance Assessment Tools

The tools examined in this paper (BREEAM, LEED, CASBEE and SBTool) vary in their philosophy, approach and structure. The criteria used to assess visual comfort in each one of the four tools are organized in a different way, depending on the general assessment context, structure and system of each tool (Giarma et al., 2017). Daylighting is assessed both on a quantitative and a qualitative basis (Giarma et al., 2017). Shown (table 2) below;

Table 2 Parameters related to visual comfort in the examined methods

BREEAM	LEED	CASBEE	SBTool
1. Glare Control 2. Daylighting 3. View out 4. Internal and external lighting levels, zoning and control	1. Interior lighting 2. Daylight 3. Quality views	1. Daylight 2. Anti-glare measures 3. Illuminance level 4. Lighting controllability 5. Perceived spaciousness and access to view (in sub-item "Amenity", of the item "Service Ability")	1. Appropriate daylighting in primary occupancy areas 2. Control of glare from daylighting. 3. Appropriate illumination levels and quality of lighting in non-residential occupancies. 4. Controllability (including several criteria with regard to the degree of control for lighting systems) 5. Access to exterior views from interior

(Source: Giarma et al., 2017. Visual comfort parameters in buildings' environmental performance assessment tools)

Most of the codes originate to the ones released by the Illuminating Engineering Society of North America (IESNA) and the European Standards (EN). Both of them recommend a target illuminance of 200lux - 500 lux for classrooms and the minimum daylight factor in classrooms is 2%.

2.2 Contextual review

Ethiopian government launched the Education Sector Development Program phase II from 2002 to 2004 (ESDP-II), and ESDP-III from 2005 to 2009 with objectives to improve the quality of education.

The response now is to the real needs and reasons for education, to change and flexibility and an awareness that the buildings are simply and primarily for children to learn in and teachers to teach.

Ethiopian building code standards 12 (EBCS 12)

Building special design

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).

a. Required exterior openings are permitted to open in to a roofed porch, where the porch.

  i. Abuts a public way, yard or court.

  ii. Has a ceiling height of not less than 2100 mm

  iii. Has a longer side at least 65 percent open and unobstructed.

b. 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).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Sampling technique

There are thirteen governmental elementary schools at Adama city which are located in different kebele. By using purposive sampling after all the thirteen schools. the study covered those which aligned to the four cardinal direction (north, south, east and west) oriented class rooms. The location of schools shown on the figure 5 below;

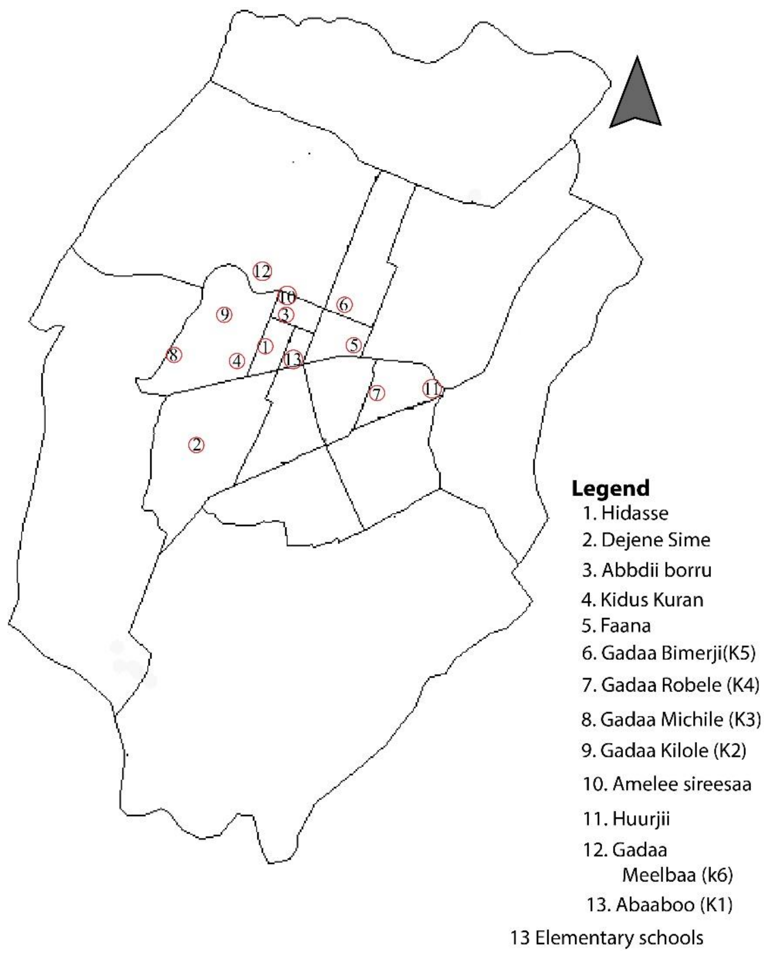


Figure 1 Location of elementary schools found in Adama city

In these schools, there are 192 classrooms as shown on figure 6. After assessing classrooms arrangement and number of classrooms with their specific window orientation, the specific sample classes were selected. The classrooms which have same orientation, window size and room depth, one sample classroom were selected randomly. Table 3 shown the number of main window facing the respective direction.

Table 3 Classroom orientation

No	Orientation	Number of classroom
1	North	42
2	South	22
3	East	44
4	West	84

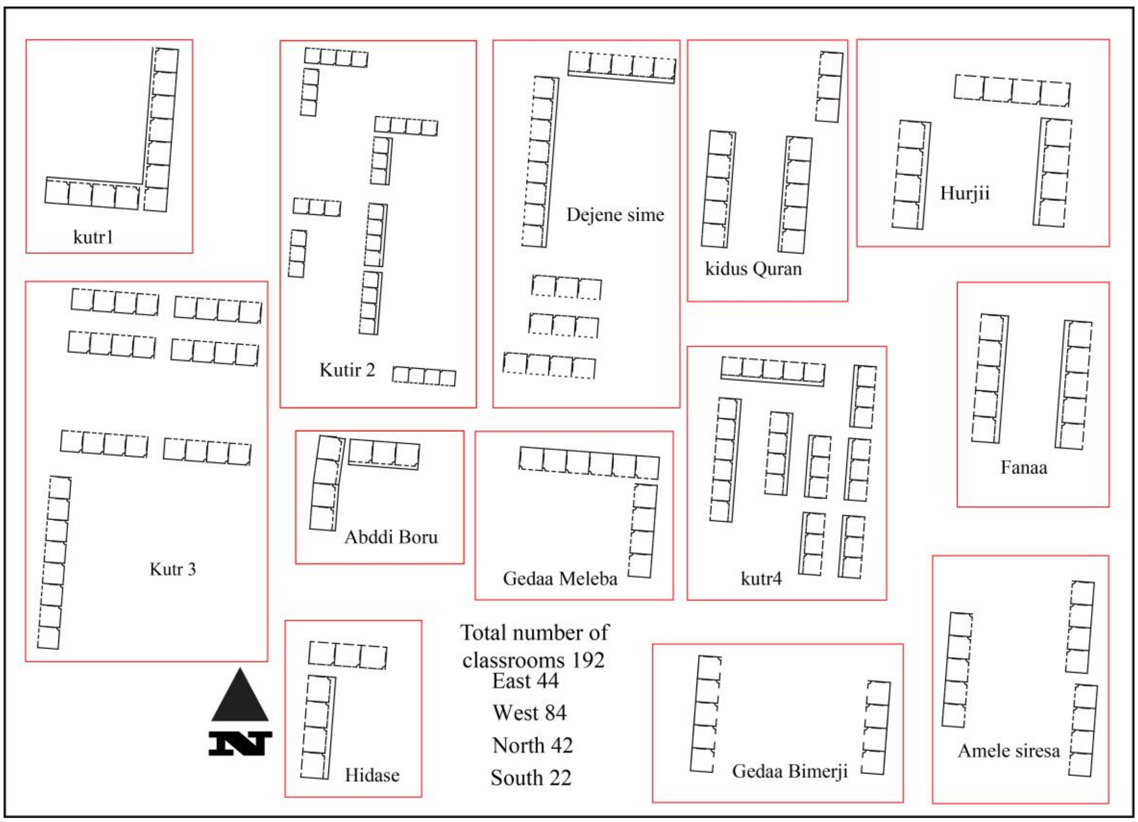


Figure 2 Plan view of full sample classrooms

Based on the assessment, six classrooms are selected shown on figure 7. Form these classrooms, two has north orientation which has different widow size from Kutir 1 and Dejene Sime, two has west orientation also having different widow size from Kutir 1 and Kidus Quran, one south from Dejene Sime and one east orientation from Kutir 4.

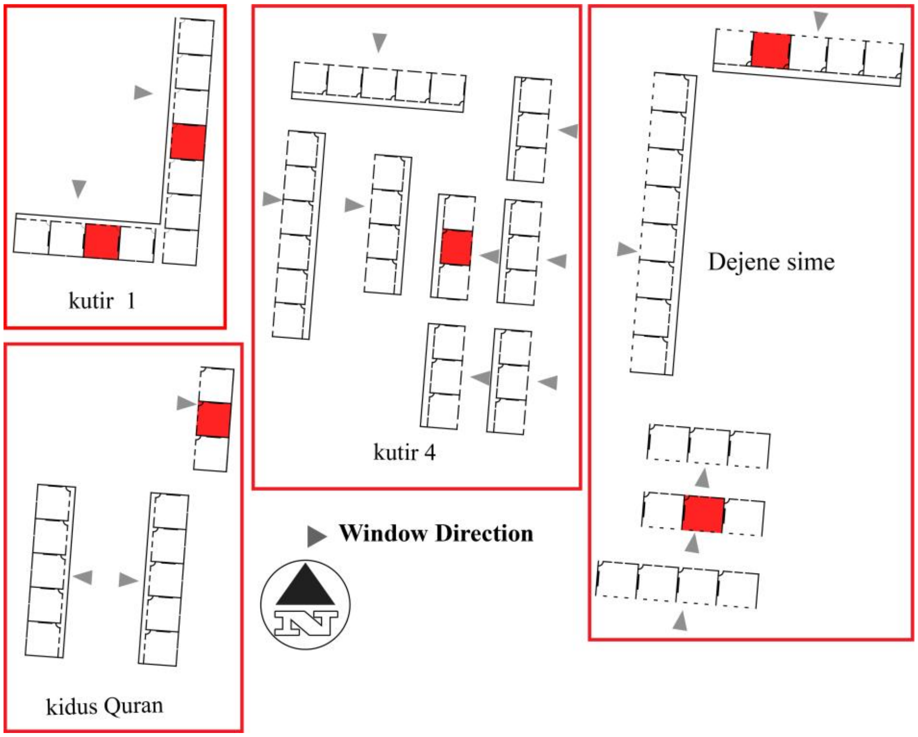
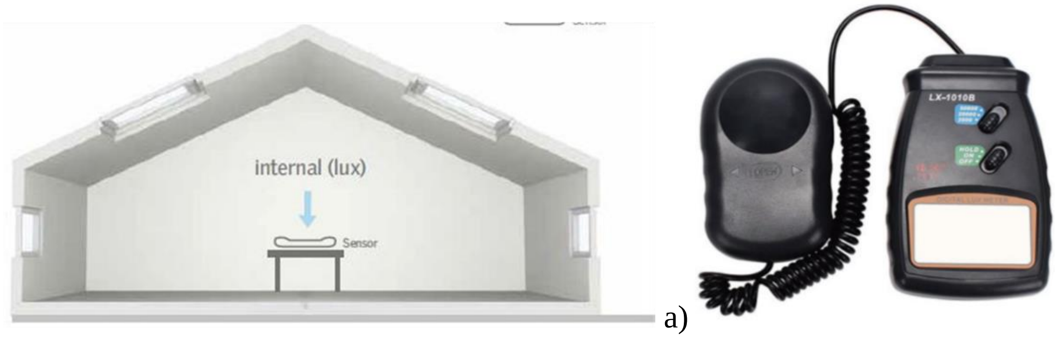


Figure 3 The six selected school class rooms plan showing window direction

3.2 Data

To accomplish the purpose of this research, data have been collected from both primary and secondary sources. As far as secondary data are concerned books, journal articles and official documents were used as a source. The basic data of this research is the illuminance level in the classrooms and the student perception towards their visual satisfaction in the classrooms. Illuminance is the measure of the amount of light received on a surface. It is typically expressed in lux (lm/m^2). It is the measure of light currently used by most performance indicators to determine daylight availability in the interior. Illuminance levels can be measured with a lux meter (Figure 8) or predicted through the use of computer simulations with Ecotect. The student perception data is conducted through by informal interview using questionnaire.



a) b)

Figure 4 Measuring room with Lux Meter(Nielsen et al., 2003)

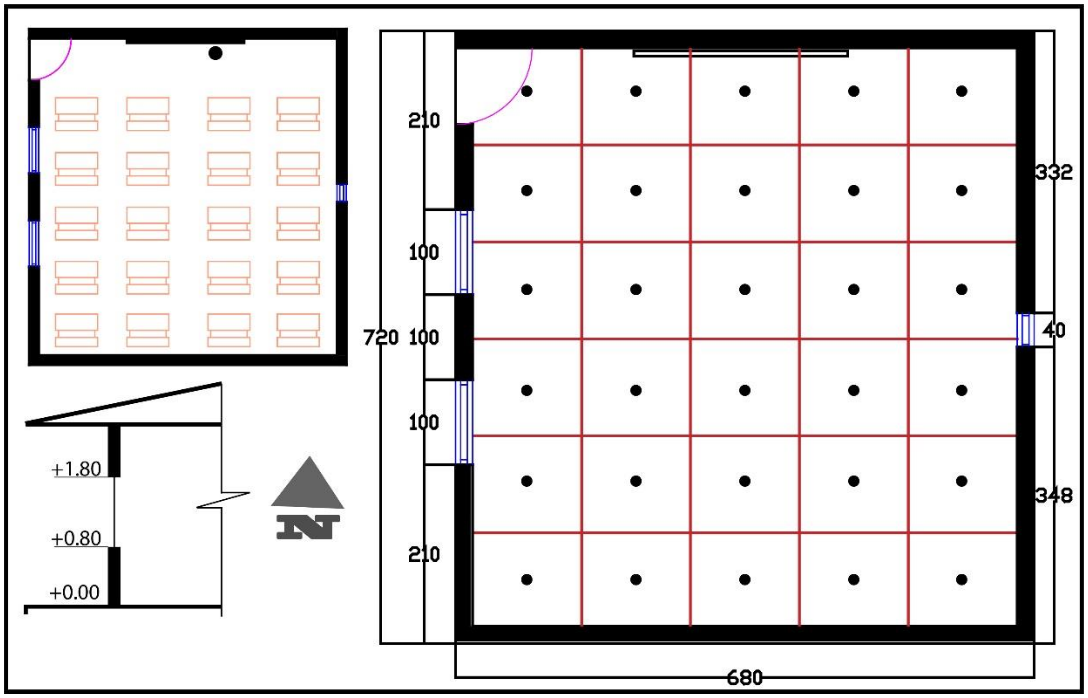
3.3 Data collection

The data's are collected in three ways; by measuring using lux meter, Questionnaire and formal interview.

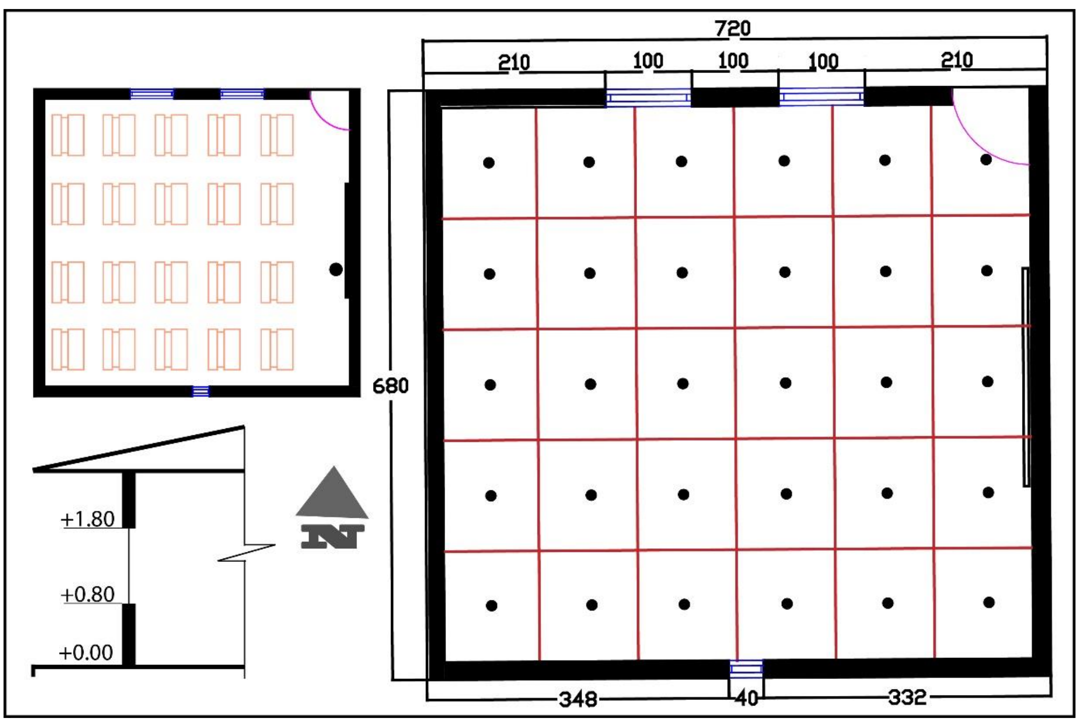
3.3.1 Daylight measured data collection

At this stage of the study, six lux meters were used to measure the distribution of daylight in the six classrooms at different time of a day and different days of a month. The measurement was done starting from window side to the opposite side at 1.2m on average interval. In doing daylight measurement, the work area should first be divided into a number of equal small areas which should be as nearly square as possible then measure the center of each squares show by dote on the (figure 9 a-f). This classrooms has the capacity for 45 students on average, although the student's work plane is often rearranged in the classrooms.

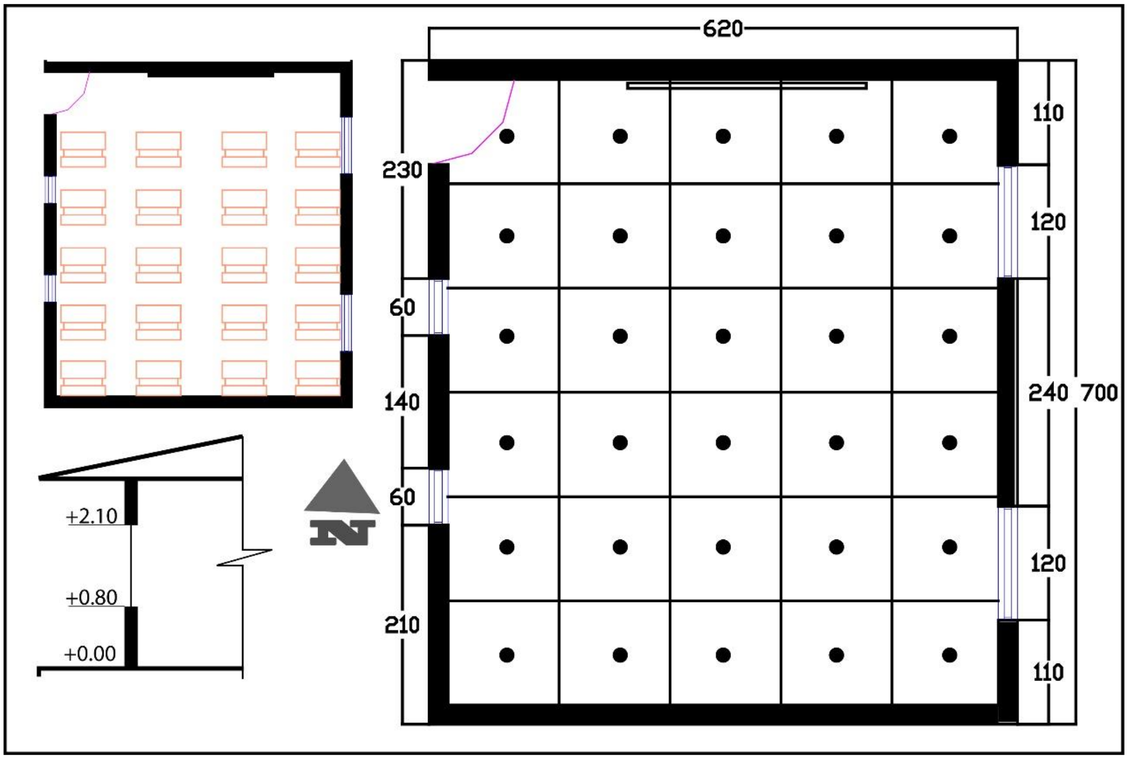
The measured data has been taken four times a day at 3:00, 5:00, 7:30 and 9:30 local time that regular learning time of Adama city and two times a week, Wednesday and Saturday. Then the measured data had been taken the average daylight distribution in each days. Finally take the average value of the whole days then analyzed by using ecotect day light contour shown on data analysis part.



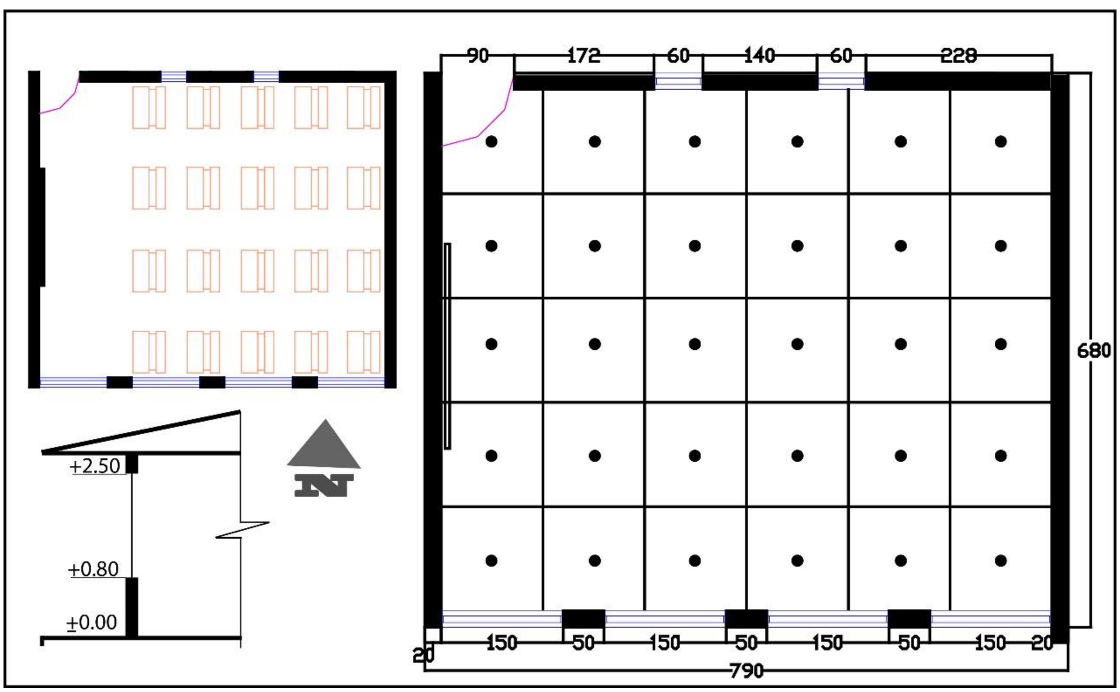
a) Classroom one (Kutir 1)



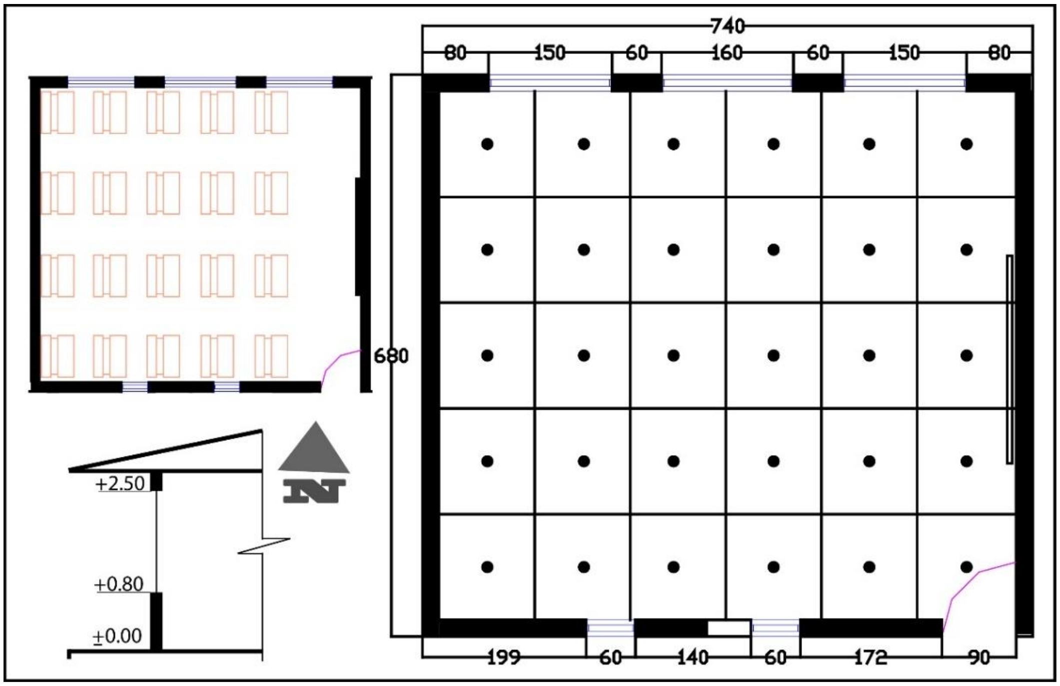
b) Classroom two (Kutir 1)



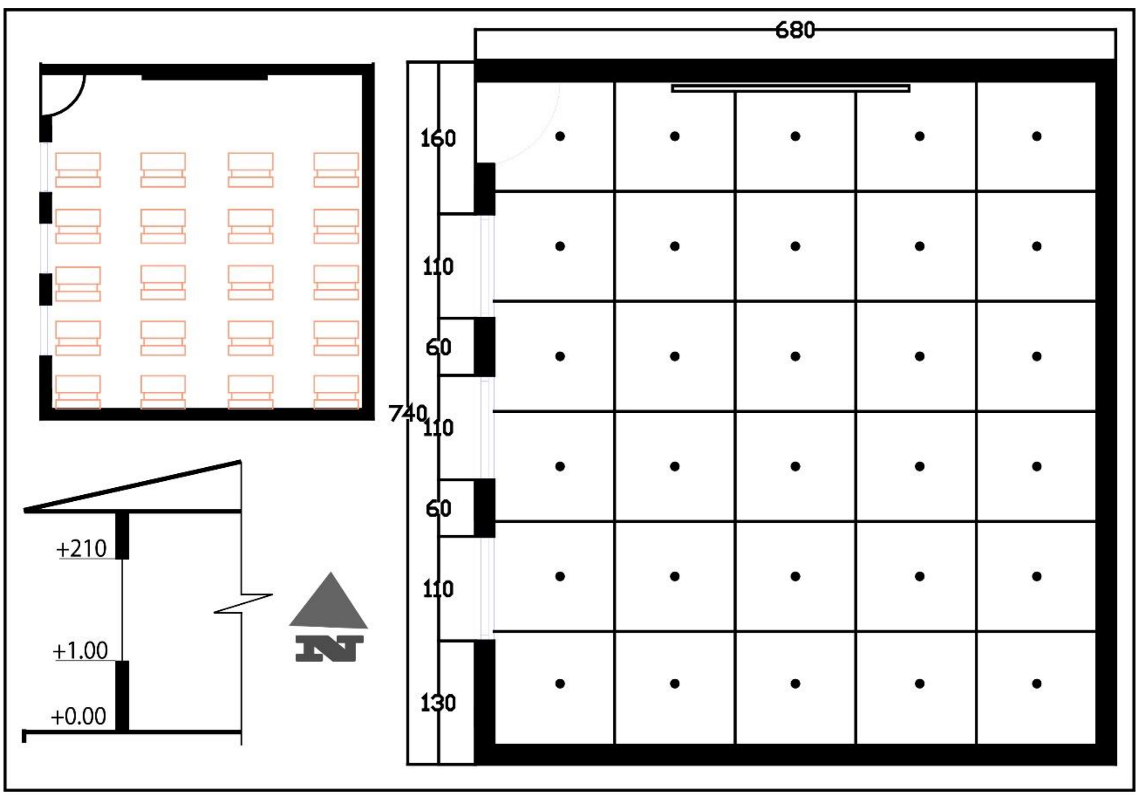
c) Classroom three (Kutir 4)



d) Classroom four (Dejene Sime)



e) Classroom five (Dejene Sime)



f) Classroom six (Kidus Quran)

Figure 5 Plan and section view of sample classrooms

3.3.2 Questionnaire survey and formal interviews

The questionnaires were used to analyze the visual perception of the students. Questionnaires were distributed for purposively selected sample informants. The questions were focused on the perception of the students, who have different sit in the classroom. Comparison between different rows of sits enables to understand the perception of the students towards visual comfort and the method that they use to regulate this visual comfort in the class.

272 sample informants were selected. This 272 informants are the whole students who were study in the sample classrooms. The informants were selected using a purposive sampling method from the total number of students. According to Tayie, (2005) purposive sampling is one that includes subjects who are selected based on certain specific criteria needed for the study. Therefore, the queried was distributed to the students study in the sample class room using purposive way. The total number of questionnaires distributed was 194. The rest of the informants (78) by using formal interview. The interview was done for these students who are below grade six. Table 4 shows the summery of all methods based on the specific objectives.

Table 4 Summary of Data collection

No	Specific objective	Data used	Collection method	Analysis
1.	To survey the day light level distribution of typical classrooms in Adama elementary schools.	Measuring the level of daylight distribute thought the class room at the working height.	By using lux meter measured the parcels of the class rooms.	Compare the measured data with Ecotect data by using different graph
2.	To identify student perception towards the existing daylight distribution in the class room.	The negative and positive effect will be identified	Questioner and formal interview	By Using MS Exel chart and graphs
3.	To identify the correlation between natural light and learning environment in Adama elementary school.	The measured value will be compared with the standard light for the specific purpose.	Onsite observation and Questioner and formal interview	Data from measurement and questioner

3.4 Research design

The analytical procedure of the research presented in figure. 10

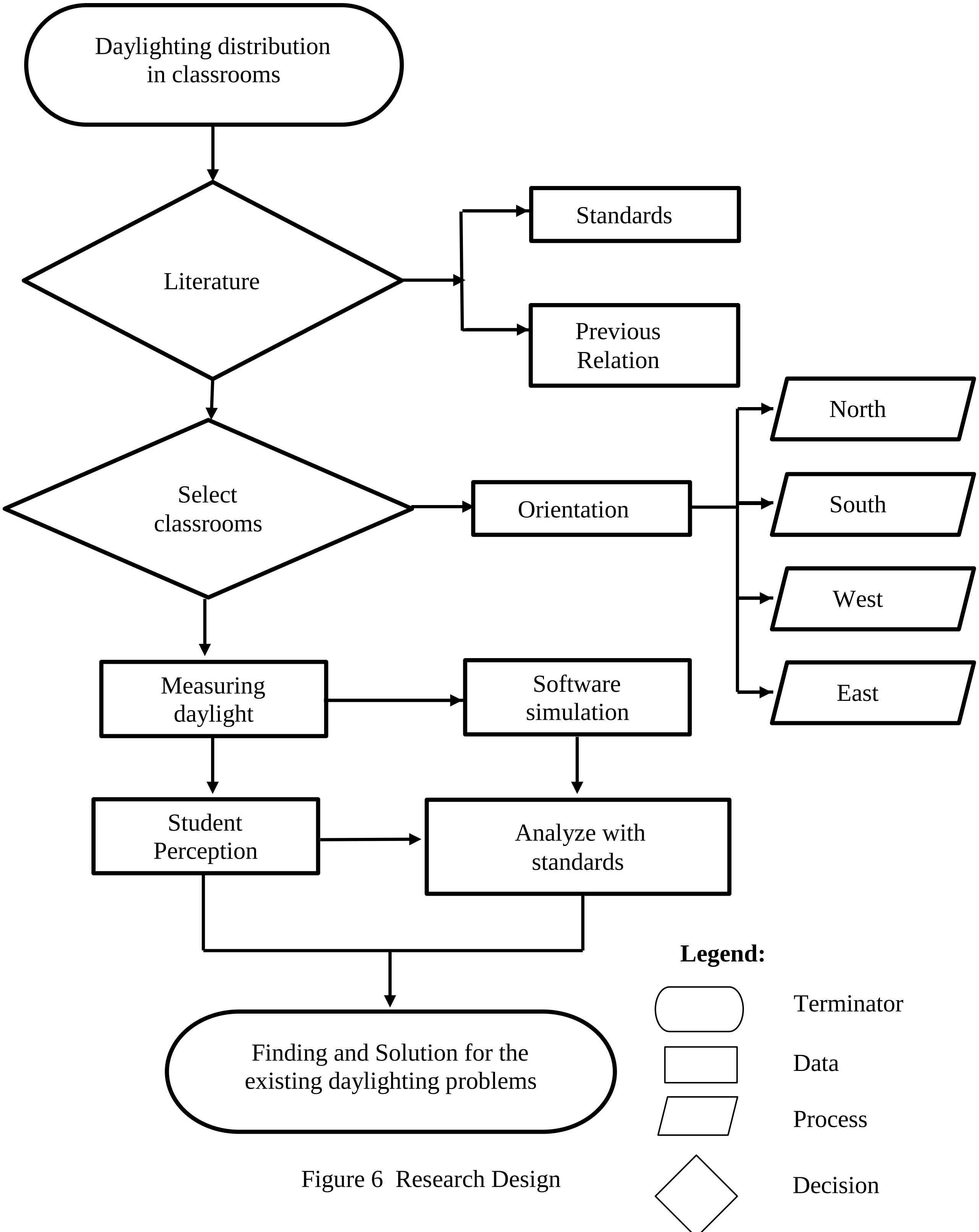


Figure 6 Research Design

3.5 Data Analysis

The research aimed to investigate the effects of six different classes lighting conditions at four schools students' visual comfort.

3.5.1 Measured Data Analysis

School 1 (Abaabaa /kutir 1)

In this school there are 11 classrooms with similar room and opening size but in two different orientation. Four class rooms are oriented north and the rests are oriented to west show on (figure 11). One classroom from each orientation has been analyzed.

Figure 7 Kutir 1 classrooms orientation and field image

Class One (1)

The main windows are facing west and one top very small window is facing east. The overall opening size of this class room is $2.64m^2$ which means 6 percent of the floor area of the room served. Because of the main window orientation direct sun glare passing through the window. But the window size is not proportional. There is no even distribution of light in the class shown in the figure 12. In figure below, the daylight analysis was done using Ecotect and then daylight contour was made. The color contrast shows different level of light. Classroom one 3D view of daylight contour, daily sun path and annual sun path shown on the figure 13 and figure 14 respectively.

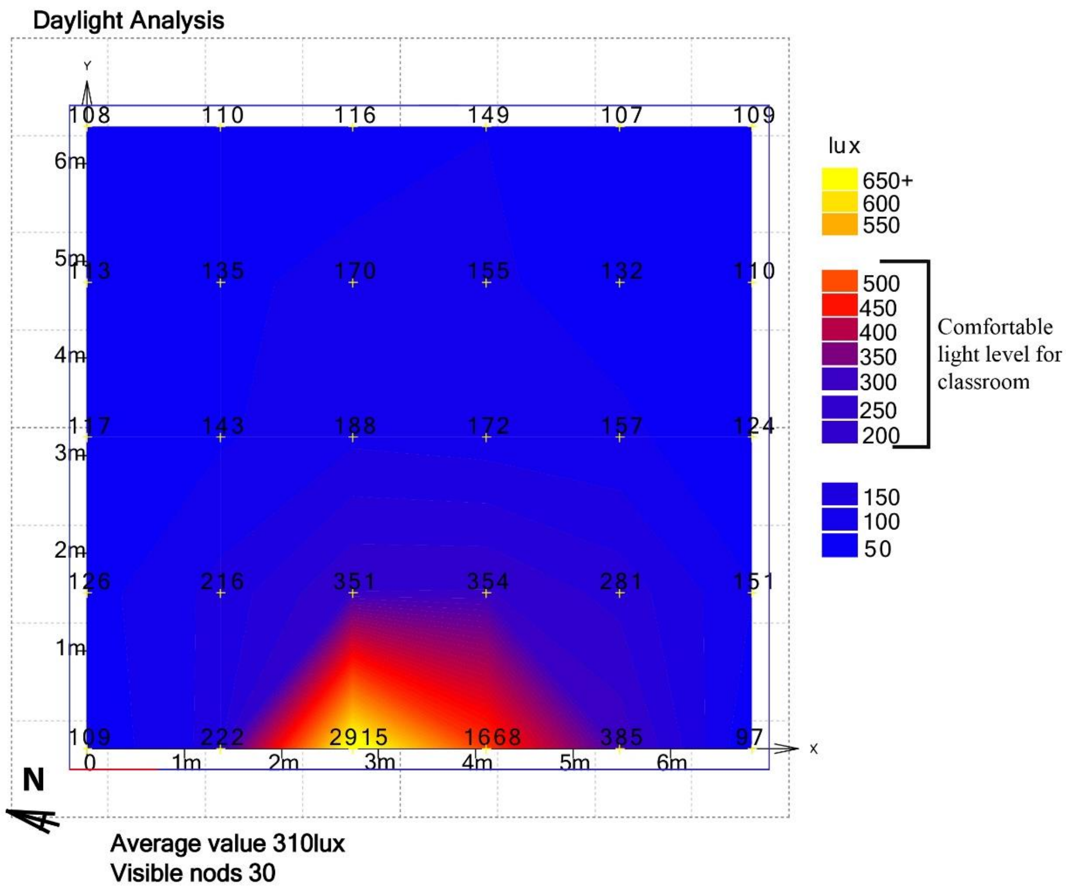


Figure 8 Daylight contour of class one

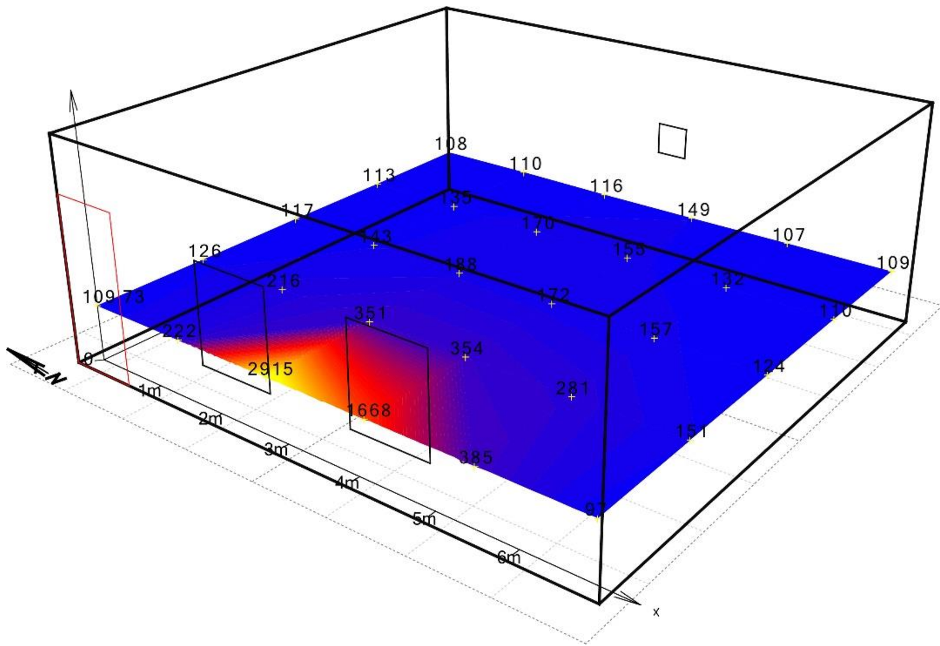


Figure 9 3D view of classroom one daylight contour

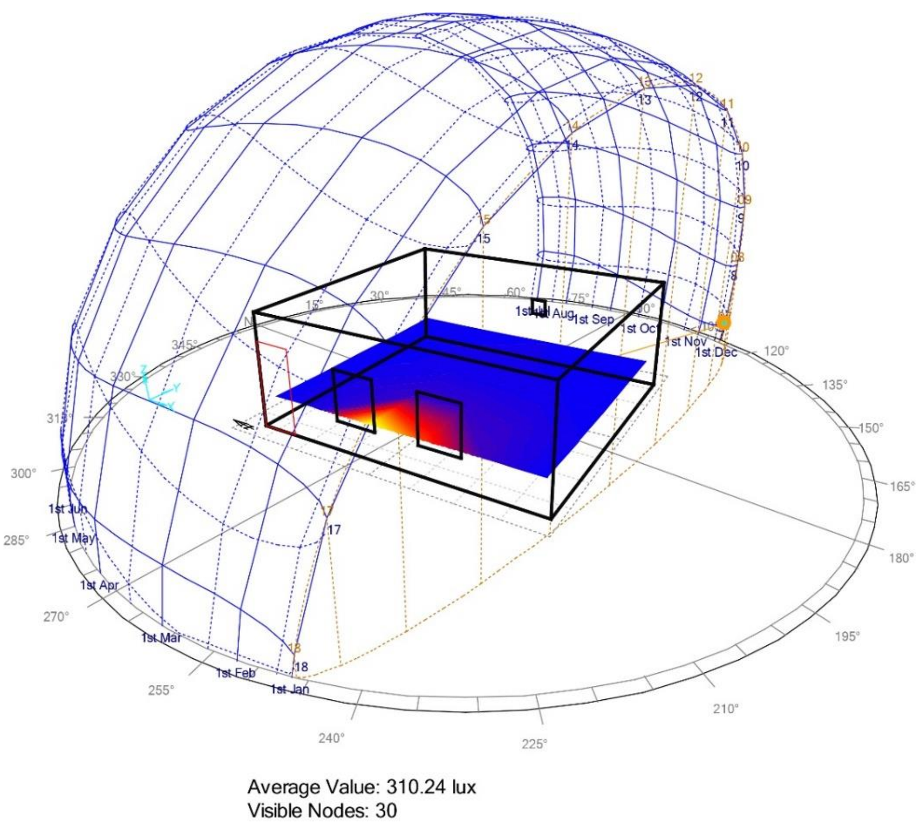


Figure 10 Class 1 daily sun path and annual sun path

Class Two (2)

The room depth as shown on the plan view 6.8m length 6.4m width and 3m height. The main windows are facing north and one top window is facing south. The overall opening size of this class room is 2.64m^2 which means 6 percent of the floor area of the room served. Finally take the average value of the whole days then analyzed by using Ecotect day light contour as shown in figure 15. Classroom two 3D view of daylight contour, daily sun path and annual sun path shown on the figure 16 and figure 17 respectively.

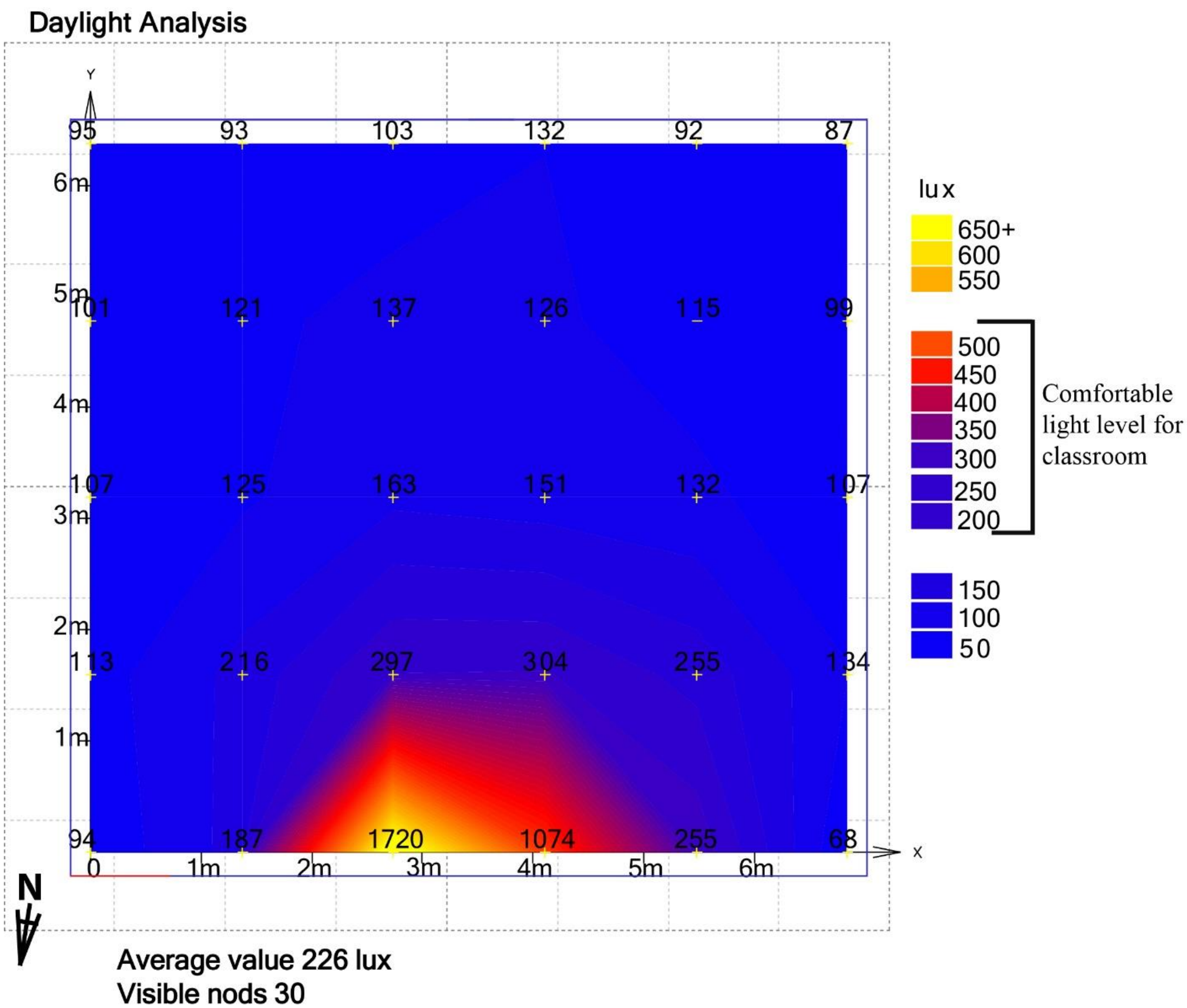


Figure 11 Daylight contour of class two

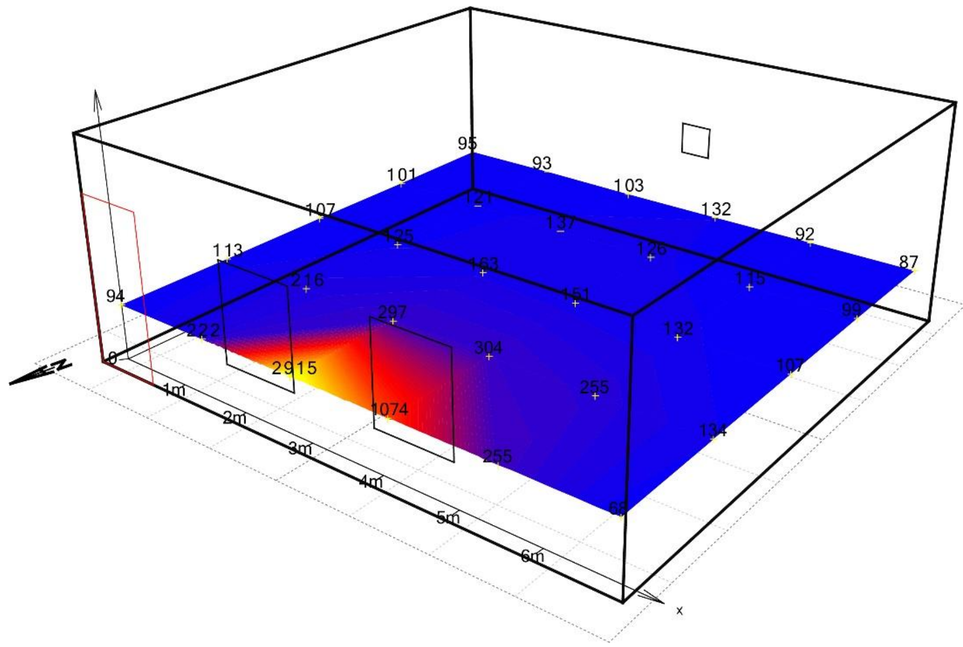


Figure 12 3D view of classroom two daylight contour

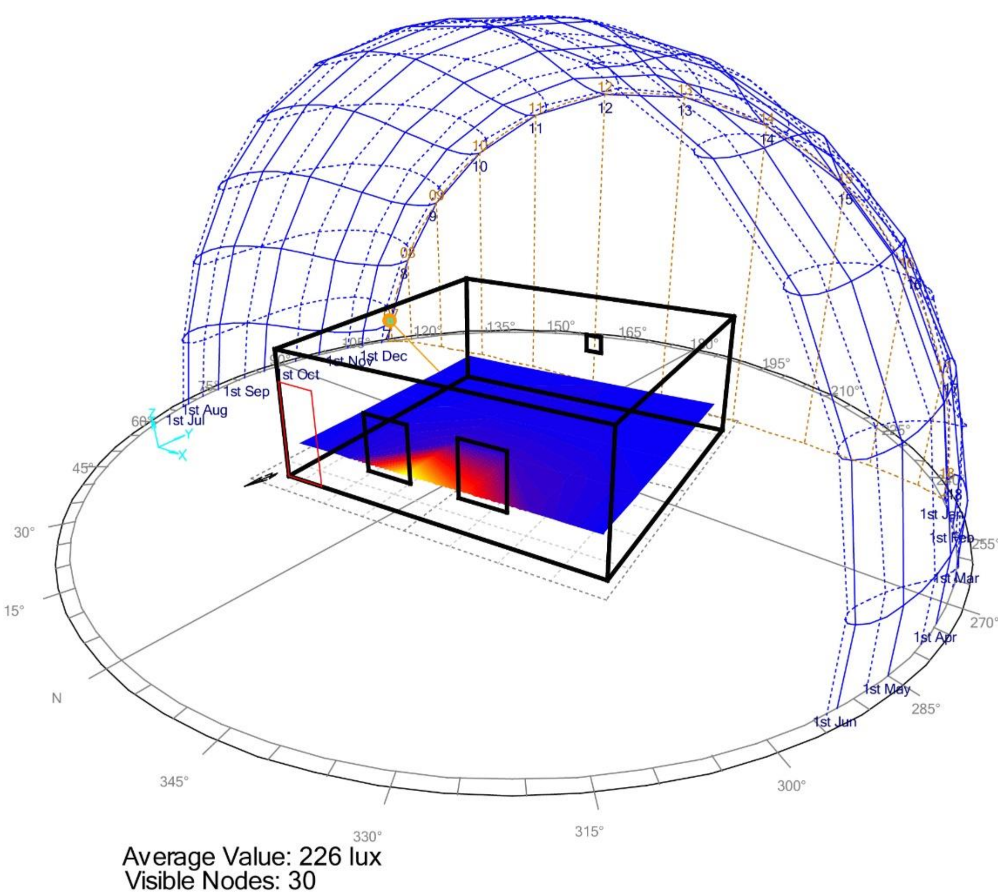


Figure 13 Class two daily sun path and annual sun path

School 2 (Gadaa Robelee/kutir 4)

In this school there are 30 classrooms with similar room and opening size but in two different orientation. Five class rooms are oriented north, fifteen classes are oriented east and the rests are oriented to west. One classroom has been analyzed in this school which is oriented to east.

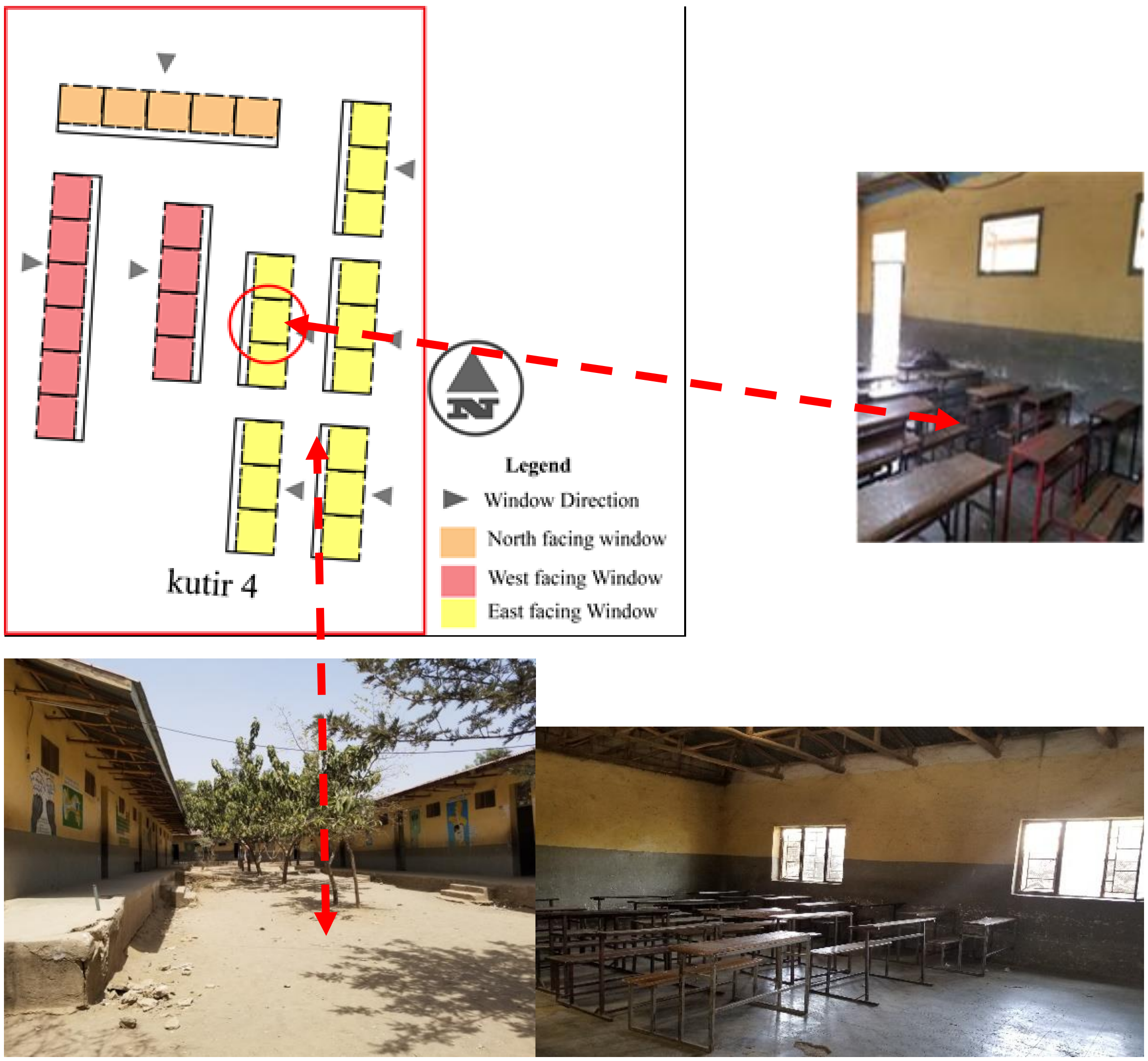


Figure 14 kutir 4 classrooms orientation and field image

Class Three (3)

The room depth as shown on the plan view measures 7.5m * 6.4m * 3.2m high. The main windows are facing east and the top windows are facing west. The overall opening size of this class room is 3.36 m^2 which means 7 percent of the floor area of the room served. Finally take the average value of the whole days then analyzed by using ecotect day light contour as shown in figure 19. The 3D view of classroom three daylight contour and Class 3 daily sun path and annual sun path shown on the figure 20 and figure 21 respectively. This classroom has the capacity for 50 students, although the student's work plane is often rearranged in the classroom.

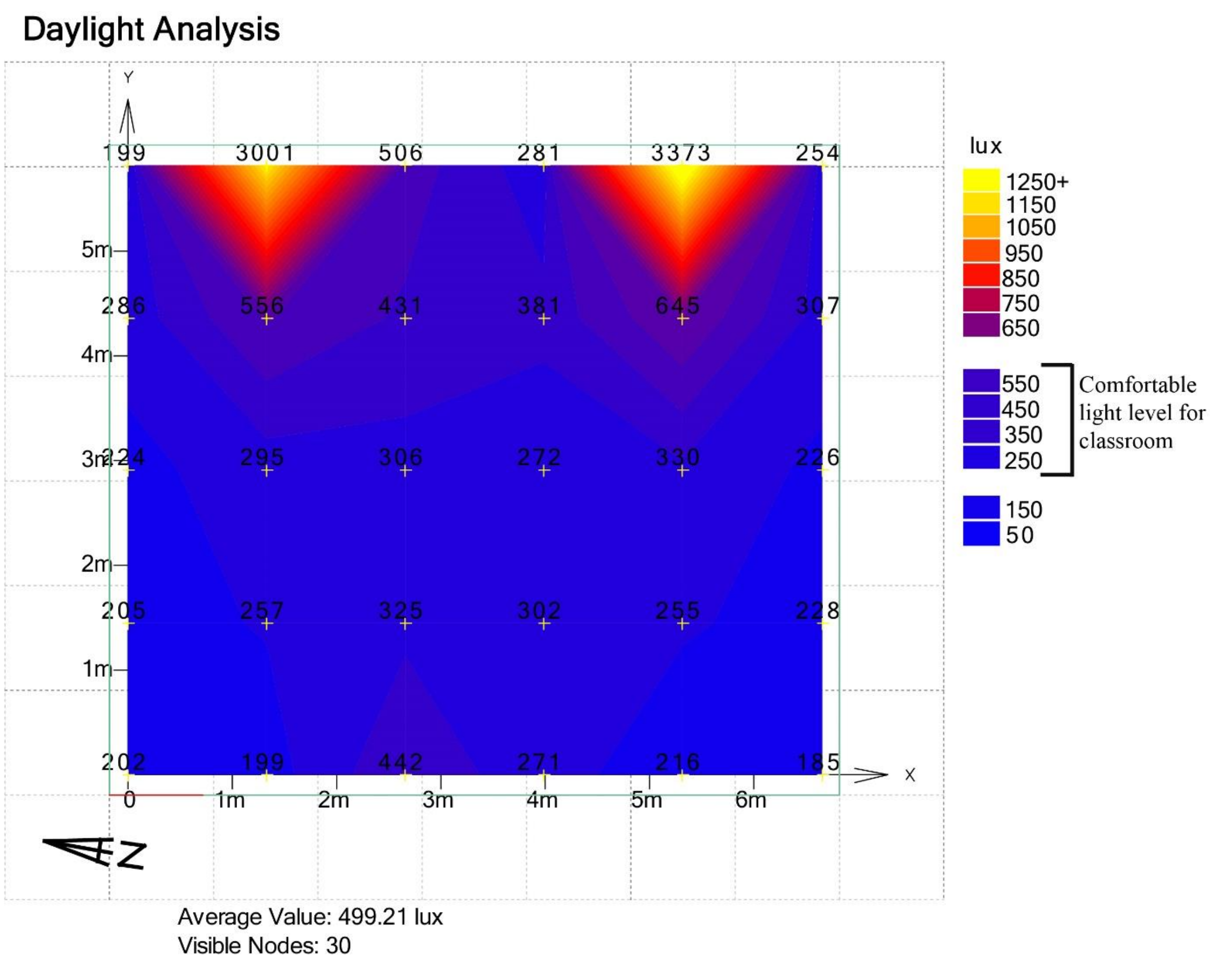


Figure 15 Daylight contour of class three

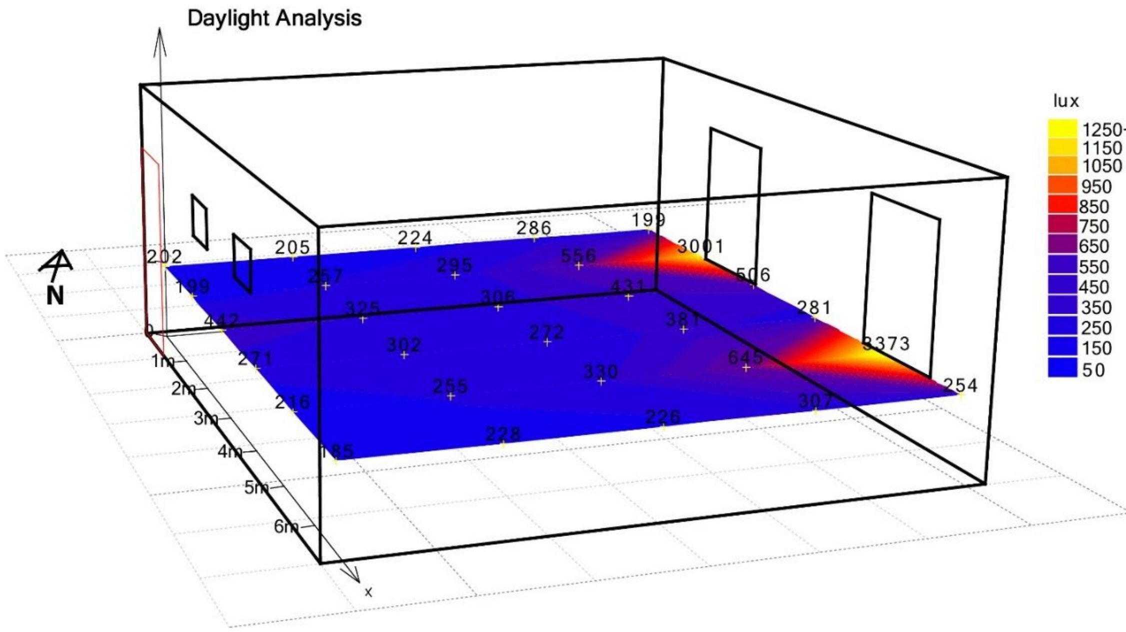


Figure 16 3D view of classroom Three daylight contour

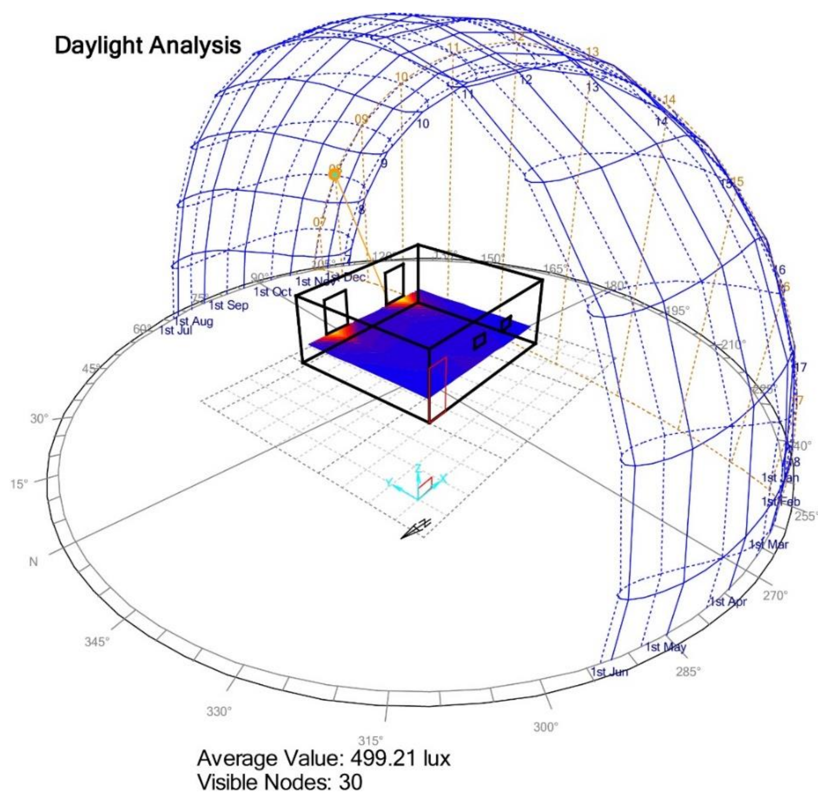


Figure 17 Class three daily sun path and annual sun path

School 3 (Dejene sime)

In this school, there are 23 classrooms having different room size and opening size with in three different orientation. Four class rooms are oriented north and the rests are oriented to west. One classroom from each orientation has been analyzed as showed in the figure 22.

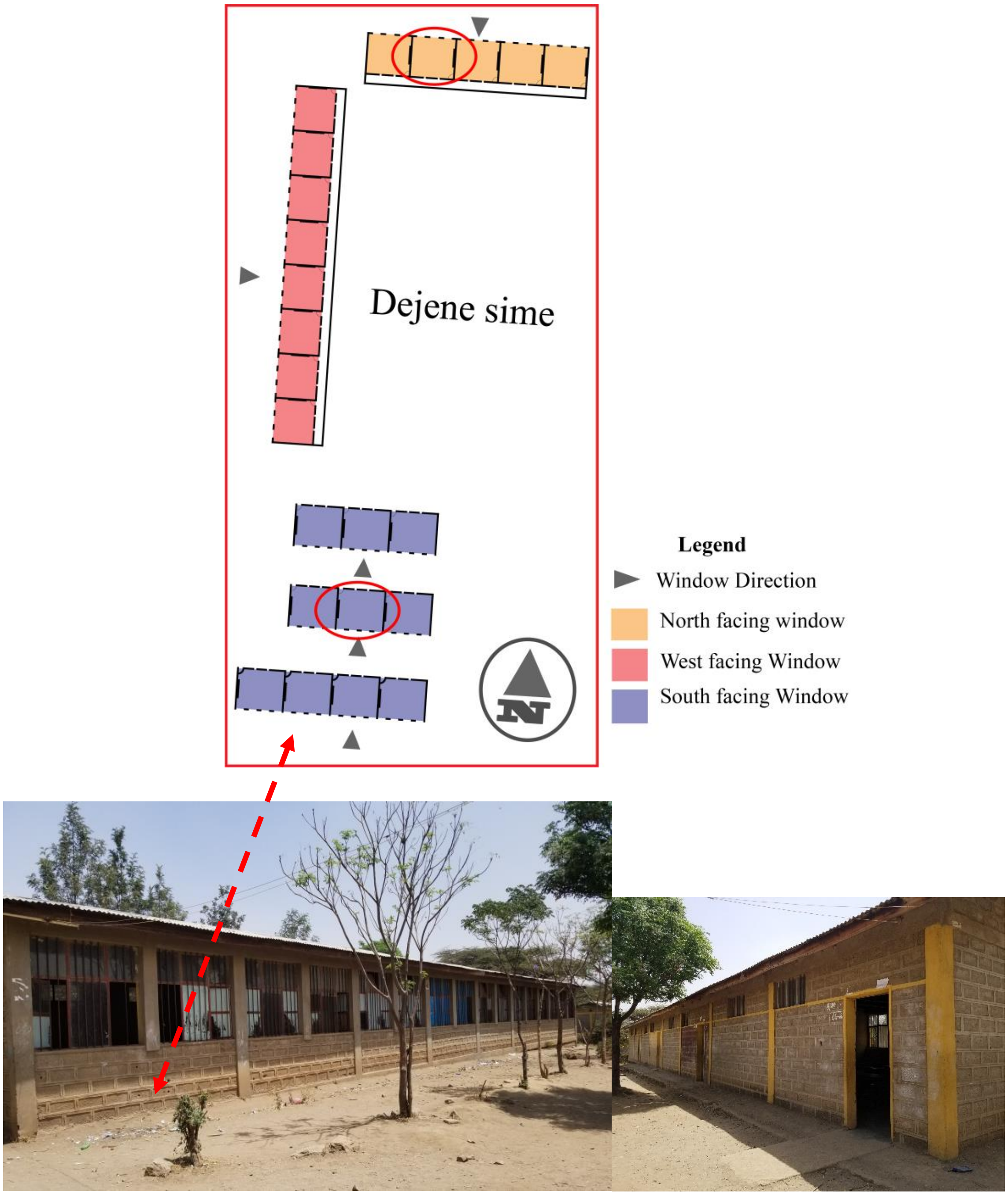


Figure 18 Dejene Sime classrooms orientation and field image

Class Four (4)

The room depth as shown on the plan view measures 7.5m * 6.4m * 3.2m high. The main windows are facing south and one top window is facing north. The overall opening size of this class room is $11.28m^2$, which means 23.5 percent of the floor area of the room served. Finally take the average value of the whole days then analyzed by using Ecotect day light contour shown in figure 23. The 3D view of classroom four daylight contour and Class 4 daily sun path and annual sun path shown in the figure 24 and figure 25 respectively.

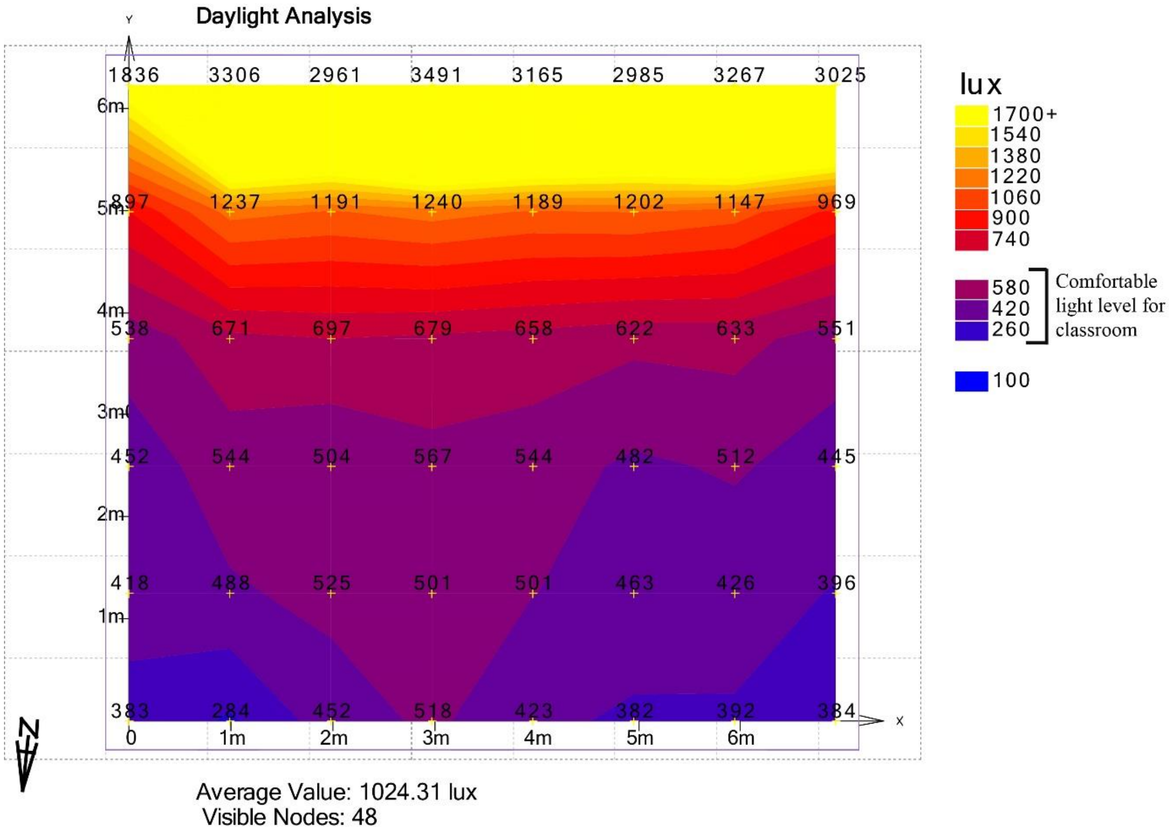


Figure 19 Daylight contour of class four

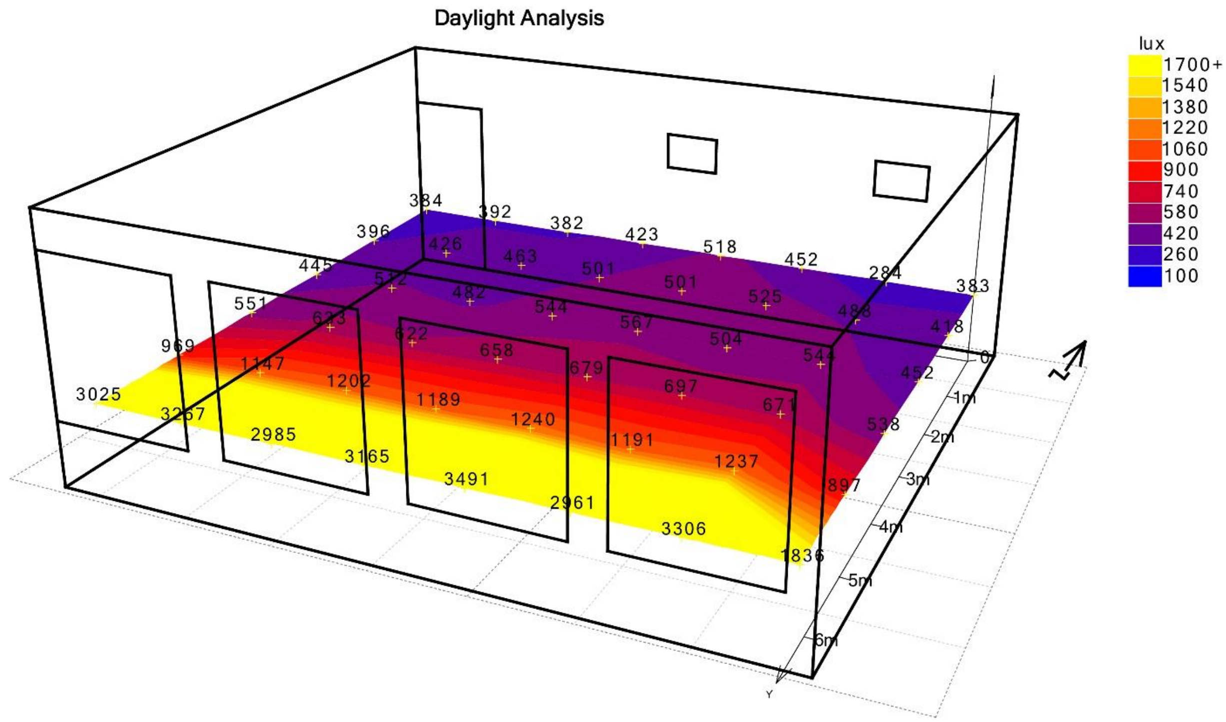


Figure 20 3D view of classroom Four daylight contour

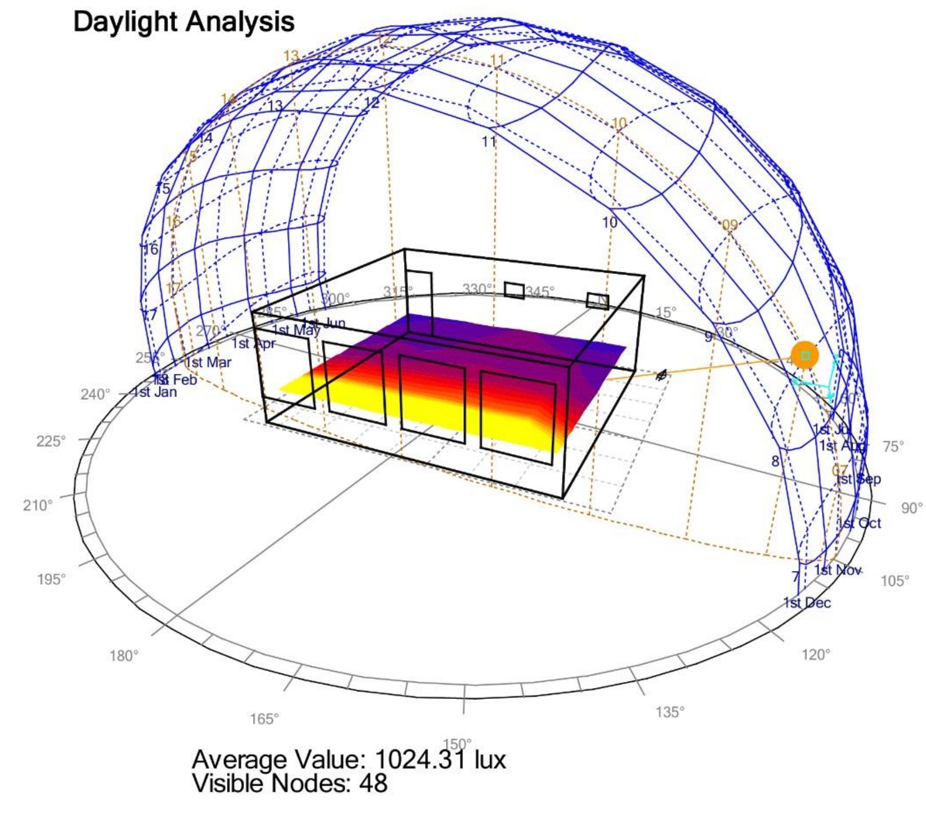


Figure 21 Class four daily sun path and annual sun path

Class Five (5)

The room depth as shown on the plan view measures 6.8m length 6.4m width and 3m height. The main windows are facing north and one top window is facing south. The overall opening size of this class room is 2.64m^2, which means 6 percent of the floor area of the room served. Finally take the average value of the whole days then analyzed by using ecotect day light contour shown in figure 26. The 3D view of classroom five daylight contour and Class 5 daily sun path and annual sun path shown on the figure 27 and figure 28 respectively.

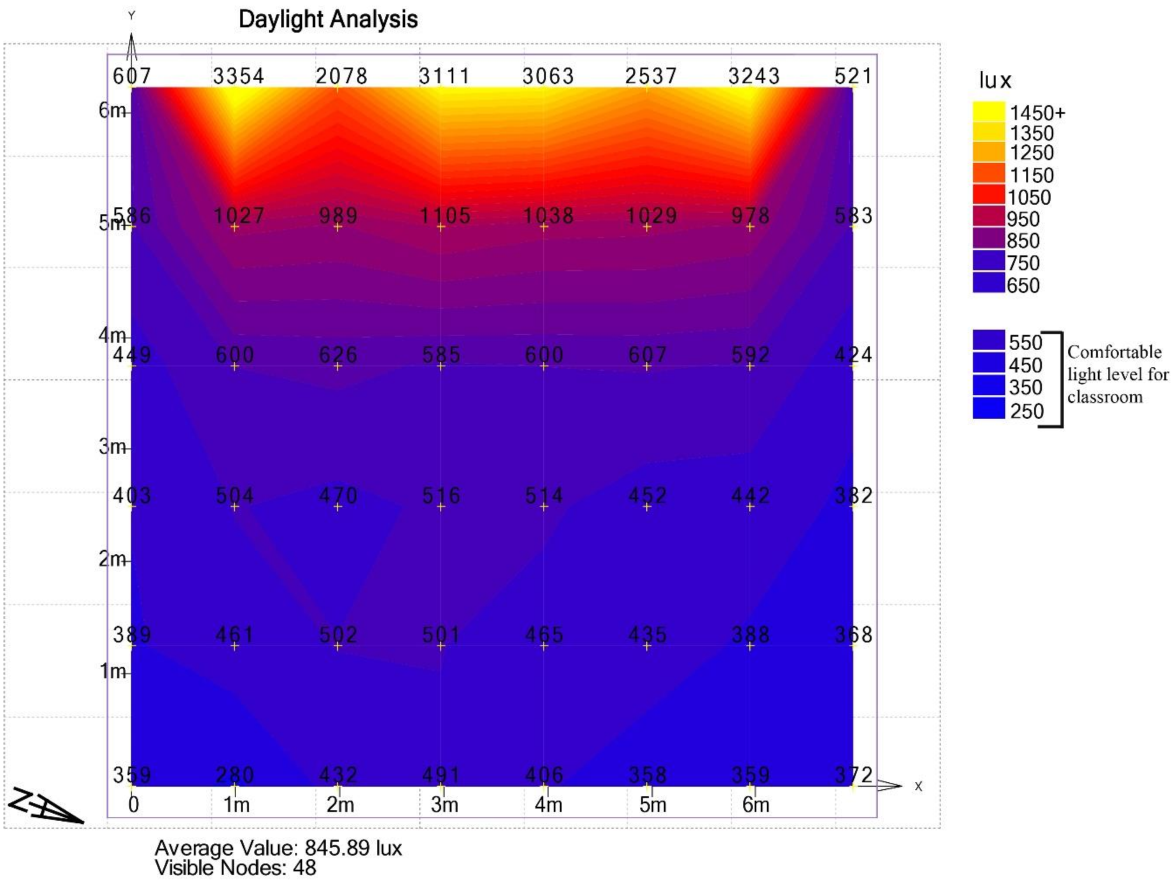


Figure 22 Daylight contour of class five

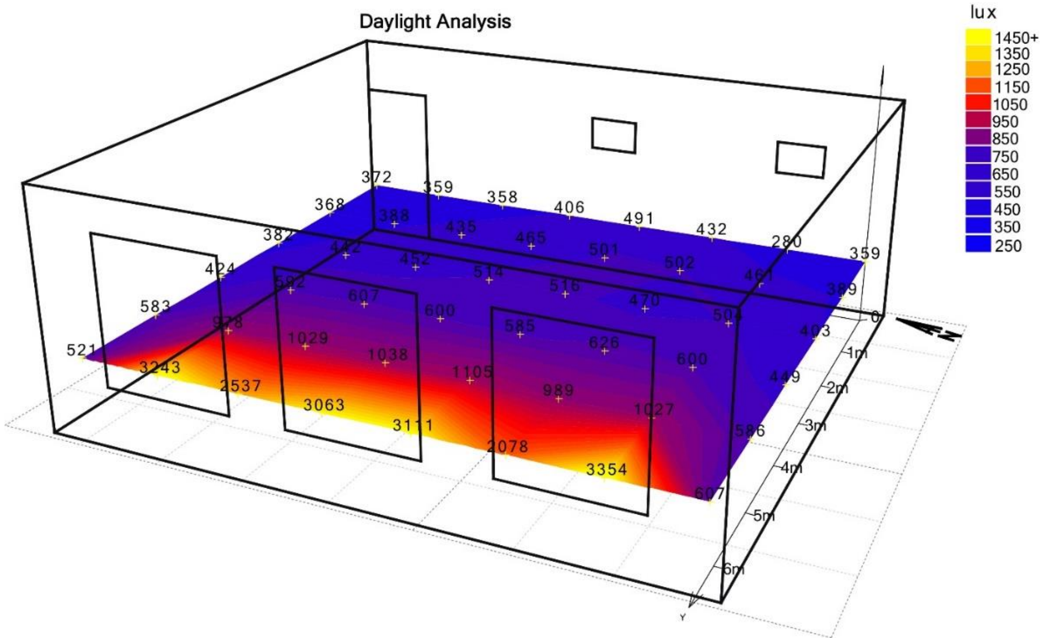


Figure 23 3D view of classroom Five daylight contour

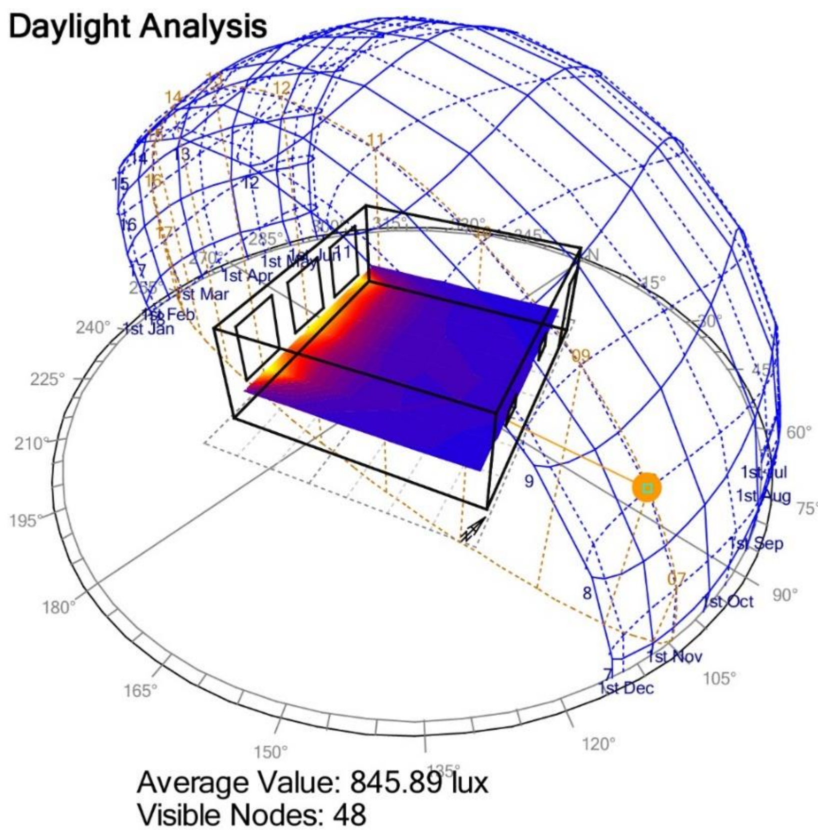


Figure 24 Class Five daily sun path and annual sun path

School 4 (Kidus Quran)

In this school there are 13 classrooms with similar room and opening size but in two different orientation. Five class rooms are oriented east and the rest are oriented to west. One classroom has been analyzed from this school.

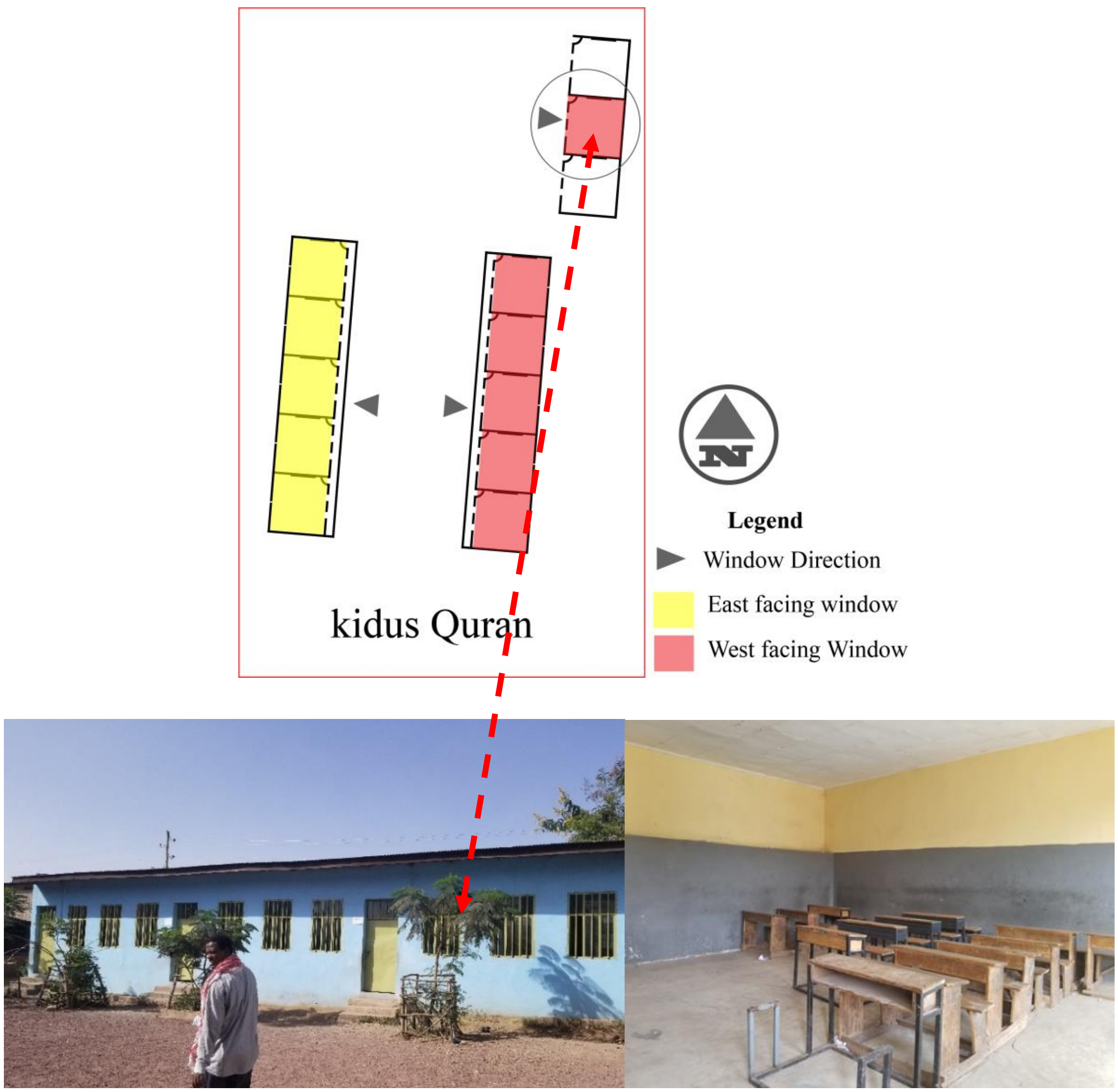


Figure 25 Kidus Quran classrooms orientation and field image

Class six (6)

The room depth as shown on the plan view measures 7.0m * 6.4m * 3.2m high. It has one side window which is facing west. The overall opening size of this class room is 4.62m^2, which means 10.3 percent of the floor area of the room served. Finally take the average value of the whole days then analyzed by using Ecotect day light contour shown in figure 30. The 3D view of classroom six daylight contour and Class 6 daily sun path and annual sun path shown on the figure 31 and figure 32 respectively

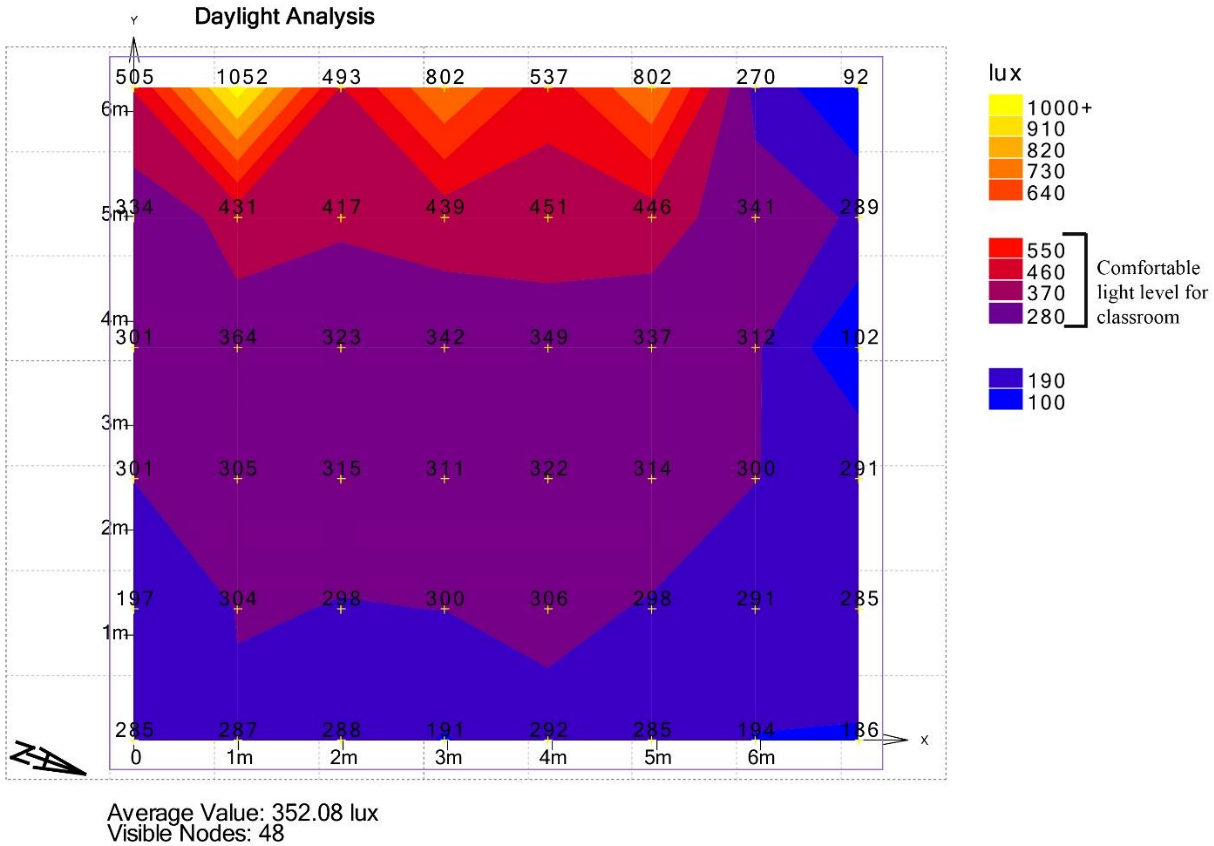


Figure 26 Daylight contour of class six

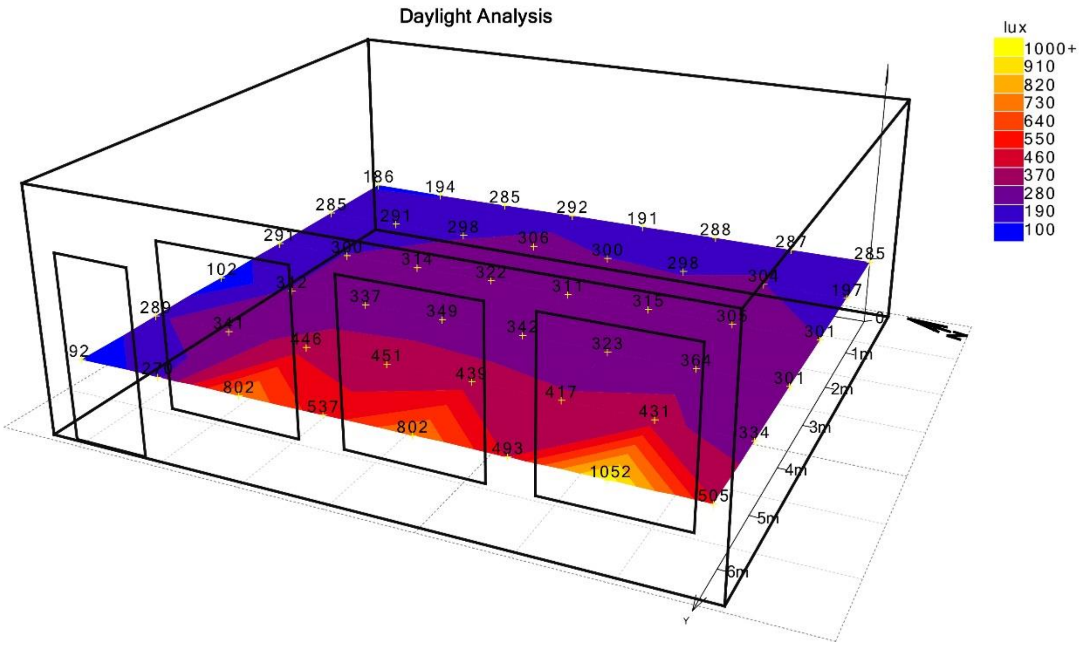


Figure 27 3D view of classroom Six daylight contour

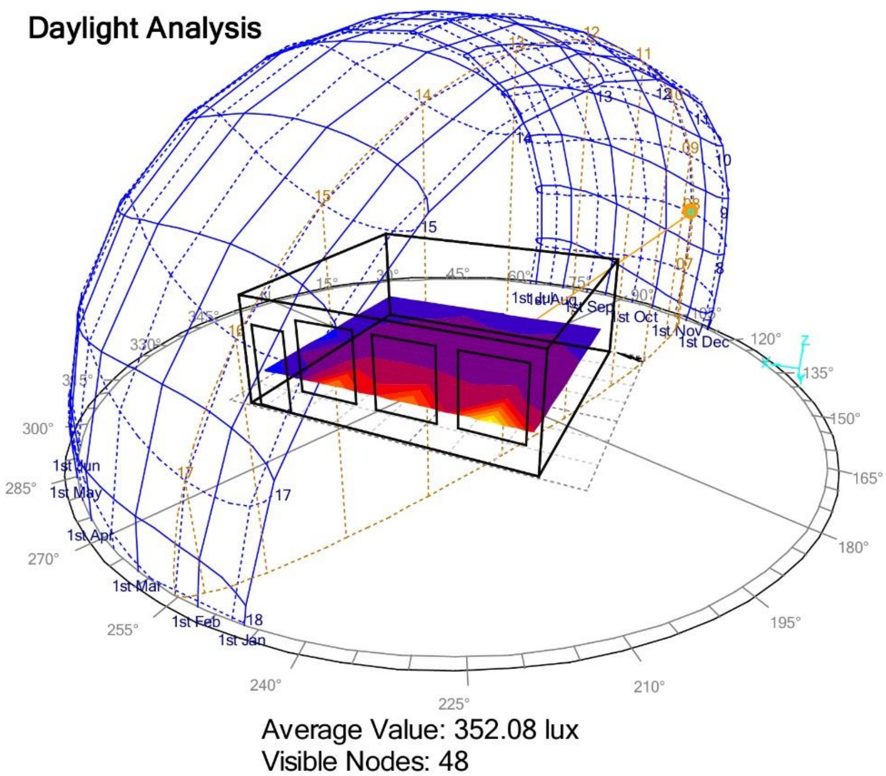


Figure 28 Class six daily sun path and annual sun path

3.5.2 Student perception Data Analysis

The survey questions were geared toward gathering information related to general attitudes towards daylighting in the classrooms.

Classroom one (Abaabaa /kutir 1)

The gender group of the respondents was 29 (61.7%) female and 18 (38.3%) male students. The total number of respondents in this class room was 47 (100%). 39 (82.9%) of this class room students feel about the shortage of daylight in this classroom shown in figure 33.

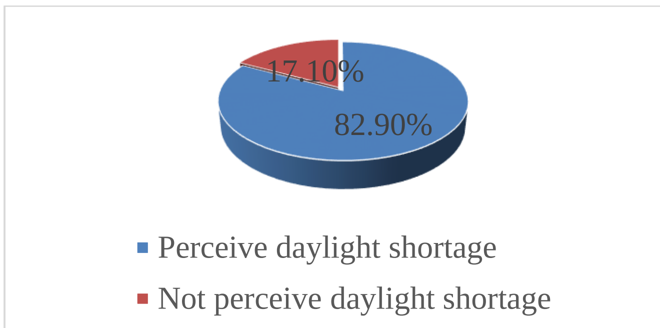


Figure 29 Class one student daylight perception

The student's response to the question "Are you comfortable with the lighting environment in your classroom?" was 18 (38.3%) of the students are strongly disagree, 13 (27.6%) disagree, 11 (23.4%) just right and 5 (10.6%) are Agree as shown in figure 34.

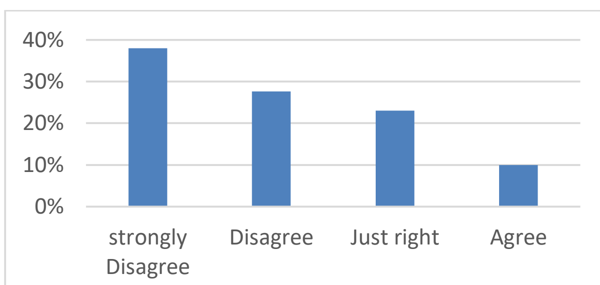


Figure 30 Class one students visual comfort level

Regarding the students choice of sit, 34 (72.3%) are like to sit on the window side and 13 (27.7%) are on the center no one of the respondents are like to sit on the dead wall side. The reason behind their choice was the darkness of the classes makes them difficult to do their tasks. They also use artificial light at the day time.28 (59.6%) like to use artificial light and 19 (40.4%) like to use natural light.

Classroom Two (Abaabaa /kutir 1)

The gender group of the respondents was 26 (63.4%) female and 15 (36.6%) male students. The total number of respondents in this class room was 41 (100%). 38 (92.6%) of this class room students feel about the shortage of daylight in this classroom shown on figure 35.

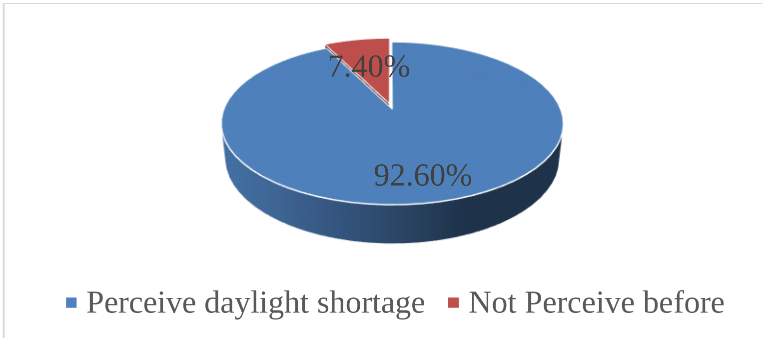


Figure 31 Class two student daylight perception

The student’s response to “Are you comfortable with the lighting environment in your classroom?” was 20 (48.7%) of the students strongly disagree, 11(26.8%) disagree, 8 (19.5%) just right and 2 (4.8%) are Agree as shown in figure 36.

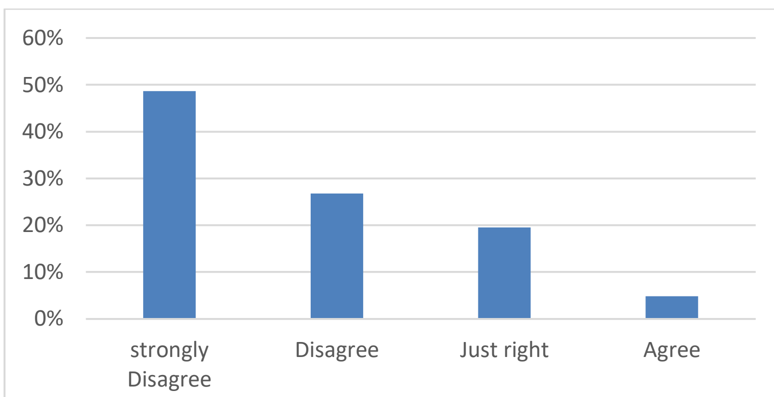


Figure 32 Class two students visual comfort level

Regarding the students choice of sit, 35 (85.3%) are like to sit on the window side and 12 (14.7%) are on the center no one of the respondents are like to sit on the dead wall side. The reason behind their choice was the darkness of the classes it make them difficult to do their tasks. Also this classroom students use artificial light at the day time. 30 (73.1%) like to use artificial light and 11 (26.9%) like to use natural light.

Classroom Three (Gadaa Robelee/kutir 4)

The gender group of the respondents was 28 (52.8%) female and 25 (47.2%) male students. The total number of respondents in this class room was 53 (100%). Only 7 (13.2%) of this class room students feel about the shortage of daylight in this classroom shown in figure 37.

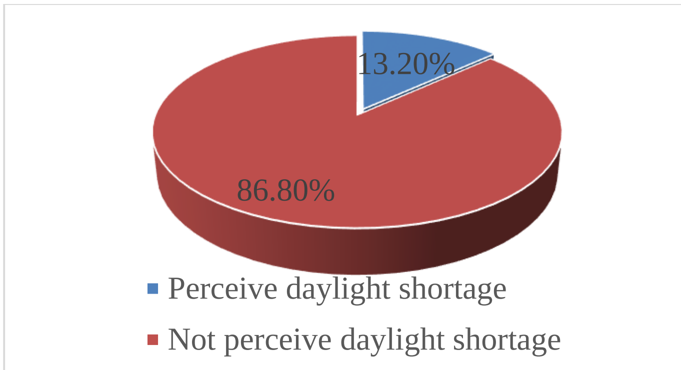


Figure 33 Class three student daylight perception

The student's response to "Are you comfortable with the lighting environment in your classroom?" was 5 (9.4%) of the students strongly disagree, 7 (13.2%) disagree, 7 (13.2%) just right, 28 (52.8%) are Agree and 6 (11.3%) strongly Agree shown in figure 38.

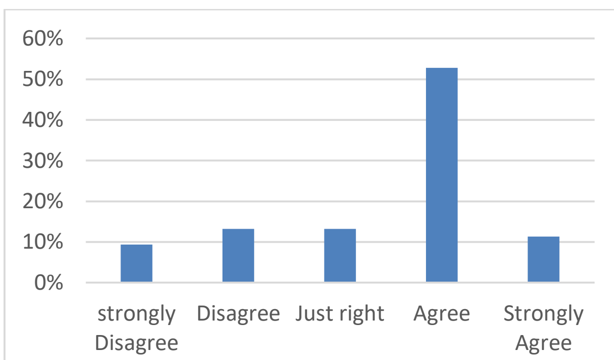


Figure 34 Class three students visual comfort level

Regarding the students choose of sit, 21 (39.6%) are like to sit on the window side and 18 (33.9%) are on the center and 14 (26.4%) of the respondents are like to sit on the dead wall side. These result shows that the daylight distribution in this class is better than the previous classes (classroom one and two). Also Most of the time they don't use artificial light. 18 (33.9%) like to use artificial light and 17 (50.9%) like use natural light 18 (33.9%) has no feeling.

Classroom Four (Dejene sime)

The Gender group of the respondents was 26 (63.4%) female and 22 (36.6%) male students the total number of respondents in this class room was 48 (100%). 39 (81.2%) of this class room students feel about the harsh glare of daylight in this classroom shown in figure 39.

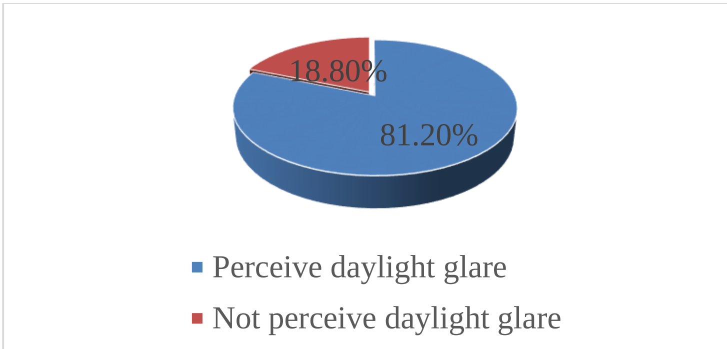


Figure 35 Class four student daylight perception

The student's response to "Are you comfortable with the lighting environment in your classroom?" was 22 (45.8%) of the students strongly disagree, 10 (20.8%) disagree, 11 (23.4%) just right and 5 (10.6%) are Agree shown on (figure 40).

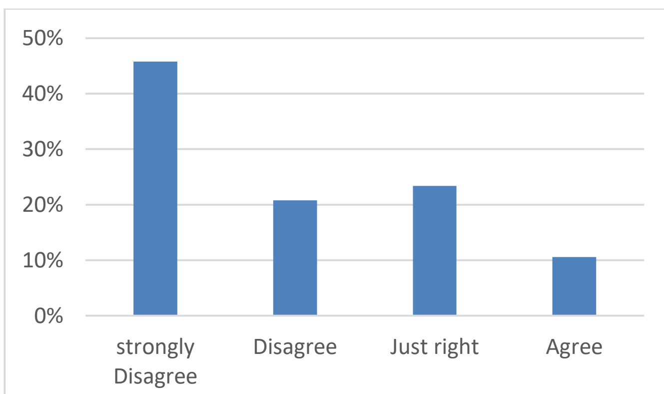


Figure 36 Class four students visual comfort level

Regarding the students choose of sit, 8 (16.6%)of them like to sit on the window side, 17 (35.4%) are on the center and 28 (58.3%) of the respondents like to sit on the dead wall side. The reason behind their choice was the glare of the classes makes them difficult to do their tasks. Therefore, the student use only natural light at the day time. 21 (43.7%) like to use artificial light and 12 (25.5%) like use natural light 15 (31.2%) has no feeling.

Classroom Five (Dejene sime)

The gender group of the respondents was 25 (55.6%) female and 20 (44.4%) male students the total number of respondents in this class room was 45 (100%). 32 (71.1%) of this class room students feel about the glare of daylight in this classroom as shown in figure 41.

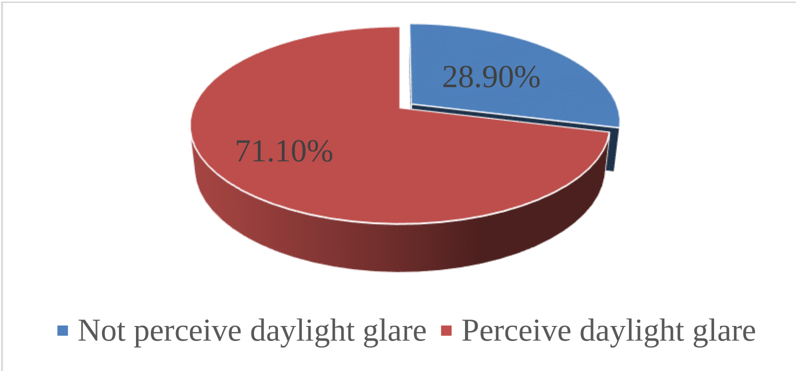


Figure 37 Class five student daylight perception

The student's response to "Are o you comfortable with the lighting environment in your classroom?" was 19 (42.2%) of the students strongly disagree, 11 (24.4%) disagree, 8 (17.1%) just right and 7 (15.5%) are Agree as shown in figure 42.

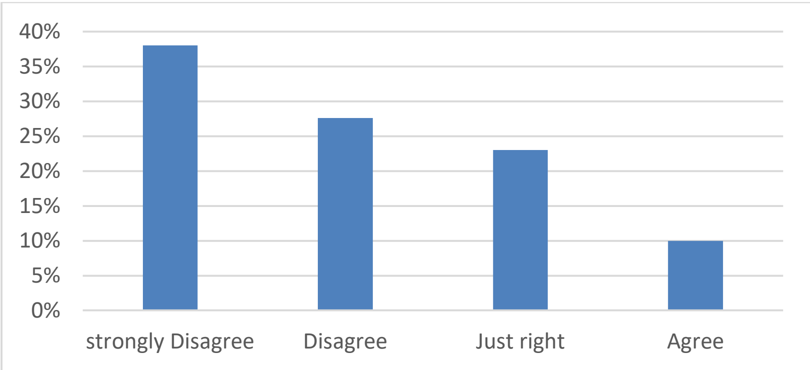


Figure 38 Class five students visual comfort level

The students choice of sit, 10 (16.6%) like to sit on the window side, 12 (35.4%) on the center and 23 (58.3%) of the respondents like to sit on the dead wall side. The reason behind their choice was the glare discomfort of the classes make them difficult to do their tasks. Therefore, the students in this classroom uses only natural light at the day time. 19 (42.2%) like to use artificial light and 11 (24.4%) like use natural light 15 (33.3%) has no feeling.

Classroom Six (Kidus Quran)

The gender group of the respondents was 18 (47.3%) female and 20 (52.6%) male students the total number of respondents in this class room was 38 (100%). 31 (81.5%) of this class room students feel about the glare of daylight in this classroom as shown in figure 43.

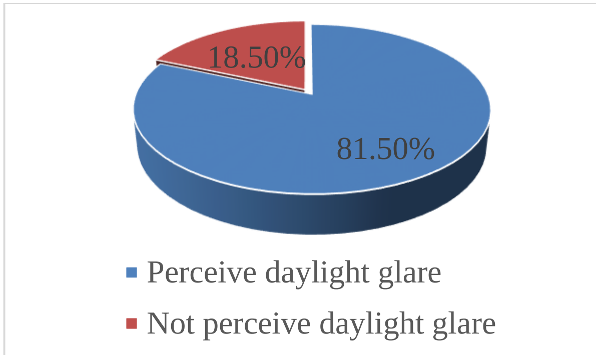


Figure 39 Class six student daylight perception

The student's response to "Are you comfortable with the lighting environment in your classroom?" was 18 (47.3%) of the students strongly disagree, 9 (23.6%) disagree, 7 (18.4%) just right and 4 (10.5%) agree as shown in figure 44.

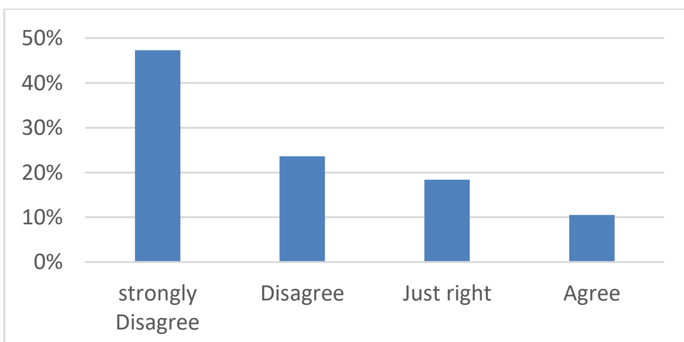


Figure 40 Class six students visual comfort level

The students choice of sit, 2 (5.2%) like to sit on the window side, 18 (47.3%) in the center and 18 (47.3%) of the respondents like to sit on the dead wall side. The reason behind their choice was the high level of daylight passing through window to the classes that make them difficult to do their tasks. Therefore, the students in this classroom use only natural light at the day time. 8 (21.0%) like to use artificial light and 21 (55.2%) like to use natural light, the rest 9 (23.6%) has no feeling.

CHAPTER FOUR

RESULT

4.1 The measurements value

The results of the measurements are summarized below on table 5.

Table 5 the distribution of daylight at working plane

Classroom	the distribution of daylight < 200lux	the distribution of daylight > 500lux	comfortable lighting zone	Total number of classrooms facing similar problem
1	73.3%	6.6%	20%	7 classroom
2	76.6%	6.6%	16%	14 classroom
3	10%	20%	70%	44 classroom
4	-	68.7%	32.3%	22 classroom
5	-	56.2%	43.8%	28 classroom
6	10.4%	10.4%	79.2%	77 classroom

Classroom one (Kutir 1) and classroom two (Kutir 1) these classrooms had also deficiency of daylight. Classroom three (Kutir 4) has better distribution of daylight. Classroom four (Degene Sime) and classroom five (Degene Sime) has more than sufficient daylight. Classroom six (Kidus Quran) had sufficient daylight.

4.2 The Students visual comfort perception

The results of Students perception are summarized below on table 6.

Table 6 Student level of comfort in classroom daylight

Classroom	Comfortable students with daylight level	Not comfortable students with daylight level	Total number of classrooms facing similar problem
1	10.3%	65.9%	7 classroom
2	24.3%	75.5%	14 classroom
3	64.1%	22.6%	44 classroom
4	10.6%	66.6%	22 classroom
5	15.5%	66.6%	28 classroom
6	10.5%	70.9%	77 classroom

4.3 Relation between daylight and learning environment

The importance of capturing subjective evaluations in addition to objective photometric information. Although current simulation tools can produce accurate photometric data. Simulated illuminance and luminance levels could be correlated with the users' visual satisfaction, uncovering the links between stimulus and response. A reasonable relationship between this variable and occupants' glare perception has been observed in some cases. Individual interest affects their perception towards the light and visual comfort. In these classroom students observed the above effect.

Classroom one (Kutir 1) :- As shown on the above tables the distribution of daylight in this type of classrooms is 73.3% of the working plane get daylight less than 200 lux which is not enough light for teaching and learning process. This classroom has deficiency of daylight. Thus the student response 65.9% are not comfortable with the daylighting. Of all 13 elementary schools, 7 classroom, which have same orientation and window size, have similar daylight problem.

Classroom two (Kutir 1) :- As shown on the above tables the distribution of daylight is 76.6% of the working plane get daylight less than 200 lux which is not enough light for teaching and learning process. This classroom has also deficiency of daylight. Thus the student's response 75.5% are not comfortable. Of all 13 elementary schools, 14 classroom, which have same orientation and window size, have similar daylight problem.

Classroom three (Kutir 4) :- As shown on the above tables the distribution of daylight is 10% of the working plane get daylight less than 200 lux and 20% of the working plane get daylight greater than 500 lux, on average 70% of working plane get daylight comfortable lighting zone. This classroom has better distribution of daylight. Thus the student's response 64.1% are comfortable with daylight in the classrooms. Of all 13 elementary schools, 44 classroom, which have same orientation and window size, have similar daylight effect.

Classroom four (Degene Sime):- As shown on the above tables there is no working plane, that gets daylight less than 200 lux which is not enough light for teaching and learning process. Although 68.7% of the working plane get daylight greater than 500 lux. Thus the student's response 66.6% are not comfortable from all 13 elementary schools, 22 classrooms, which have same orientation and window size, affected by glare.

Classroom five (Degene Sime) :- As shown on the above tables there was no daylight distribution of the working plane get daylight less than 200 lux and 56.2% of the working plane get daylight greater than 500 lux. Thus the student's response 66.6% students are not comfortable. Of all 13 elementary schools, 28 classrooms, which have same orientation and window size, affected by glare.

Classroom six (Kidus Quran) :- As shown on the above tables the distribution of daylight is 10.4% of the working plane get daylight less than 200 lux which is not enough light for teaching and learning process. Although 10.4% of the working plane get daylight greater than 500 lux. This Classroom has sufficient daylight. But 70.9% students are not comfortable, this happens because of the windows are fully transparent there was no treatment is used to control the direct glare. Of all 13 elementary schools, 77 classrooms, which have same orientation and window size, affected by glare.

CHAPTER FIVE

DISCUSSION

5.1 The measurements value

The minimum 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). Most of the sample classrooms do not fulfill this criteria but there is a lot of glare passing through the window that disturb the student's task.

LEED standard that a certain area should have daylight autonomy. If the spatial daylight autonomy is achieved for at least 55% of the occupied floor area, 2 points are given, while if the criterion is met for at least 75% of the floor area, the points are increased to 3. The working plane is considered at a height of 0.76m from the (finished) floor level (Giarma et al., 2017). The finishing material and the paint have a great effect to have smooth distribution of light. But in case of this classrooms there is no such consideration rather some class windows are painted to control the glare as shown in figure 45.

Figure 41 Painted windows

5.2 The student perception

Most of the students spend their days in classrooms where lighting conditions influence visual and non-visual functions. The full research comprised by analyzing the distribution of daylight using daylight contour then by using the result of the research, correlated with the student perception towards the daylighting. The research aimed to investigate the effects lighting conditions at on subjective alertness, mood, wellbeing and visual comfort.

The careful introduction of daylight into educational buildings reduces operating costs, improves students' vision and perception, and contributes to students' health, comfort, and productivity. In general, classrooms should get as much daylight as possible, although designers must control the illumination of areas within the students' fields of vision. Effective use of daylight in classrooms can help educational buildings realize significant energy savings, increase students' attendance, demonstrate environmental responsibility, and provide a better environment in which students can learn.

5.3 Relation between daylight and learning environment

Physiologically, daylight is an effective stimulant to the human visual system and the human circadian system. The lack of a sufficient light stimulus at the appropriate time can disrupt the circadian system, which can in turn lead to a range of negative health outcomes, such as poor sleep, reduced alertness. Daylight does have a greater probability of maximizing visual performance.(Boyce et al., 2003).

Here the analyzed some classrooms (especially classroom one and two) have shortage of daylight, this affects the students circadian system the ability of alertness in the classroom. This means affect the student performance in the classroom. The rests (especially classroom four and five) are having over delight that create discomfort to concentrate on the lecture.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

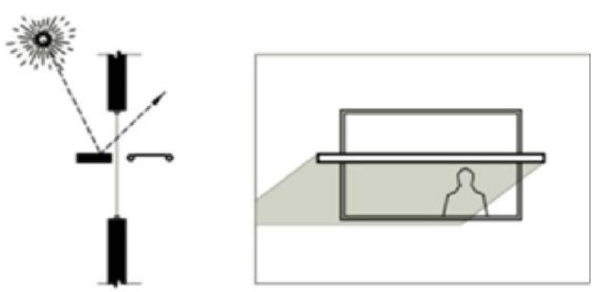
7.1 Conclusion

Daylight has many particular benefits including excellent visual performance of the circadian systems. This study can help designers and architects in designing daylight in schools, which generally have inadequate natural light.

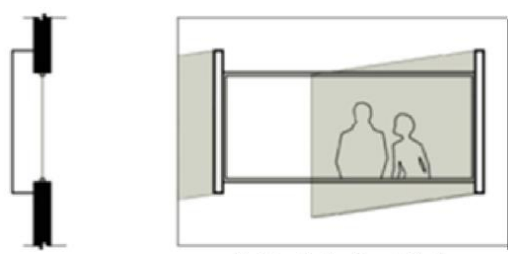
The average illumination in the south oriented classrooms is higher than the north oriented classrooms. The average illumination in the west oriented classrooms is higher than the east oriented classrooms. Not only the orientation of opening highly affect daylighting system of a indoor environment but also the size and indoor reflecting materials have a great effect on the distribution. The intensive use of glare free daylighting within buildings can be promoted as a preferable light source in classrooms, for visual comfort and non-visual functions.

7.2 Recommendation

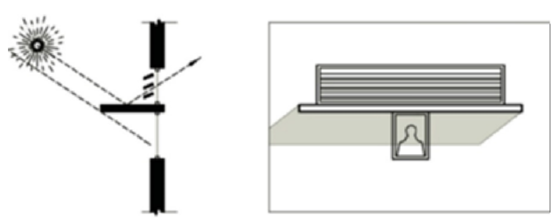
- Window to wall ratio the daylight distribution is also affected by greater areas of openings. Therefore, for the possible situations maximize or minimize the window size to have minimum of 15% of window to floor depth ratio.
- South facing window get harsh sun glare, using different type of shading devices based on the orientation of windows.



a) South Facing Window



b) North Facing Window



c) East or West Facing Window

- The approach of improving surface reflectance has significant advantages over other methods such as expanding the window area (daylighting), because the former

    (i) More effectively increases indirect corneal illuminance with a super-linear dependence,

    (ii) Only improves the indirect portion of corneal illuminance, which helps avoiding glare, and

    (iii) does not require additional energy cost or a serious reconstruction (expanding the window area).

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APPENDIX

Adama Science and Technology University

School Of Engineering, Department Of Architecture

Thank you for your time, you can answer by Using English or Amharic and Please give the correct answer.

This research is about The Relationship of student Visual comfort and level of daylight at elementary school classrooms in Adama, Ethiopia.

Researcher; Afomia Million

1. Gender female ☐ Male ☐

2. Do you feel about your class room lighting before?

Yes ☐ No ☐

3. Are you comfortable the lighting environment in your classroom?

Strongly Disagree ☐ Disagree ☐ Just right ☐

Agree ☐ Strongly agree ☐

4. Which raw do you prefer to sit?

Window side ☐ Center ☐ Dead wall side ☐

No filling ☐

5. Why do you prefer to sit there?

____

____

6. Is there any day that the daylight affect to do your task in the classroom?

Yes No

7. What measures do you take to keep your lighting comfort?

____

____

8. Which light is do you prefer?

Artificial ☐ Natural ☐ No Feeling ☐