COMPARATIVE ANALYSIS OF BIO-CLIMATIC THERMAL COMFORT FOR CONDOMINIUM AND TRADITIONAL HOUSE IN AFAR, SEMERA.

Haven Hailu Beyene

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 's in Environmental Architecture

Office of Graduate Studies

Adama Science and Technology University

Adama, Ethiopia

July 2020

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APPROVAL OF BOARD OF EXAMINER

We, the undersigned, members of the Board of Examiners of the final open defense by **Haven Hailu Beyene** has read and evaluated his thesis entitled "**Bio-climatic thermal comfort analysis of condominium and traditional house in Afar Semera**." and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirement of the Degree of Master's in Environmental Architecture.

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DECLARATION

I hereby declare that this MSc Thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been duly acknowledged.

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Therefore, I recommend that the student has fulfilled the requirements and hence hereby he can submit the thesis to the department.

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ABBREVIATIONS

ASHRAE: American Society of Heating, Refrigerating and Air condition Engineers

BL: Building

CIS: Corrugated Iron Sheet

Fig: Figure

GIS: Geographic Information System

HCB: Hollo Block Concrete

HVAC: Heating, Ventilation, Air conditioning

IAQ: Indoor Air Quality

RCC: Reinforced Concrete

RH: Relative Humidity (%)

TABS: Thermally Activated Building System

ABSTRACT

To ensure occupant's health and productivity the thermal comfort of the indoor environment is paramount. This research was conducted in the capital city of Afar regional state of Semera, on a comparative analysis of thermal comfort of condominium and traditional house. The objective of this study was to evaluate the bio-climatic thermal comforts of condominium building with respect to the old traditional house. The investigation was conducted using both objective and subjective thermal comfort evaluation methods. The objective method was conducted by measuring the indoor environment thermal comfort factors such as the temperature and relative humidity by using two Digital infrared thermometer and two hygrometers and both houses were evaluated for three consecutive months within three days interval within three-hour difference. The subjective method refers to informal interview, structured questioners including ASHRAE 7-points of thermal sensational scale which were able to investigate the perceptions of the society in question. For the survey 106 targets groups of respondents were purposively selected from the population based on their living experience in both houses. This paper discussed findings from both methods used for thermal comfort evaluation. Accordingly, from the total respondents 87.73% of respondents replied as the thermal sensational scale of traditional house is better than the modern house,83.2% informants were reacted as the thermal preference of traditional house was better than the modern house and concerning to thermal satisfaction,79.24% respondents prefer traditional house than modern house. In case of recorded temperature and humidity data the traditional house was better than the modern houses in all three consecutive months. Generally, the thermal comfort of the traditional house is better than the condominium house this is because of traditional house was built with locally available materials and with the consideration of the local climate context. However, this is not to recommend to return back to the traditional house rather to improve the modern house so as to adapt some important traditional methods and strategies.

Key words: Bio-climate, Comfort Zone, Thermal comfort, Vernacular

CHAPTER ONE

1.INTRODUCTION

This thesis is written for a study that has been conducted in Semera city of Afar Regional State, Ethiopia for the partial fulfillment of the requirements the Degree of Master's in Environmental Architecture at Adama Science and Technology University. The study aimed at analyzing the bio-climatic thermal comfort of condominium and traditional houses and providing appropriate housing design that takes into consideration the local environmental condition of the city. Thermal comfort is one of the criteria in sustainable building. This criterion is important in ensuring a healthy indoor environment for the occupants. Despite the fact that the consideration of environmental concerns at the early design stage would receive high attention worldwide, they are still not receiving full attention in sub-Saharan Africa in general and in Semera city of Ethiopia in particular, and consequently, residents exposed to thermal discomfort, lose their productivity and encountered with some health problems. As architecture and a resident of Semera city, the researcher was aware of several aspects of this general situation. Therefore, these things motivate the researcher to better understand the existing situation by carrying out more comprehensive and comparative thermal comfort investigations on condominium and traditional houses.

This chapter deals with the background of the study, statement of the problem, objectives of the study, research questions, scope of the study, the significance of the study, limitation of the study and description of the study area.

1.1. Background Of the study

The quality of life of human beings to a very large extent depends on the quality of their indoor environments because people spend most of their time in indoors (Smiełowska et al., 2017). Thus, buildings should have to take in to consideration on the bio-climatic condition of the place where they are built so as to improve the living standard of its resident. According to the study conducted by (Akande & Adebamowo, 2010) the term bio-climatic Architecture refers to designing a building based on the context of the local environment to provide the best thermal comfort of the place more suitable for residents. The primary purpose of all buildings is to conform to the predominant climate and to have an indoor and outdoor atmosphere that is convenient and desirable to the inhabitants. However, in this age of climate change and global warming, it is very difficult and necessary to offer the building's inhabitants comfort. It is attributed to the growing number of obstacles currently confronting designers to have structures that would be built and comfortable for the 21st century (Akande & Adebamowo, 2010).

Currently, green (environmentally friendly) buildings are considered as a good example of a building that improves the indoor thermal comfort of houses for occupants. Studies stated that green building materials are best to improve thermal comfort of buildings. That's why occupants are construct their dwellings from locally available materials, and the materials have good capability to protect the environment from unwanted natural resource depilation and the materials are easy to recycle without using external energy. Besides, as the studies stated the forms of buildings also has an important factor for providing good thermal comfort (Edition, 2014).

Microclimate condition such as humidity, radiant temperature, air temperatures, air movement, and human physiological aspects like body metabolic rate, level of activity and clothing of the occupants are the many factors that need to be considered in designing comfortable residential building (Rajapaksa, et al., 2002; Jamaluddin et al., 2014). Good indoor thermal condition plays a significant role in human performance at both mental and physical levels and sustains occupants' living quality (Abbaszadeh et al., 2006**).** According to Dovjak et al., (2013) failure of humans to respond to the environment through the thermo-regulatory mechanism causes thermal discomfort. Thermal discomfort in building causes psychological stress, depression, and anxiety, as well as lower physical health, manifested as heart disease, insomnia, headache, fatigue, boredom, and poor arousal (Fanger, 1970; Markus and Morris, 1980).

The western civilized countries give more emphasis for thermal comfort for all their indoor activities and they try to adjust the thermal comfort of their buildings using different techniques rather than merely sticking with a behavioral adjustment that our body endowed with by its nature so as regulate the temperature governing the thermal balance. They use different clothes and various types of mechanical cooling and heating system (technologies) to regulate thermal comfort. As a result, they exposed to the high cost to install these machines, and also the machines by itself consume high electric power(de Dear & Brager, 1998).

Whereas in case of developing country there is no study on how they balance thermal comfort, but in case of Ethiopia peoples use different traditional techniques that's why they can't afford to buy air conditioner mechanical Machine, therefore, the peoples try to regulate using locally available materials such as mud block, grass roof, planting is some examples. In the case of

Semera City, there are different locally available traditional materials and traditional strategies. Even if they enforced to sleep outdoor due to the high temperature. Generally, according to de Dear and Brager, (1998) report, almost all developing countries' peoples stay 85%of their time at home(including office, hotels, cafeteria, school and church) to increase the productivity of the peoples it's better to regulate the thermal comfort of the building.

1.2. Statement of the problem

Our country Ethiopia has a different climatic condition and also buildings are expected to design with the consideration of different climatic conditions to meet the best thermal comfort. But the fact indicates that the Federal Government, collaborating with the Housing Development, has developed remarkable approaches to provide shelter for the low-income peoples of the country and standard condominiums are the one and the widely accepted approach that the government provide to address the housing problem. These modular condominiums are designed at the federal level and then distributed to every cities and towns without the consideration of climatic factor. Therefore, peoples are suffered for thermal discomfort. Especially in the case of Semera town which have an average temperature of 33.0°C a lot of condominium was constructed and transferred to the people but the people are not interested to live in the house due to high temperature of the indoor space and some condominiums are under construction without the consideration of thermal comfort. The uncompleted condominiums are still waiting for help. All this is supposed to be due to the inappropriate placement of the standard condominium being out of its climatic context.

Although research into the field of thermal comfort climates around the world has been undertaken, there is little or no comprehensive research on thermal comfort in general and in residential buildings in particular Ethiopia. One study carried out in Jimma town, Ethiopia by Yadeta et al., (2016) analyzed the perception of the residents towards thermal comfort and investigate the source of heat which enables to increase the temperature of the indoor environment through using only questioners. The study investigates the perception of the residences using only subjective evaluation method. In total, the above study is limited in scope of subjective evaluation method this method is affected by adaptation of the residents if it is supported by objective evaluation method. Yet, there is no single, research on the thermal comfort of a residential building in Semera city. Hence, this study is intended to contribute to filling these gaps. The aim of this research is therefore to carry out more comprehensive thermal comfort investigations in the relatively highest climate area by using both objective as well as subjective evaluation method. The research also aims to provide passive solutions and strategies that fit the city's climate conditions that would be culturally accepted, affordable, especially for low-income households, and reduce energy use.

1.3. Research Objective

1.3.1. General objective

The general objective of the research is to evaluate the bio-climatic thermal comfort of condominium buildings with respect to the old traditional house in the Afar-Semara.

1.3.2. Specific objectives

The specific objectives of the study are

- To evaluate the existing physical characteristics of the buildings concerning thermal comfort.
- To assess the user's preference with regard to the traditional house and standard condominium in terms of thermal comfort.
- To compare the comfort level of the traditional house with respect to the standard condominiums.

1.4. Research Questions

The following research questions are formulated based on the specific objective of the study.

1. What is the existing physical characteristics condition of the thermal comfort of the condominium as well as the traditional house?
2. What are the perceptions of the society towards preference of living in a condominium and traditional house with respect to thermal comfort?
3. Which building type (i.e. Condominium and traditional) is comfortable for residents concerning to thermal comfort?

1.5. Significance of the study

The study will be very important for the improvement of thermal comfort in residence in different aspects, among these;

- To improve the thermal comfort of the dwelling to enhance the productivity and the morale of the residents as well as to protect the residences from different health problem such as itch, headache, stress, depression, asthma, allergies which may cause by indoor thermal discomfort.
- Along with the thermal comfort to protect depletion of natural resources by constructing eco-friendly buildings or sustainable.
- It has its significance for the policymaker, decision-makers in the construction industry. This research will have its significance as an academic input, social transformation, economic development, and technological improvement.

1.6. The scope of the research

Spatially the study is confined within the afar regional state of Semera city. Since all condominiums are found at kebele 01and 02 of the city, the study evaluates and analyzing the bio-climatic thermal comfort of the condominium buildings which found at these two kebeles. Thematically the study evaluates and analyzing the bio-climatic thermal comfort of the condominium building in comparison with the old traditional house found in Afar Semera city. The comparative assessment is based on the conducted temperature and humidity of the buildings and analysis was conducted based on those two climatic factors.

1.7. Limitations

As intimated earlier the study was mainly focused on the temperature and humidity data of buildings. To measure humidity and temperature only two digital infrared thermometers and two hygrometers were used which is not sufficient to collect data within planed time. Thus, as a solution, the researcher determined to measure only two buildings one building from the modern house and one building from old traditional houses. It would have been better to test more buildings to make the study more comprehensive. Furthermore, the pandemic disease called COVID 19 was also the other problem that impedes carrying out the research activities including data collection on the proposed due time. This is because due to the pandemic disease transportation services and other facilities were banned by the government state of emergency decree.

1.8. Organization of the report

The thesis is categorized into five (5) interdependent chapters. Chapter one presents "General Introduction" it explains the background of the research and the problem which necessitating research efforts. The research aims, research questions, objectives, and scope are also contained in this chapter. Chapter two “contains the literature review”. The review provides a wide-range of earlier works. Chapter three presented under the title of “Materials and methods”. The first aspect of this chapter deals with the method, population, and sample of the study whereas the second part provides the tools and techniques employed by the researcher to analyze and present the collected data. Generally, the whole plan of the study is discussed in detail under this chapter. Chapter four presents the results and discussion of data gathered. The last chapter which is chapter five presents a summary of findings, conclusion, and recommendations of the study.

1.9. Operational definition of the study

The term of the central concept of evaluation of bioclimatic thermal comfort of Afar Semera condominium buildings discussed below.

Bio-climate: refers to the design of buildings and spaces (interior – exterior – outdoor) based on local climate, aimed at providing thermal and visual comfort, making use of solar energy and other environmental sources. Basic elements of bioclimatic design are passive solar systems that are incorporated into buildings and utilize environmental sources (for example, sun, air, wind, vegetation, water, soil,)(Ho, 2002).

Comfort zone: comfort zone refers to the mixtures of air temperature, mean radiant temperature (tr), and humidity that is predicted to be an acceptable thermal environment at particular values of airspeed, metabolic rate, and clothing insulation (Fanger, 1970).

Thermal comfort: according to Khairy et al., (2012) thermal comfort is defined as “the perception of building users to feel satisfied in terms of the indoor temperature, moisture level, and ventilation.” Psychological state of mind a person feeling too hot or too cold.

Vernacular: is described as a built environment that is based upon local needs; defined by the availability of particular materials indigenous to its particular region, and reflects local traditions and cultural practices (Brunskill & Brunskill, 2000).

1.10. Description of the study area

1.10.1. The geographical location of the study area

Semera is a new town on the Awash-Asseb highway in the northeast of Ethiopia, planned to replace Asaita as the capital city of the afar region located in the administrative zone 1. Semera has a latitude and longitude of 11°47′32″N 41°0′31″E (Mamo et al., 2013) and situated at a distance of 595 from Addis Ababa.

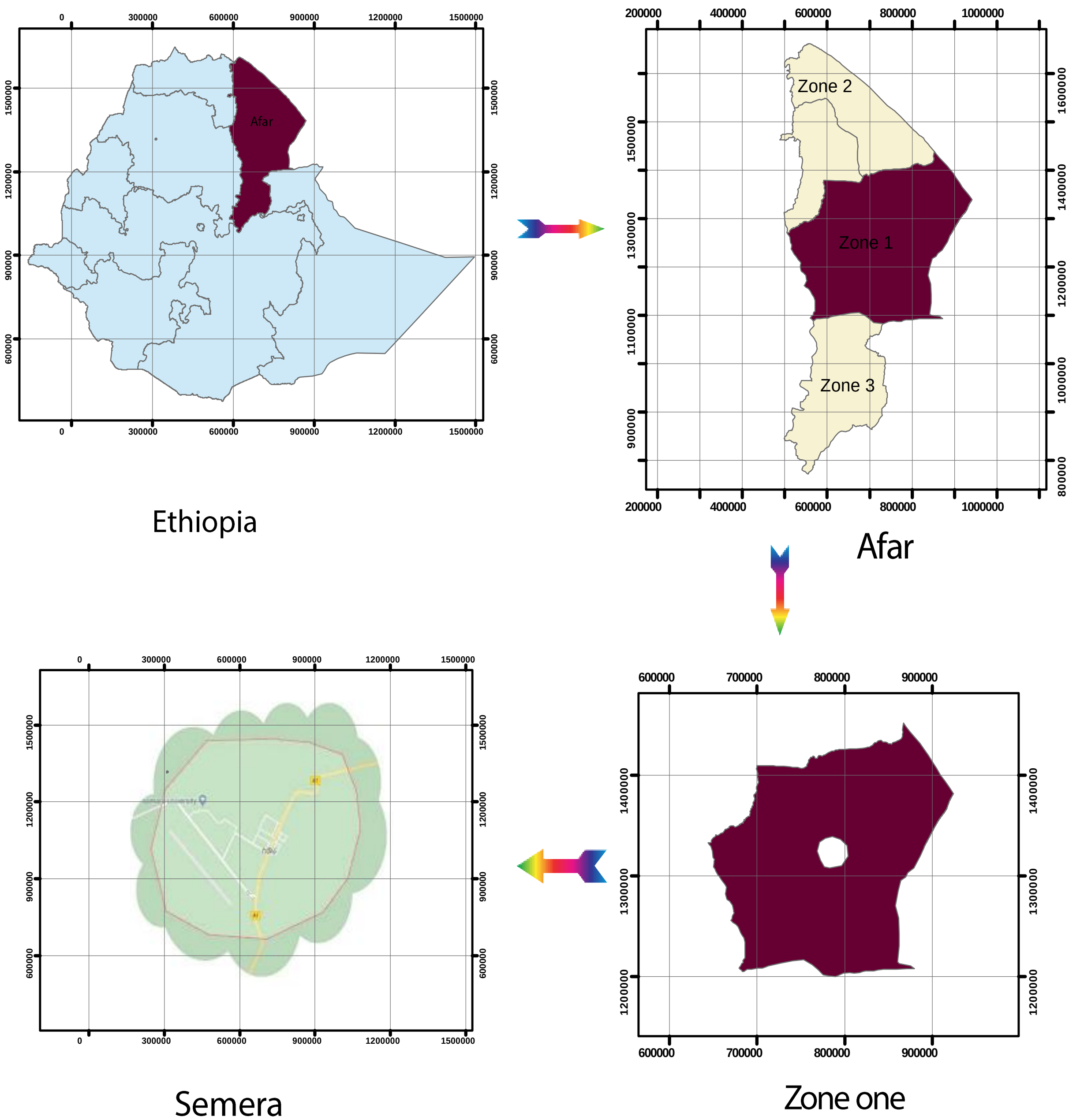

Figure 1 Location map (Ethio-GIS data)

1.10.2. The climatic condition of the study area

Semera city characterized by an arid and semi-arid climate with low and erratic rainfall. Rainfall is bi-modal throughout the region, with a mean annual rainfall below 500 mm in the semi-arid western escarpments and decreasing to 150 mm in the arid zones to the east. The altitude of the Region ranges from 120 m below sea level in Danakil depression to 1500 m above sea level. Temperatures vary from 20°C in higher elevations to 48°C in lower elevations.

Table 1 Annual climatic data Afar Semera.

Climate data for Semera													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high °C (°F)	30	30	32	34	37	39	38	36	36	34	32	31	34
	86	87	90	94	98	103	100	8	97	94	90	87	94
Daily mean °C (°F)	24	25	27	28	30	32	31	30	30	28	26	25	28
	76	77	80	83	86	90	88	86	86	83	79	76	82
Average low °C (°F)	18	20	21	22	24	26	24	24	24	22	20	19	22
	65	68	70	72	75	78	75	75	76	71	68	66	71
Average precipitation mm (inches)	7	8	29	20	11	5	40	52	16	6	7	2	203
	0	0	1	1	0	0	2	2	1	0	0	0	8

Source ("Semera climate: Average Temperature, weather by month, Semera weather averages - Climate-Data.org," 2019)

The graph above indicates that there is high temperature in Semera which is difficult to live and the climate is characterized by high temperature and low humidity in the dry season, the diurnal temperature varies from an average daily maximum of 36.7°C to daily 18.3°C the mean humidity is highest in November (74%) and lowest in July (28%). especially in June, July, and August the temperature will fall 40°C which is the highest temperature. This indicates that it is impossible to stay in building rather the building will construct with the consideration of high thermal.

1.10.3. Socio-economic characteristics of the study area

Afar region is among the nine regional states found in the northern part of Ethiopia which cover around 150,000 Km^2 and structured into 5 zones and 29 woredas. Semera is the capital city of the region. There are more than 1.5 million people are estimated to live in the region which is dissected into one hundred clan families which in principle classified the land equally among themselves. The head of the clan families is called Mekaban under him each tribe is ruled by a Kedo Aba. These leaders together with elders are ruling the Afar society, especially they are responsible to arbitrate when conflict arises between or among clans, tribes, or individuals. The majority numbers of the Afar population are pastoralists who engaged in cattle breeding activities to subsist themselves and their families. There are around 1.9 million cattle in the Afar region of which almost 90% are managed through pastoral and the remaining are in the agropastoral production system. The cattle in the region is dominated by two specious i.e. camel and goat.(Missions et al., 2001).

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Thermal comfort and its importance

According to ASHRAE standard 55-2004,(55, 2010), Thermal comfort can be described as the condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation of the occupants based on checklists. Thermal comfort is key to an acceptable quality of the indoor environment. And these environmental elements are such as Heat from electrical light, lack of enough ventilation, high humidity level, and those elements can expose the occupants to less productivity and performance." (James et al., 2012).

By managing thermal comfort of the indoor environment, likely to improve morale, productivity as well as improving health and safety of residents (Edition, 2014). People working in uncomfortably indoor environments are more probable to perform unsafely because their ability to make decisions and/or perform manual tasks deteriorates due to thermal discomfort (Njomo, 2010).

2.2. Thermal comfort in outdoor spaces

Outdoor thermal comfort is one of the most influential factors in the habitability of space. The thermal level is defined not only by climate variables but also by adaptation of the people to the environment (Ho, 2002). (Njomo, 2010) presented an evaluation of thermal comfort in four square locations of the condominium Downtown, in the west zone of Rio de Janeiro. They showed the applicability of the Fanger's model in evaluation studies of the thermal comfort in outdoor spaces. Also, from the considered environment conditions, they showed that it was possible to establish this influence on the thermal comfort for the locations selected in the square. However, one should be very careful when interpreting the results of thermal comfort campaigns. The actual standards help but should not be considered as absolute references.

2.3. Thermal comfort zone

Refer to an acceptable temperature, humidity and air velocity in which as the condition of mind which expresses satisfaction and residents able to be feel healthy and becoming productive (Njomo, 2010). The graph below in figure -2 indicates that the temperature and humidity level of comfort. And according to ASHARE and as the figure indicates that temperature between 23^0C-27^0C and Humidity from 30RH – 60RH refers to comfort zone(55, 2004).

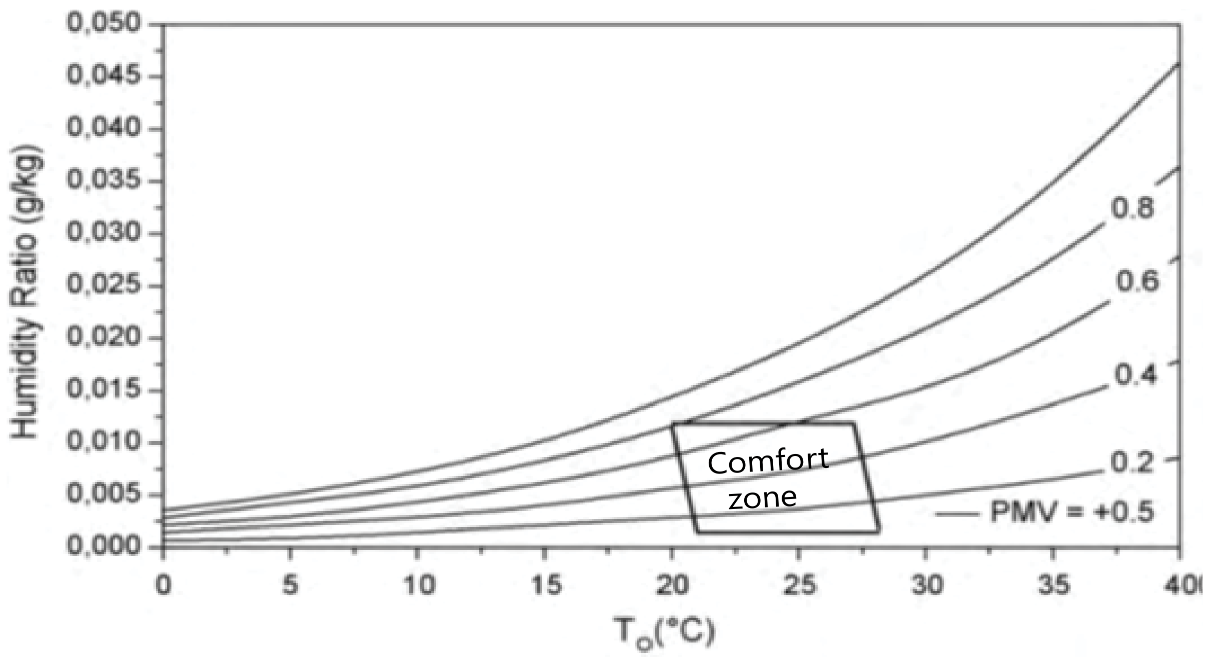

Figure 2 Thermal comfort zone source (Njomo, 2010)

2.4. Bio-climatic thermal comfort

Bioclimatic thermal comfort refers to the perfect remedy degree of indoor space to attain the quality of life interims of customers physical and psychological overall performance(Akande & Adebamowo, 2010). Bio-climatic thermal comfort can be improved by taking advantage of the nearby condition of the environment such as climatic condition, the orientation of the building, wind direction, humidity, groundwater, and also a good choice of building material regarding consideration of locally (traditional) available, which have high capability to insulate Temperature and economically good (Yadeta et al., 2016).

2.5. Bio-climatic zones in the tropics

The hot-arid areas are marked by using an absolute humidity (vapor pressure) of beneath 2.5 kPa and excessive daily temperatures in the summer time, to extra than 50ºC, coupled with excessive photo voltaic radiation. Summer and winter differ significantly and temperatures in winter can drop to 0ºC. Temperature differences between day and night can be as much as 20ºC in winter. Countries within this zone have sturdy direct radiation by means of the earth surface; moderate precipitation and humidity; and the possibility of dust and sand storms and high temperature difference between day and night (Nicol & Humphreys, 2002). Figure 3 shows that the climatic zones in the tropics and moderate areas.

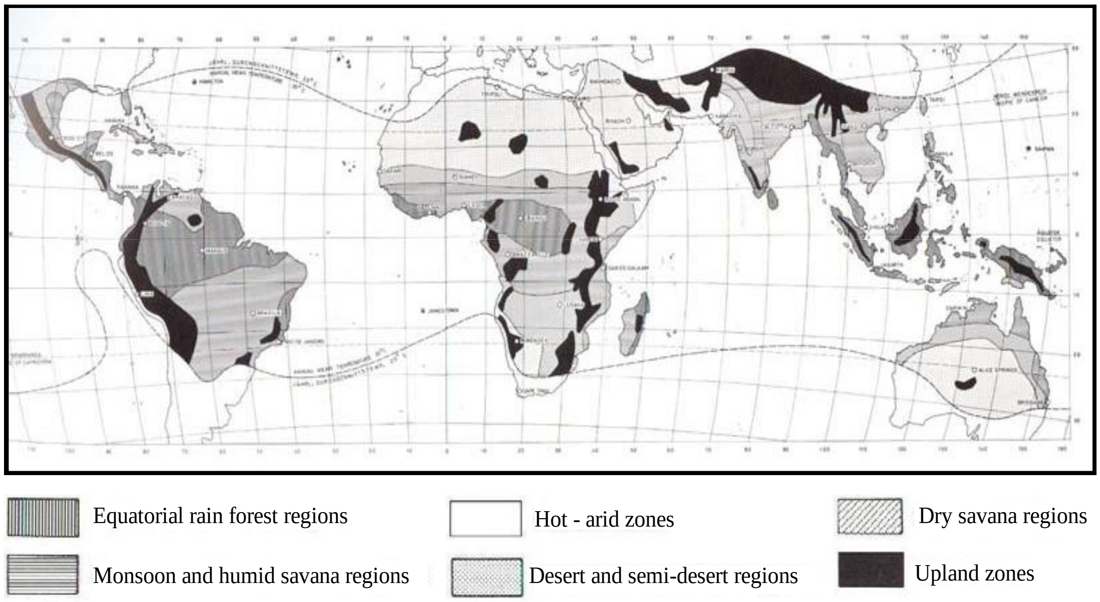

Figure 3 Climatic zone source(Carmona, 2018)

2.6. Bio-climatic thermal comfort factor

Indoor human thermal comfort is an important factor in indoor quality assessment and thermal comfort affects human health, work efficiency, and overall wellbeing. And thermal discomfort indoors will enhance to lower emotional and physical health of the occupant. (Yadeta et al., 2016), therefore according to (“HSE - Thermal comfort: Measuring thermal comfort,” 2010.), indoor thermal comfort mostly can be affected by six basic fact.

2.7. Basic factors of thermal comfort

The comfort of indoor space can be affected by different factors with different degrees the most commonly used indicator of thermal comfort is air temperature it is easier to use and most peoples can rate it. however, air temperature alone is not a valid or accurate indicator of thermal comfort. The factors affecting thermal comfort are both environmental and personal. These factors may be independent of each other, but together contribute to an employee's thermal comfort(de Dear & Brager, 1998).

2.7.1. Environmental factors

These factors are created environmentally due to different reasons such as the high emotion of gases and any other pollutions which may have an impact on the environment (Mamo & Worku, 2013). Such as

Air temperature: this is the temperature of the air surround in and a reason for thermal radiation which radiates from warm objects radiant heat may present if there is a heat source in an environment. Radiant heat source includes the sun fire, ovens, kiln walls, cookers, dryers, hot surface, and machinery are the source to increase the indoor temperature of the buildings.

Air Velocity: this can be describing the speed of air moving across the employee and maybe help cool them if the air is cooler than the environment. Air velocity is an important factor in thermal comfort. Still or stagnant air, for instance, in the indoor environment that is artificially heated may cause people to feel stuff. It may also lead to a built-in odor and also moving air in warm the humid condition can increase heat loss through convection without any change in air temperature. Physical activity also increases air movement, so air velocity may be corrected for a personal level of physical activity Small air movement in cool or cold environments may be corrected to account for a personal level of physical activity. Smaller air movements in a cool or cold environment may be perceived as a draught as people are particularly sensitive to those movements.

Humidity: refers to water is heated and it evaporates into the surrounding environment, the resulting amount of water in the air will provide humidity**.** The relative humidity is the ratio between the actual amount of water vapor in the air and the maximum amount of water vapor in the air and the maximum amount of water vapor that the air can hold at the air temperature. Relative humidity between 40% and 70% do not have a major impact on thermal comfort. it works place which is not air-conditioned or where the weather conditions outdoor may influence the indoor thermal environment relative humidity may be higher 70% humidity in indoor environments can vary greatly and maybe depends on whether there are drying processes where steam is given off. High humidity environment has a lot of vapor in the air, which prevents the evaporation of sweat from the skin, in a hot environment, humidity is important because less sweat evaporates when humidity is high (80+). The evaporation of sweat is the main method of heat reduction (Eddy et al., 2017).

2.7.2. Personal factors

Clothing insulation: thermal comfort highly depends on the insulating effects of clothing on the wearer. Wearing too much clothing may primarily cause of heat stress even if the environment is not considered Warm or hot. If clothing does not provide enough insulation, the wearer may be at risk of cold injuries such as frostbite or hypothermia in cold conditions. ("The Bioclimatic Architecture. Green building | Bioclimatic Architecture, Bio construction, Urban Planning, and Environment," 2012.). therefor clothing is both a potential cause of thermal discomfort as well as a control for it as we adapt to the climate in which we work. And it is important to identify how the clothing contributes to thermal comfort or discomfort. by periodically evaluating the level of protection it is possible to improve the level of thermal comfort.

2.8. Design factors affecting the level of thermal comfort

To the enhancement of indoor thermal comfort of housing, it is better to protect the buildings from diffirent obstacles that directlyaffect the thermal comfort during design. It has been found that many factors affect the level of this comfort; major effects are such as urban design, the architectural design of the house, and material selection for the buildings, united with minor ones, such as economy, quality, etc. (55, 1992).

2.8.1. Urban design factor

The urban design of a settlement is one of the primary elements which have an essential impact on the thermal performance of the buildings within it. In general, most buildings in hot climates have evolved as a cluster more or less connected to each other to prevent the penetration of solar radiation and to provide shade. Moreover, the building designs and shapes are also appropriate to the local climate, as seen in the general view of a traditional city in Morocco. The city plans of other ancient cities, such as Tripoli and Ghadames in Libya reflect similar attitudes (Study et al., 2020).

2.8.2. Architectural design factor

The architectural design of the house is one of the factors that affect the thermal comfort within. The architectural elements play a great part in influencing the thermal comfort of the house; one of these elements is the courtyard. Many studies have been carried out on courtyards in houses, which emphasize the importance of this enclosed space as being multi-functional, able to provide a convenient natural environment to the interior, which makes it an appropriate architecture solution for semi-arid hot areas.

2.8.3. Construction materials

Many studies focused on the benefits of using local construction materials as a solution to many problems such as; pollution, economy, complicated construction.

2.9. Methods for evaluating indoor thermal comfort

According to ASHRAE (55, 1992) indoor thermal comfort can be evaluated based on two methods such as subjective evaluation method and objective evaluation. Subjective evaluation is an evaluation based on the feeling of the residents by using the ASHRAE thermal sensational scale, structured questioners and interview. This method of evaluation can be affected by the adaptation of the residents as well as their mood. In case of objective evaluation method, it is based on evaluating the indoor thermal comfort factors such as air temperature, relative humidity, air velocity as well as mean radiant temperature of the indoor environment and compering the value with standards which was discussed by ASHRAE 55. But for good output both methods are important.

2.10. Experience in developing and developed countries on thermal comfort

According to different scholars' thermal comfort is crucial for all residents to be productive and healthy. Due to this to regulate the indoor thermal comfort or for best HVAC system the developed country used different methods and techniques. According to (Nielsen, 2012) most buildings in the developed countries use Thermo active technology during construction. This enables to activate the building's thermal mass with the help of embedded piping as well as it enables to gives an optimal indoor climate-energy consumption for heating and cooling is minimized. Again, by combining the TABS heating and cooling system with embedded pipes in the structural concrete slab or wall typically applied for the building where occupancy pattern yields large cooling load during day time and it is possible to shift from day time tonight time.

But in the case of developing countries due to lack of technologies, buildings use the different traditional methods of cooling systems such as locally available construction materials, building orientations, using plants, and the like. Some strategies that the traditional(vernacular) house use different methods and techniques (Manzano-agugliaro et al., 2015).

In addition to the locally available materials (Vernacular) developing countries have some methods to regulate the indoor thermal comfort such as using different shading methods specially upper shading, installing external parapet wall as divider between the houses to prevent the hot air on the neighbor roof to move to house, providing slop to the roof in the direction of courtyard this enables cold night air to flow in to the court and using external structure such as wooden pergola embodied with vegetations and such water elements to enhance the moisture of the air (Njomo, 2010).

2.11. Summary and gaps of the literature review

In this exploration phase, while assessing different sources and studies in the related field of study Thermal comfort is discussed in different aspects of buildings. But, some of the studies have some limitations which can be summarized as follows;

- In the case study journal entitled "Human Thermal Comfort in Residential House Buildings" Of Jimma town, southwest Ethiopia. Yadeta et al., (2016) Aims to assess the thermal comfort qualities of the indoor environment to enhance the productivity and health of the occupants could be seen through many aspects as follow. The study is conducted through questioners by the perception of the peoples only but the perception of the peoples can be affected by the conditional mood of the occupants and adaptation also has its factor for the accuracy of the outputs.
- The title "indoor comfort for a residential building in the hot dry climate of Nigeria" by(Akande & Adebamowo, 2010) will try to assess the thermal comfort indoor space with both questionaries' and by using instruments which are used to measure humidity, temperature, air velocity, and the study will focus on the comparison of the dry season and the rainy season thermal comfort but the factors that affect thermal comfort will not consider such as building materials and other factors and it is clear the dry season is more thermal discomfort than the rainy season due to the amount of humidity in the air.

CHAPTER THREE

3. RESEARCH METHODOLOGY

3.1. Overview

This chapter is about the research methodology used in the study. The study was conducted based on four (4) items such as 1. Filed survey on both traditional and the standard condominium which is found in Semera town, 2. Informal interview was conducted, 3. Questioner was prepared to the residents and evaluated accordingly 4. Temperature and Humidity data for both types of the house were recorded by digital infrared thermometer and hygrometer respectively.

The method of the study was focused on the comparative analysis of thermal comfort level between the old traditional (vernacular) houses which is made by Afar Semera people with that of the standard condominium which is found in Semera town. Due to similar features of the modern house only one building was selected randomly and also the selection criteria for the traditional house was based on the construction material, availability of a traditional method of cooling and ventilation, location. Having these criteria, one from the old traditional houses and one from standard condominiums were selected for a detailed survey

There were some challenges during the survey time in the research area. For instance, since the temperature was very high, it has been too much difficult for the researcher to stay there till the end of the research mission. And also, because of language constraints, there were some communication problems with those who reside in the traditional houses. Besides they were not interested to give some information and difficult to take photos and, record the temperature and humidity data for three consecutive days within three hours intervals.

3.2. Research design

This study is a comparative research design and uses both descriptive and explanatory research methods. A mixed approach which is both qualitative and quantitative data were used. Through quantitative (physical measurement) and qualitative (questionnaire, interview, and filed survey). This research carries out the comparative analysis of thermal comfort of condominium and traditional houses and also examine the comfort level, how the different factors affect highly thermal comfort of the buildings in Afar/Semera, and also analyze the preference of the people and on what base it depends on.

3.3. Type and source of 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, official documents, and governmental reports were used as a source. To this end reviewing relevant literature was made to overview other countries' experiences about the importance of and the weight that they give to indoor thermal comfort whereas, primary data were collected through questionnaires and interviews administered to the respondents which have experience living on both types of houses. Furthermore, those data collected by personal measuring of the temperature and humidity of buildings are failing under the categories of primary data.

3.4. Sampling technique and sample size

From those individuals who reside in Keble one and two, and who have been the experience of living in both traditional house and condominium buildings respondents to fill the questionnaires were drawn. The number of the sample size was determined using a formula developed by kish (1665) (Ajay & Micah, 2014).

$$N = \frac{n^1}{1 + n^1/N}$$

Where n = sample size

N = Total population size

N=1750 (total population size)

$$n^1 = \frac{S^2}{V^2}$$

S = maximum standard deviation among the population of elements

(total error of 0.1 at a confidence interval of 95%)

V= standard error of the distribution assumed to be 0.05

S^2 = p (1-p) where p represents the proportion of the population elements belonging to the class defined

S^2=0.5 (1-0.5)

S^2= 0.25

$$n^1 = \frac{0.25}{(0.05)^2}$$

$$n^1 = 100$$

$$N = \frac{100}{1 + \frac{100}{1750}}$$

$$N = 94.59 \approx 95$$

$$\frac{12}{100} \times 95 = 11.4 \approx 11 \text{ (contingency)}$$

n= 11+ 95 = 106 (population sample size)

Accordingly, out of 1750 households, 106 sample Informants were selected for household surveys. The sample informants were selected using a purposive sampling method from the total household. According to (Tayie, 2005) purposive sampling is one that includes subjects who are selected based on certain specific criteria needed for the study. The nature of the study is such that privilege and sensitive information is required. This required the use of purposive sampling techniques for the study is to select respondents based on their experience of living on both types of houses.

3.5. Data Collection

3.5.1. 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, LR02 made in America and the temperature and humidity was recorded in both the traditional house as well as the standard condominium in the absence of any kind of mechanical cooling and ventilation system. The record stayed for the consecutive three-months in a gap of three (3) days which means eight (8) days per month and Twente four (24) days per three (3) months and the data was recorded with a three-hour interval starting from 1:00 pm – 12:00am because of the average inclination of the sunlight. Due to the high temperature season the recorded data was started from 5th February 2020 to 25th April 2020 and the data was recorded five (5) times in a day within the difference of three (3) hours and the data was recorded manually.

A. Digital infrared thermometer

Figure 4 Inferred thermometer

Infrared thermometer color screen display

Range: -50 ~ 400^{o} C (-58^{O} F ~ 752^{o} F)

Accuracy: $\pm$ 1.5^{o} C/ $\pm$1.5%

Resolution: 0.1 ^{o} C/0.1^{o} F

Distance spot ratio: 12: 1

Emissivity: 0.95 (fixed)

^{O}C/^{o} F unit selectable

B. Digital hygrometer

Figure 5 Hygrometer device

Humidity range: 10% ~ 99 %RH

Resolution humidity 1%RH

Accuracy humidity $\pm$5%RH (40% - 80 %)

Storage condition 20 -80 %RH

Auto power off and Data hold

Laser ON/OFF selectable

The study was used two digital infrared thermometers and two digital hygrometers and the consistency of the materials were cheeked by comparing their readings to each other, all the instruments which were used for study manufactured in different companies this enable to check the reliability of the instruments. Both the infrared thermometer and the hygrometers can read both temperature and humidity and it was easy to check their accuracy. The detail descriptions, specifications, manuals for all instruments is given in appendix A.

3.5.2. Questionnaire survey

The questionnaires were used to analyze the thermal perception of the occupants. Questionnaires were distributed for purposively selected sample informants who had experienced in living both types of buildings. The questions were focused on a comparison between both building types and it enables to understand the perception of the society towards comfort and the method that they use to regulate the thermal comfort of both buildings including comfort level, energy consumption, construction material, cooling, and heating method, opening size, and utilities such as electric. The questions were given to the peoples selective randomly through a mutual contact. The total number of questionnaires distributed was 106 and the total number of questionnaires collected was 101 but 5 of them were not collected due to the bad welling of the respondent and a total of 101 questionnaires from each respondent were evaluated and the questionnaire is given in appendix B. the Thermal sensational scale of the respondents was assessed by the ASHRAE 7-points of sensational scale (Version, 2016) as shown in the table below.

Table 2 Thermal sensation scale source:(Version, 2016)

Thermal sensation scale						
Cold	cool	Slightly cool	Neutral	Slightly Warm	Warm	Hot
-3.0	-2.0	-1.0	0.0	1.0	2.0	3.0
Thermal preference scale						
Much cooler	cooler	slightly cool	No change	Slightly Warmer	Warmer	Much warmer
-3.0	-2.0	-1.0	0.0	1.0	2.0	3.0
Satisfaction scale						
Very dissatisfied	dissatisfied	Slightly dissatisfied	Neutral	Slightly satisfied	satisfied	Very satisfied
-3.0	-2.0	-1.0	0.0	1.0	2.0	3.0

3.5.3. Informal interviews

Informal interviews were collected with the owners of the traditional house, and also with the people who had earlier experienced living in both types of houses, with construction workers and visitors in the city and some experts of local architecture in Semera town. Many questions were asked, about the particular features of the houses, especially about the comfort level and the solution, which they adapt to provide optimum thermal comfort in the house and to understand user preferences concerning residential architecture in the city.

3.6. Field survey

The field survey was focused on observation of the lifestyle of Semera people and how they challenged by temperature and also observe the techniques that the people use to heat and cool the indoor temperature, the ways of constructing a building, the construction material, opening type and size, form and space utilization and the overall activity to get optimum thermal comfort of the building .Two buildings were selected from both types of building for the study during the field survey based on certain criteria which stated above.

3.7. Data processing and analyses

Data analyses were carried out by spreadsheet software MS Excel. The spreadsheet has been used to calculate the mean value of environmental variables and to generate tables showing the percentage of temperature and humidity. The first phase of analysis was related to the collected temperature and humidity data, which were presented in linear charts that show the situation in the traditional houses compare to the modern (condominium) one. The second phase of data analysis was related to the questionnaire data, which was presented in tabular forms, chart and it analyzed using a mixture of descriptive statics. Graphs used for the analysis. This data gives brief information about both types of buildings including the challenges they faced.

3.8. Ethical consideration

This thesis is my original work and all material used throughout the study have been duly acknowledged. The researcher informed the respondents about the nature and the very objective of the study and the confidentiality of their answer and secured their permeation before they gave their response. All data in the study have been gathered in due respect with individuals' right to privacy as a researcher gained owners and/ or residents' permission to have an access to their premises to measure the humidity and the temperature condition of their devilling house. All states of the study were carried out in conformity with basic research standards as well as all data was analyzed, presented and concluded with objectively without the influence of the researcher's personal perceptions and experience.

3.9. Data quality and control

For good output of this research the researcher tries to use methods that enhance the quality of the outputs. Accordingly, small sample size of questioner was distributed before and for the instruments accuracy the researcher tries to compare the instruments with standard temperatures.

CHAPTER FOUR

4. RESULT AND DISCUSSION

In this chapter analysis and results are reported to draw the inferences of the study. Different types of information or data were gathered through different information or data gathering techniques such as observation, informal interviews, filed surveys such as humidity and temperature measurement.

4.1. Characteristics of the Sample population

4.1.1. Age of the respondents

The age group of the respondents was ranged from 20 years old to over 51 years, from the total respondent n=106(100%) the most respondents were n=42 (39.6%) were aged from 31 to 40 years old, some respondents were n=29(27.4%) aged from 41 to 50,n=22(20.6%) were above 51 and few respondents which were n=13(12%) were aged between 20 to 30 years old.

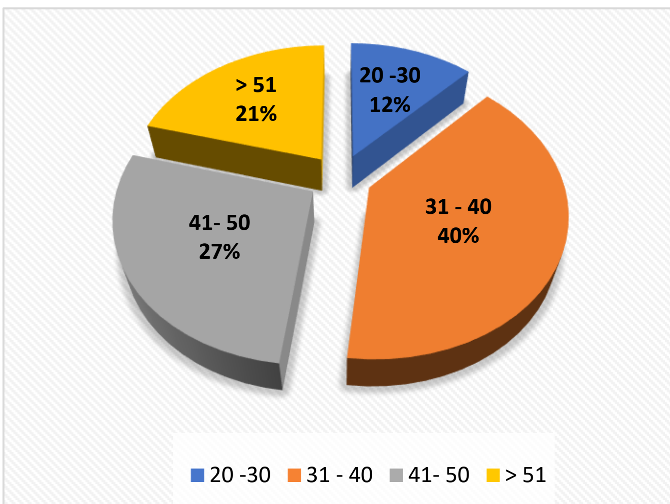

Figure 6 Age of the respondents (field survey,2020)

4.1.2. Level of education

According to the survey result, the majority of the respondents were not educated. From the total respondents, n=106,100% the highest respondents n=45(42.5%) of the total respondents were not educated, n= 26(24.5%) of the respondents had finished elementary school, n=25(23.6%) of the respondents had finished high school and few respondents n=10(9.4%) were had finished university degree. Accordingly, since the majority of the informants lack the basic skills that allow them to write, read and understand information on paper there for the researcher and other supporters fill the questionnaires according to the perception of the respondents.

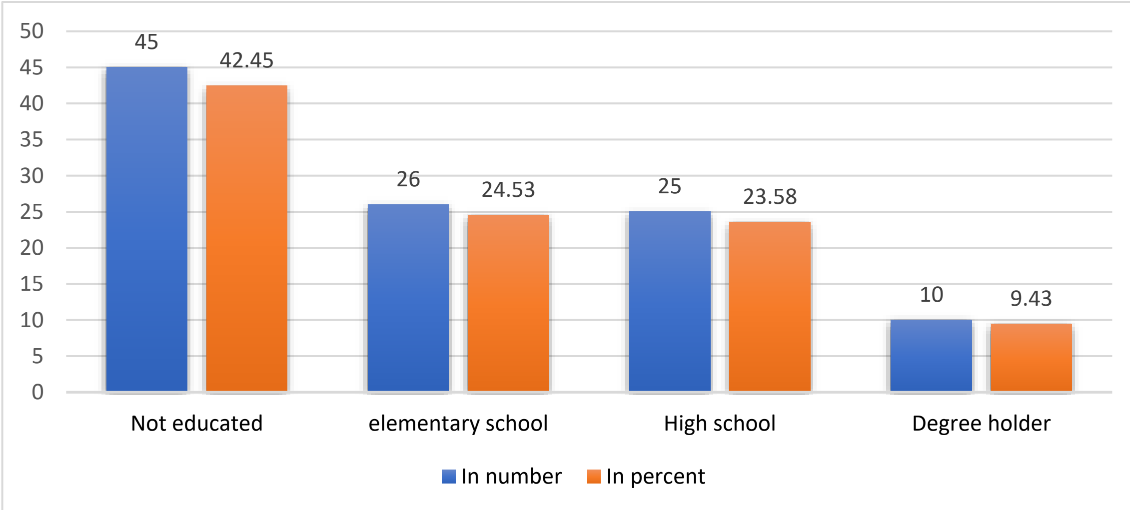

Figure 7 Level of education (field survey,2020)

4.1.3. Family size of the respondent

Concerning to the family size n=52(49.1%) of the residents were have 4-6 family size,26(24.5%) of the respondents were have between 7 to9 families, n=21(19.8%) had a family number of 1-3 and finally, n=7(6.6%) were above 1-3.

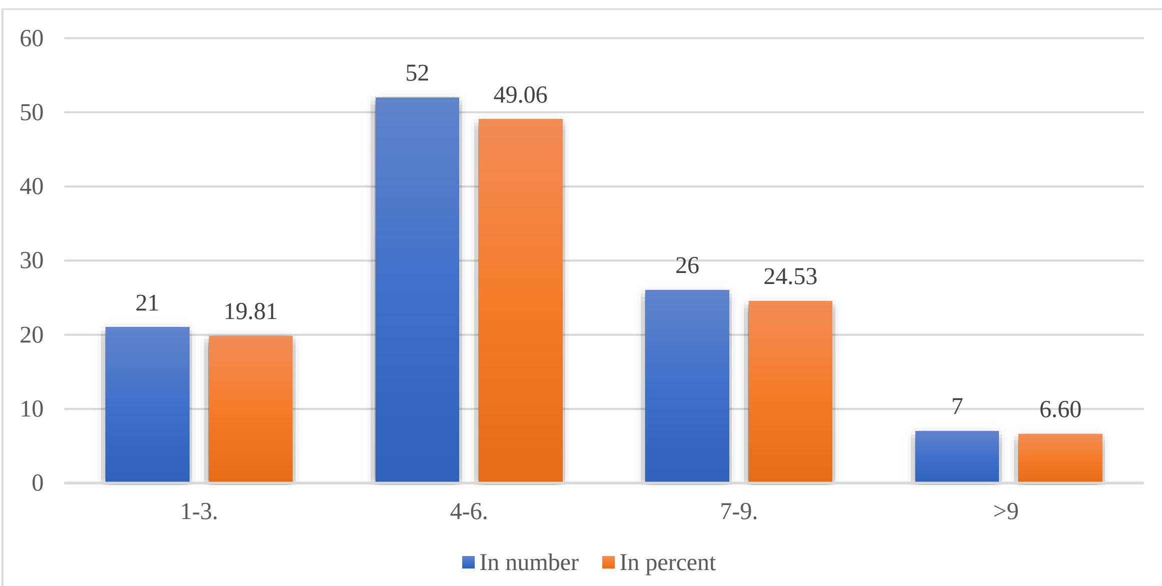

Figure 8 Family size of the respondent (field survey,2020)

4.1.4. Housing Type of respondent

Concerning the housing type of the residents the major houses n=59(55.7%) were categorized under row house, n=21(19.8%) of the houses were semi-detached and few houses n=26(24.5%)

were detached house these indicate that row houses are preferable by the respondents to have openings in all direction especially windows for cross ventilation.

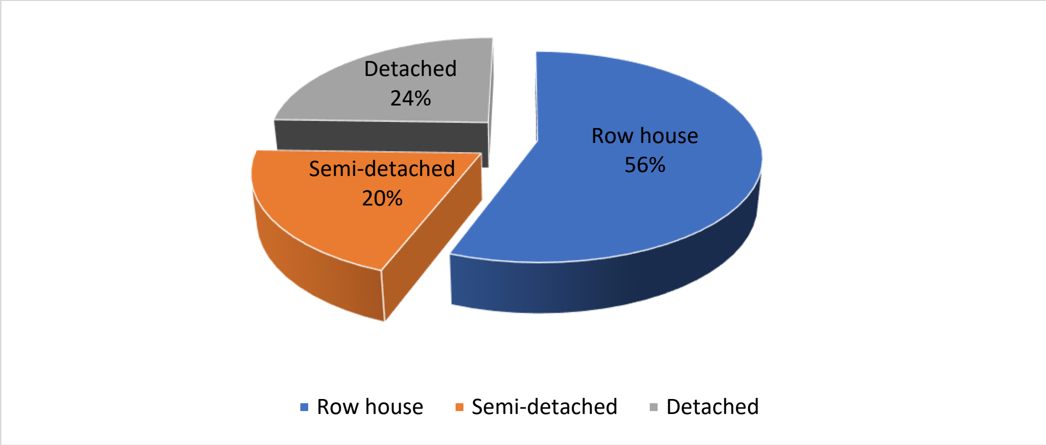

Figure 9 Housing Type of respondent (field survey,2020)

4.1.5. Experiences of respondents related to living in the traditional house

The survey result shows that from the respondents in living in the traditional house n= 47 (44.3%) have experience in living in a traditional house for more than ten (10) years, n= 41 (38.7%) were living in the house from 6-10 years and few number respondents n=18 (17%) were living in the traditional house for less than five 1-5 years.

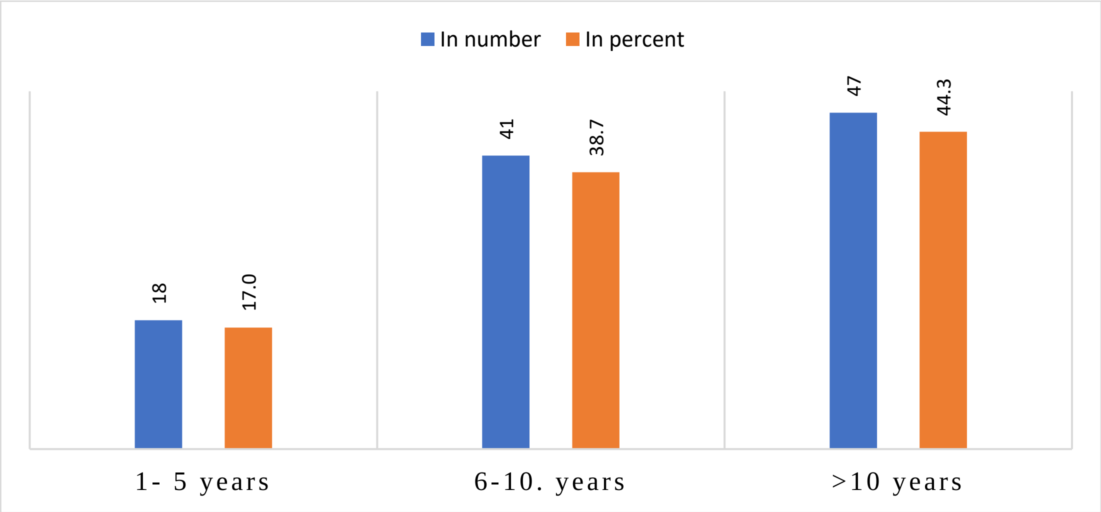

Figure 10 living in the traditional house (field survey,2020)

4.1.6. Experiences of respondents related to living in modern houses

According to information obtained from respondents living in modern house majority of the respondents, n=55 (51.9%) had experience in living in a modern house from 1-5 years, n= 40

(37.7%) were experienced in living 6-10 years in a modern house and few numbers of respondents n=11 (10.4) were living in a modern house more than 10 years. This indicates that they have enough experience to express the modern house character.

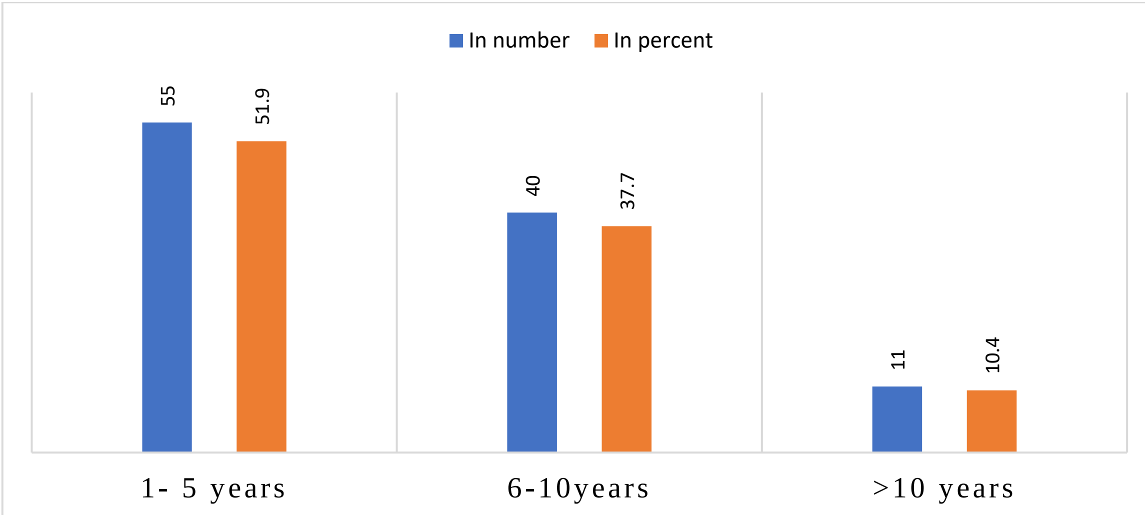

Figure 11 Experiences living in modern houses (field survey,2020)

4.2. Existing physical characteristics of the buildings

The house of all the respondent's living in modern houses have similar physical feature since the house is standard condominium having a concrete floor with marble and ceramic floor finishes, the wall is constructed from 20cm thick hollow concrete block and plastered and painted the ceiling have a height of 280 cm. The house is covered by CIS and they used flat roof type and there are 4 (four) to 6 (six) windows per one household room and have an average size of 120mm x 80cm,100cm x 90cm and 150 cm x 120 cm this type of window attached to the door and some of the windows are fixed.

According to information obtained from the field survey, the traditional house of the respondent has some common physical character but there is also some difference in the physical characteristics of the house. All traditional houses use mud as a flooring material because they use the kitchen in the internal space and concerning wall material, they use mud integrated with wood, basket as it is, and also grass and plastics for roof cover. They have no ceiling at all and the roof of the house is covered by grass, soil, and other materials. This all materials and construction method were used in order to regulate the thermal comfort of the indoor environment by using those locally available materials.

4.2.1. Housing Type

Afar is one of the lowest areas on the rift valley region, and this makes it to one of the hottest places in the world, the temperature gets up 40 degree Celsius. The afar people are nomad's pastoralists who travel from place to place in order to find grazing land for their cattle and drinking water for their family. The people use a unique type of architecture which enables them to move around their house from place to place without requiring cutting of trees. This architectural technique enables them to design adaptive types of housing in that harsh environment. Afar vernacular architecture is unique from every vernacular style that is found in Ethiopia in terms of its mobility and its types of shell structure which stand without an intermediate column, and this helps to create a vast open space inside it. And the construction process described in the figure below.

Figure 13 Movable house materials (field work,2020)

Figure 12 Movable house structure outline (field work,2020)

Figure 15 movable house roofing material (field work,2020)

Figure 14 final structure (field work,2020)

4.2.2. Characteristics of the local traditional architecture

According to study the emergences of dwellings at the town, old thick brick houses are tailed next to the temporary straw houses, so that old thick break houses are the second permanent living houses of the town. The local people who know well the climate condition of the area made the houses. These buildings were built before 40 to 50 years according to inhabitants of the area. They were able of being a living space, but not 100%. The buildings are cool enough during the day time but are hot at night. The inhabitants can't sleep in the building at night during the hot season. Instead, they will furnish their bed on the open field or under the tree.

Figure 16 Old thick brick houses with basket shelter extension (field work,2020)

Straw shades without walls were also among the spaces for sleeping. But now these straw shades are replaced by bamboo basket shelter which is made of basket wall and basket roof (See Fig 17.).During the study, the researcher has tried to investigate the main ecological characteristics of these housing types, the main character of these houses is their thick brick wall, this thick wall has a high thermal mass. Most of these old thick brick house has small windows on top or will have one normal window per room. Even for those rooms with normal window, in most cases, the window is not functional; just remains closed as shown below in the figure.

Figure 17 Old thick brick houses with small windows (field work,2020)

Almost all of this type of housing has two opposite doors (See Fig. 19.). This allows cross ventilation to exhale the hot air from the rooms through one door and inhale the cold air from the basket shelter through the other door when the internal space gets hot. Every block can contain two, three, or more units that are oriented in a row. Behind these row houses, there is a big backyard for straw shelter and trees. These straw houses, currently advanced to basket houses are used for sleeping, cooking, dining area, and gathering. The second door has a value to pass to this courtyard (See Fig. 21)

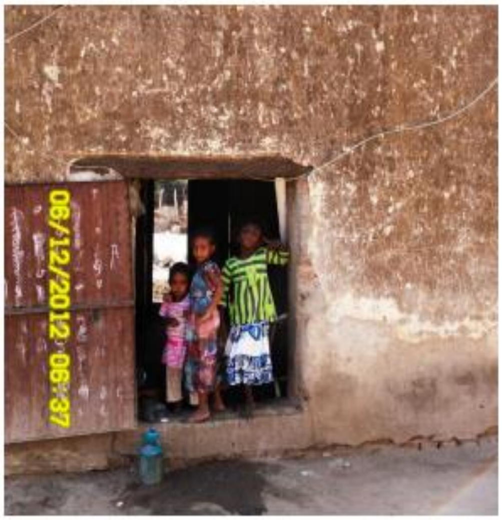

Figure 18 Old thick brick houses with opposite doors (field work,2020)

The other important characters of these houses are that they have high internal space elevation without a ceiling. This may allow the inhabitants to experience cooler air at the ground as the hot air floats to the higher roof (See Fig.22). Sand or soil floor is also among the features of these houses. Painting white the external wall is also among the characteristics observed on old thick brick houses (See Fig 20.)

Figure 19 White painted external wall (field work,2020)

Figure 20 Backyard basket shelters (field work,2020)

Figure 21 High internal space (field work,2020)

4.2.3. Analysis of old thatch roof hose

These thatch roof houses are the first permanent living house of Semera city, as the old thick brick houses are said the second permanent living house based on the probable emergence of dwellings as the researcher suggested. These houses have a similar quality to share with the thick brick houses, cool enough during the day but too hot at night. The wall of the houses is structured by wood and plastered by thick mud. The roof is also framed by wood and similarly covered with thick thatch. In most cases, the floor is made of sands but can also be of soil. Sands and soil floor promote the use of evaporative cooling. These houses have no ceilings and have high internal space elevation.

Figure 22 Thatch-village (field work 2020)

The slight connection of the roof to the wall is visible; this lessens the heat transfer from the roof to the wall during the day time. The roof of these houses is not a mere shelter for the internal space; it is also shade to the wall from the harshest sun (See Fig 24.). Small and opposite windows are very common, which are the only source of natural light when the door closed (See Fig 25). These opposite windows encourage cross ventilation.

Figure 24 Roof shaded wall (field work,2020)

Figure 23 Narrow windows (field work,2020)

These thatch roof houses also have their special approaches towards the climate of the area. At a compound level, the houses are characterized by their detachment from one another. It is not only the detachment, their orientation character; they have also arranged far apart and randomly without a pattern (See Fig 26.). So, they can possess a wide compound for air circulation.

Figure 25 Scattered house units (field work,2020)

Figure 26 Basket shelter attachment (field work,2020)

These houses are, in most cases, attached with basket shelter to their front. This shelter will feed cool air to space in (See Fig 27.).

4.2.4. Common characteristics of local traditional architecture

Thick brick wall houses and thatched-roof houses share many common characteristics in dealing with the hot climate of Semera Both are made of materials that have high thermal mass; brick, mud, and thatch (refer table 3). The flooring materials, sand or soil, are also common for both housing types which enhance the use of evaporative cooling. People spray water on the sand floor during the hot hours. When the sprayed water evaporates, it will cool the hot air inside.

Table 3 Thermal mass of some high thermal mass materials (Reilly & Kinnane, 2017)

<table>
<tr><td>No</td><td>Material</td><td>Thermal mass KJ/m^3. K</td><td rowspan="8">This chart compares the thermal mass properties of some common materials. The volume or quantity of these materials in a typical application is also important.

Compressed FC sheet flooring has a higher thermal mass value than brick or earth walls but is usually only present in 20mm thick layers which means it can’t store a lot of heat.

Brick walls are 110 to 230mm thick and earth walls are usually a minimum 300mm, giving them the capacity to store large amounts of heat.

The amount of useful thermal mass is calculated by multiplying this table by the total accessible volume of the material that is the volume of material that has its surface exposed to a heat source.

Floor coverings such as carpet, which insulate the mass, reduce the accessible volume.</td></tr>
<tr><td>1</td><td>Concrete</td><td>2060</td></tr>
<tr><td>2</td><td>HCB</td><td>1900</td></tr>
<tr><td>3</td><td>Earth block</td><td>1740</td></tr>
<tr><td>4</td><td>Rammed earth</td><td>1673</td></tr>
<tr><td>5</td><td>Brick</td><td>1360</td></tr>
<tr><td>6</td><td>Earth wall</td><td>1300</td></tr>
<tr><td></td><td>Straw</td><td>1100</td></tr>
</table>

Small & uplifted windows are also common features of these houses. These small & elevated windows are used mainly as a source of light and to eliminate-through the hot air from the ground. A very common strategy used by both the thick brick houses and the thatched roof houses is the use of two opposite openings per room. For the brick houses, it is usual to have two opposite doors, one main gate and the other is smaller (the second door) and is used to get from the room to the backyard. The second door will draw the cool air from the basket shelter or the trees and the first door will remove the hot air from the room, namely called cross ventilation. The small windows are also involved in removing hot air in most cases these shelters are oriented to the northeast of the main building. This is because the other sides are hotter than this side.

For the thatched roof houses there are two opposite and small windows fixed around the top of the wall. Even though these windows are not enough for cross ventilation they are so suitable to remove raised hot air from the room. High internal elevation without ceiling is also common in both housing types. This high internal elevation will help the hot air to rise from the bottom sphere of the room to the upper so that the peoples on the ground can entertain the cooler air. In most cases, the raised hot air will escape through the small windows.

The other very common and significant strategy that both housing types possess is the attachment of a big tree or straw shelter which is modified to bamboo basket shelter currently. This shelter will feed cooler air to the houses. The thick brick houses are attached to shelters by its second door and to trees at the main door (See Fig 27,). The thatched roof houses are attached to the shelters or trees to their front (See Fig 37,). In fact, the main purpose of these shelters is not to serve cool air, holding that task in their backs simultaneously they are multipurpose spaces. Activities like sleeping, cooking, dining, gathering…will take place there most of the time. These basket shelters are followed by wide enough compounds and trees to treat the hot air. Holding the above-mentioned common strategies these thick brick houses and thatch roof houses share one common quality, cool indoor space at day time and hot at night. Still, these old traditional houses cannot collaborate with the climate fully because peoples are sleeping out of the homes in the open shelter. Although the above mentioned old traditional houses did not match completely with the climate condition of the area, they are able of being a living space in collaboration with the basket shelters. In any event, the peoples are living well. They are more important than houses with proper walls and roofs.

4.2.5. Probable feature and alternative of dwelling at Semera town

During the study, the researcher tried to identify the type of houses and their overall feature including their age, history, and character flow. From their age and characteristics, the study able to detect the emergence of the housings over time. The probable emergence described as follows.

Table 4 Various features of the Traditional house (Own summary)

NO	Feature	Description	Remark
1	**Layout**		
a	Room shape	most of the buildings are rectangles, and circle and have an average area 30m^2 up to 50 m^2 and the rectangular shapes have semi partition and the circles have no shape all of the traditional houses have a maximum of two partition rooms	
b	opening orientation	The opening orientation was located in all directions of the building and they use the openings according to the season of the wind most	

		of the time the used too small and fixed windows used for light and ventilation. And woods are used to doors and the doors have small width and have high height.
c	opening size and materials	The size of the openings is to small and more than 7 in all direction mostly they are top widows and they are fixed
2	**Structure**	
a	Wall	Most of the buildings used old brick, basket for their external wall and they use some kinds of cloth for partition
b	Roof	basket, straw (grass) was highly used for roof construction due to good characteristics of a cooling indoor environment but some buildings use CIS roof. And the layer of the grass roof varies from season to season so to get the optimum temperature in the indoor and sometimes water was used to cool down the temperature and to lose the absorption of heat from the sunlight.
c	Celling	all most all traditional buildings have no celling
3	**Construction material**	
a	Wood	Used for structural elements such as column and also used for wall
b	Mud	Mainly used for wall and floor finish
e	Grass	Used for roof cover due to its high cooling indoor environment and also used for the wall like as a basket
f	CIS	Used for roof cover due to its high cooling indoor environment
4	**Utility and service**	
a	Electricity	Installed during the construction period.
b	Gas	No exist
c	Plumbing	not exist
d	Sewage	not exist
e	Light	Get naturally from sunlight through the top opening
f	Ventilation	Get through naturally by openings

4.3. Modern house construction

The main characteristics of the built Standard Condominiums concerning the climate conditions of the area have stated below. The condominiums are not functioning well simply, they stand almost vacant and the heat quality of the condominiums can be described as 'hot the whole day and the whole night'. The units are formed from plastered concrete hollow block (CHB) wall with wide glass window, reinforced concrete (RC) slab and ceiling (in most cases), and in most cases, there is a small balcony attached to the units and the balconies are too narrow to provide space for a bed. The wider balcony may furnish one bed for one person and also bed furnished on the corridor at BL typology Standard Condominium (Fig. 28). Also, balconies used as sleeping spaces (see Fig. 29).

Figure 28 Bed at balcony BL typology (field work,2020

Figure 27 Bed at corridor BL typology (field work,2020)

The orientation of the doors and the windows are only getting and openings without well studied ecological implications. The windows do not promote natural ventilation mostly the kitchen is located southwest with a wide glass window (see Fig30.). However, the windows are wide, the wider portion is the non-operable; the operable part is narrow so that the harshest sun will penetrate the wide fixed glass but very low wind or air circulation through the narrower operable window. This promotes the worse heat in the room.

Figure 29 Kitchen with small operable window BL typology (field work,2020)

Almost in all resident's bedroom without an operable window. Due to this and other reasons, residents use the bed as a store and the corridor and the balcony as a bedroom. Fig: 28, Fig: 29 and Fig: 31 are taken from residents' units at the BL typology. Especially the corridors have multi-purposes, Cooking, dining, coffee program, In the condominiums, every room has a mechanical ventilator which blesses the room to some extent, although these ventilators have no power to exchange the air from and to the units.

Figure 30 Bedroom as store (field work,2020)

Poor plumbing system location contributes to the hot air stay in the space, by preventing windows from being opened (see Fig. 33). The painting of the external wall also has enough effect to support the hot indoor space additionally the downpipes are bend down as shown in the figure below maybe by a high amount of temperature (see Fig. 32). These Standard Condominiums have a quality of being hot both at day time and night, unlike the old traditional houses.

Figure 32 Poor plumbing (field work,2020)

Figure 31 Bended down pipes (field work,2020)

The main reason for this quality is that the fixed glass window for the day heat; and the bounding CHB wall for the night heat. The fixed window encourages heat by preventing natural ventilation.

4.3.1. Probable feature of dwelling at Semera town

Table 5 Various features of the Modern house (Own summary)

NO	Feature	description	Remark
1	**Layout**		
a	Room shape	Almost all the condominium shape is rectangular and there are four different characters of dwellings such as studio, one bed, two bed, and three bed in all condominium building the number of three-bedroom and two-bedroom have highest in number but almost half they are not occupied	
b	opening size and material	there is a standard dimension of opening size for all classes for example main gate 120cm x 210cm, for bedrooms and kitchens 90cm x 210cm and for Toilet 70cm x 210cm these dimensions are nearly the same to Addis Abeba's condominium. All types of openings are constructed from glass and metal	
2	**Structure**		
a	Wall	The wall of the buildings constructed from 20cm plastered and painted HCB and also using 10cm HCB for some partitions like toilets and kitchens	
b	Roof	Almost all buildings use iron sheet metal to cover the roof	
c	column and beam	As usual, all the structural column and beams are constructed from RCC	
d	Celling	All rooms have a ceiling made from timber, gypsum and the height of the celling vary from room to room and have a maximum of 280cm height	
3	**Construction material**		
a	wood (timber)	used for roof trusses and internal doors	
b	Reinforced concrete	for a wall, column, beam, and plastering	
e	Ceramic, marble	for floor finish	
f	Red ash	for foundation backfill	
g	paint	for finishing	

4	Utility and service	
a	Electricity	partially installed but not for all
b	Light	all rooms have no chance to get natural light and the use of artificial light
c	Ventilation	using openings and use another mechanical ventilator

4.4. Cooling strategies for both types of dwellings

Both types of buildings have their method to cool down the temperature but they have their degree of cooling mostly traditional houses are starting the construction with the consideration of thermal comfort by using different traditional methods but the modern house (condominium) tries to cool the temperature after construction is finished. There is no consideration of the local temperature during the construction of the modern house (condominium) but the residents take their measures to cool down the temperature. The following table compares and contrasts the common features of old traditional houses with the standard condominiums in their response to the bioclimatic factors.

Table 6 Comparing old traditional houses with standard condominiums in strategies towards the climate (Own summary).

The common feature of the old traditional houses	**Features of the Condominiums on the strategy**	**Strategy**
High thermal mass wall, thick brick, and mud	High thermal mass wall, HCB, but mixed with wide glasses	Thermal mass
Sand or soil flooring	RC slab with a ceramic finish, spraying water is a mistake here	Evaporative cooling
Small and uplifted windows	Wide non-operable windows & small operable window	Stack effect
Opposite openings	Random opening	Cross ventilation
High internal 3.5 – 4.5 meter	2.80-meter internal height	Stack effect
Attachment with basket shelter or trees	No attachment at all	Cool outdoor space

The people of Semera want to be out of the room, to sleep outdoors, to bake and cook at traditional kitchens or out-door when it gets hot. But there is no place provided at the condominiums for these functions. The people of Semera have the habit of spraying water on the floor to cool the heat. This is not possible in the condominiums. They want to share a cooler compound filled by trees and basket shelters with other families and have gatherings every night but this is also impossible at the condominiums. Generally, the peoples of Semera do not want to be in a bounded space for a long time especially during the nighttime, which contradicts the standard condominiums built there. So, it can be said that the standard condominium does not match with the behavior of the peoples due to the climate of the town losing its bioclimatic context.

4.4.1. Method of cooling

As far as concerned the respondents answer in the modern house, n=86 (81.1%) of the respondents were using the electric fan for cooling the indoor environment, n =15(14.2%) used handheld fun the rest, n=5(4.7%) were used nothing due to financial problem. In case of the traditional house, n=79(74%) of the residents were use nothing for cooling the indoor environment, n=16(15.1%) were used handheld a fun and the rest, n=11(10.4%) of the respondents had an electric fan but they rarely because of electric availability in case of cooling system the old traditional houses was not mechanical cooling system rather the building by itself able to regulate the indoor environment.

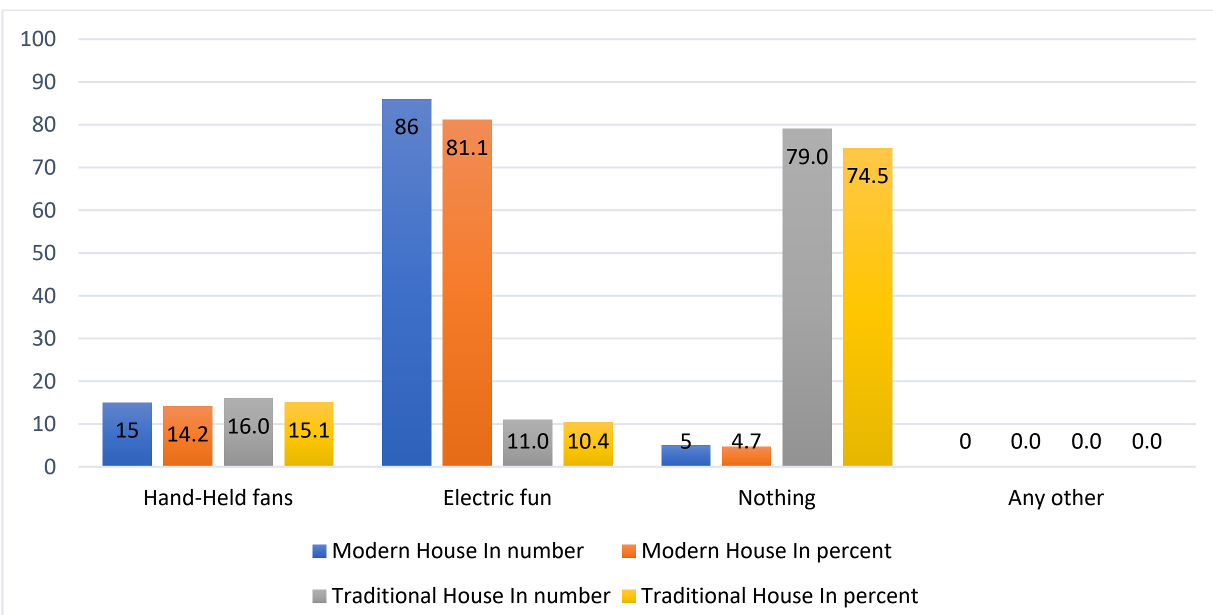

Figure 33 Method of cooling (field survey,2020)

4.5. Utilities in the on both types of House

4.5.1. Availability of electricity

Concerning the availability of electricity in the modern house, all respondents have responded as there is the availability of electric power but there is power fluctuation many times, according to the respondents they use another type of lighting during the power fluctuation. But in the case of the traditional house, the reverse is true, above half of the respondents, n=58 (55%) have not got access to electricity.

4.5.2. Level of natural light

The survey result data indicates that in the modern house n=42(39.6%) of the respondents answered as the level of natural light is good, n=41(38.7%) of the respondents replay that as the natural light is satisfactory and n=23(21.7%) of the respondents answered as weak.

Regarding the traditional house n= 71(67%) of respondents respond that the level of the natural light level was good, n=31(29.2%) of the answered as satisfactory and few n=4(3.8%) of the residents respond that it was weak. During the observation, able to understand that 4% of respondents are from the detached house type. From this, it is simple to understand that comparatively the level of daylight is good in the traditional house than the modern.

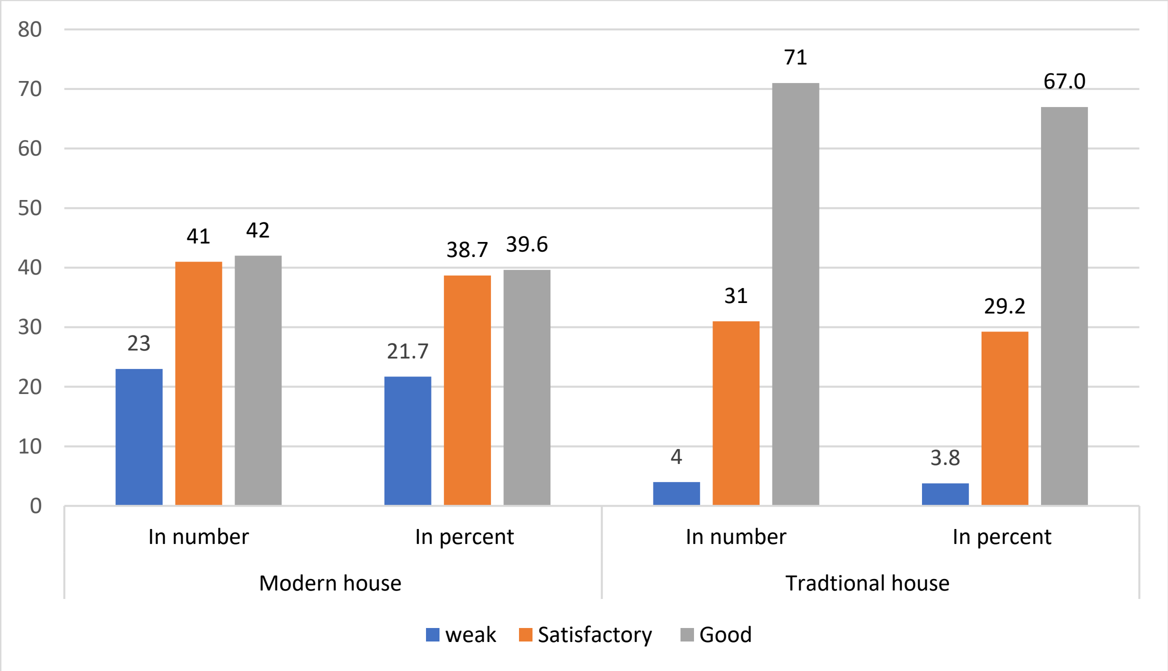

Figure 34 Level of natural light (field survey,2020)

4.5.3. Level of natural ventilation

Concerning natural ventilation, the majority of the respondents living in modern house n=35 (33%) were answered as it was weak, n= 42 (39.6%) answered as it was satisfactory and few numbers of respondents, n=29 (27.4%) were answered as it is good, this implies that the highest number of respondents were not satisfied with the modern house ventilation. For the case of the traditional house the majority of the respondents=65(62%) responded that the natural ventilation was good, n=31(29%) of respondents considered as it was satisfactory and few numbers of respondents, n=10 (9%) were answered as it was weak. As shown during observation the traditional house uses parallel openings for cross ventilation this enables the house to have good natural ventilation. Again, in the case of ventilation, the traditional house was preferable.

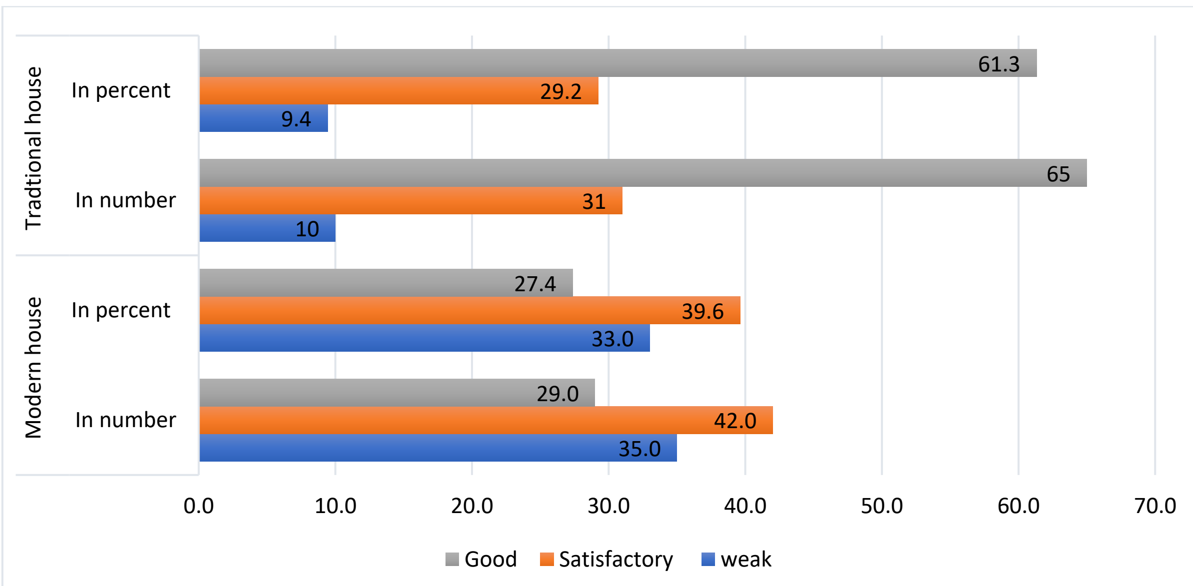

Figure 35 Level of natural ventilation (field survey,2020)

4.6. Environmental Comfort Level both House

According to ASHRAE seven points of scales thermal sensation scale, thermal preference scale, comfort scale, and satisfaction index for both houses were summarized as follows.

4.6.1. Thermal sensational scale for both types of houses

Concerning to modern house thermal sensational scale, the respondent's replays indicate that n=67(63.21%) were answered warm, an equal number of respondents n= 15(14.15%) responded as both slightly warm and hot=6 (5.66%)responds as the thermal sensational scale is neutral and n=2(2.83%) were response as slightly cool. According to ASHRAE sensational scale, +1 to -1 were indicates that comfort zone accordingly regarding to thermal sensational scale, n=82(77.36%) respondents were not on the comfort zone and, n= 24(22.64%) were responded that as they are on the comfort zone.

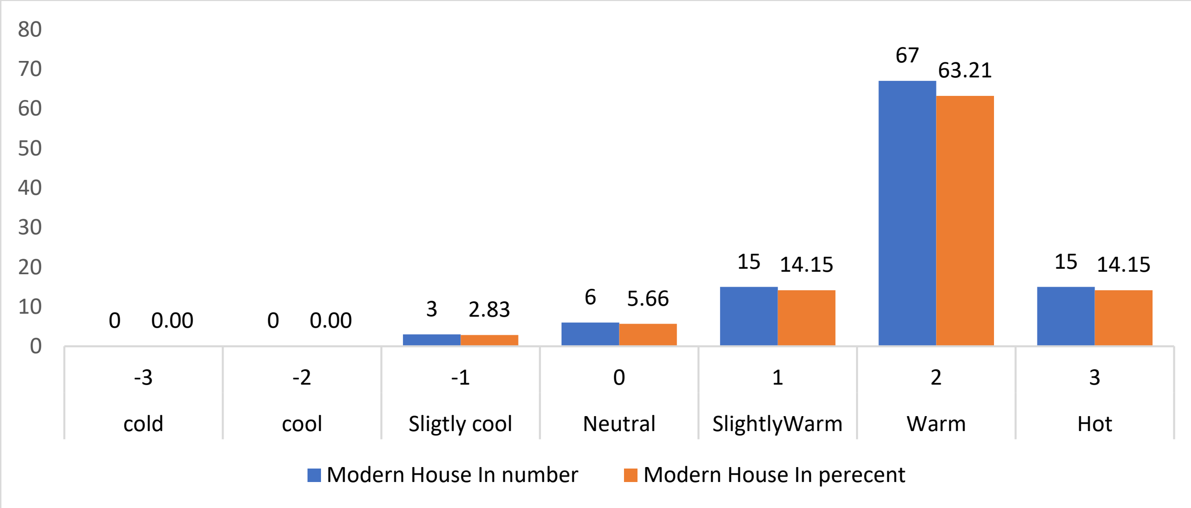

Figure 36 Thermal sensational scale for modern house (field survey,2020)

Regarding traditional house thermal sensational scale, the data from the respondents indicate that=46(43.40%) were answered slightly warm, n=35(33.02%)responds as the thermal sensational scale is neutral=12(11.32%) responded as slightly cool and n=9(8.49%)and n=4(3.77) respondent replies that warm and hot respectively. According to the standard of ASHRAE, n=93(87.73%) were under the comfort zone because it locates in +1, 0, -1, and the rest n=13(12.66%) were located out of comfort zone. Due to the gathered data the traditional house is best in thermal sensation unlikely the modern house.

According to the observation the residents of the modern house used the rooms only for stored materials and they cook, sleep and doing activities out sides of the room due to the discomfort of the indoor environment in addition the residents living in the upper floors were faced a lot of challenges due to impossible to build straw houses rather they doing activities including sleeping on the corridor and the balconies.

In case of the recorded data even though it shows different reading in different days and time to the average the temperature and the humidity of the indoor environment is out of the thermal comfort zone in all three months, comparatively from the three months the first month (February) is better even it was not in the comfort zone in the other months in some spots the modern house indoor temperature is higher than the external environment.

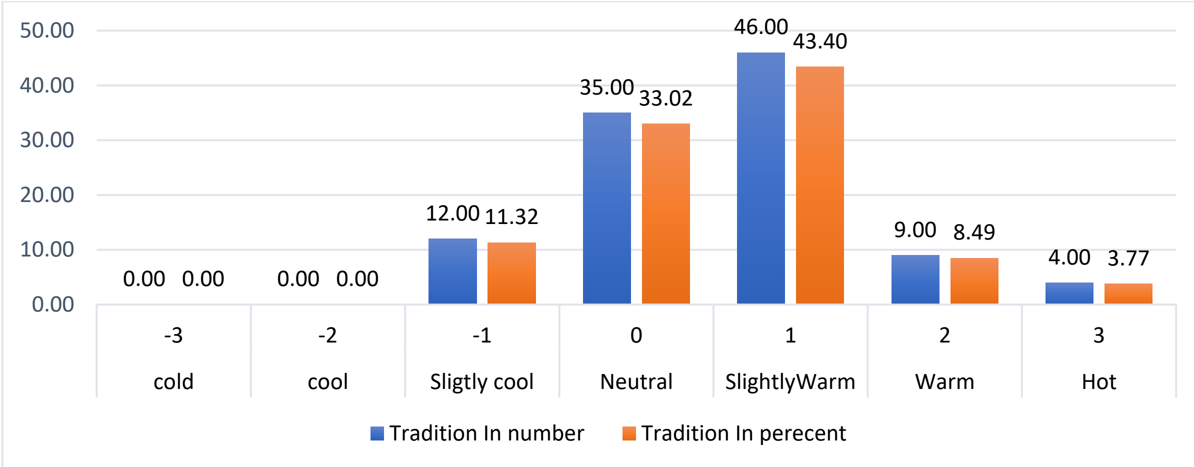

Figure 37Thermal sensational scale for traditional house (field survey,2020)

The information obtained from the thermal sensational scale has supported by the information obtained from key informant interviews. 100% were said that condominium is completely inappropriate for Semera. They condemned it because it is a multistory building so that it is not comfortable to build a basket. And it is too hot both at day time and at night. 82%of the traditional house's dwellers Sayed as they don't want to live in a condominium, they say 'it looks modern but we don't think it is comfortable'. They assured as the condominium denies the behavior of the people. 91.6%of the condominium inhabitants do not want to stay there. And some respondents in need of selling their unit and to build other traditional G+0 houses. And from the total 67%of, the inhabitants' sleep in a basket shelter made temporarily on the ground; and 33%sleeps at the balconies or at the corridor. 58%of them spends most of their time at the basket shelters on the ground; 26%spends most of their time at balconies and corridors where 16%prefers to spend their time at cafeterias away their home.

Figure 38 Beds furnished for outdoor sleep (field work,2020)

4.6.2. Thermal Preference scale for both types of houses

Concerning to preference scale, according to the collected data on modern houses shows that the distribution of preference scale, n= 62(58.08%) were out of the comfort zone of the preference scale and n=44(41.51%) were between the standard of ASHRAE.

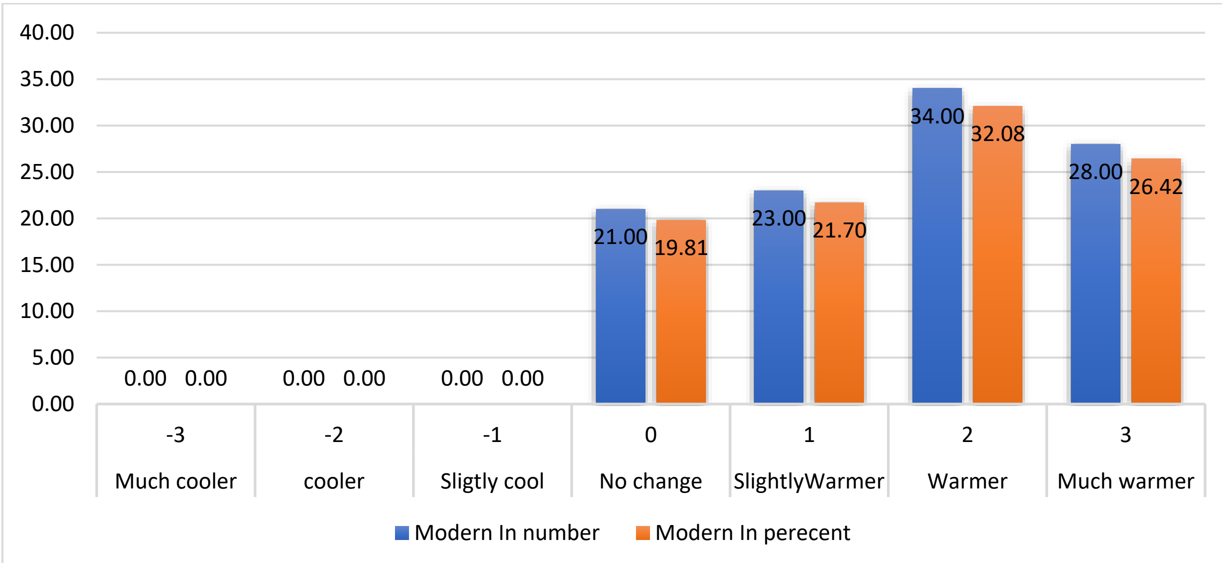

Figure 39 Thermal Preference scale for modern house (field survey,2020)

Concerning the traditional house of preference scale, the summation of slightly cooler, no change, and slightly warmer which is found on the comfort scale, n=88 (83.02) were under the preference comfort zone and, n=18(16.38%) were out of the comfort zone. According to the preference scale again the traditional house is preferable than the modern house.

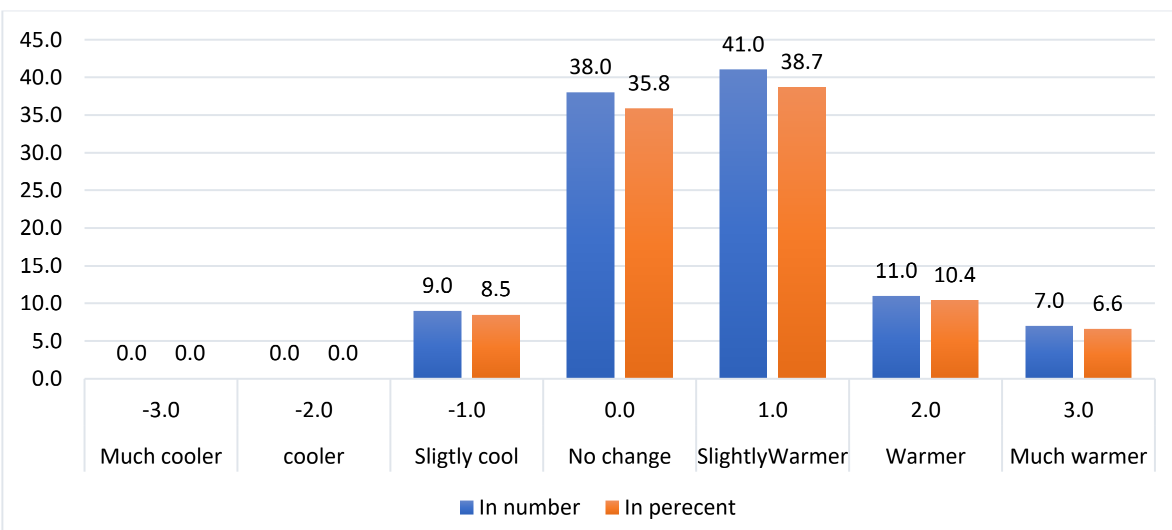

Figure 40 Thermal Preference scale for traditional house (field survey,2020)

4.6.3. Thermal Satisfaction scale for both types of houses

According to the collected data on modern house concerning to satisfaction scale indicates that n=54(50.94%) were the summation of discomfort zone such as very dissatisfied 19(17.92), dissatisfied n=35(33.02%), and concerning to comfort zone for the modern house, n=52(49.05%) were the summation of slightly dissatisfied 22(20.75), neutral 11(10.38%), slightly satisfied 9(8.49). Accordingly, the residents of the modern house were not satisfied as the data indicates that the highest respondents were answered dissatisfied and the number discomfort zone is greater than the comfort zone.

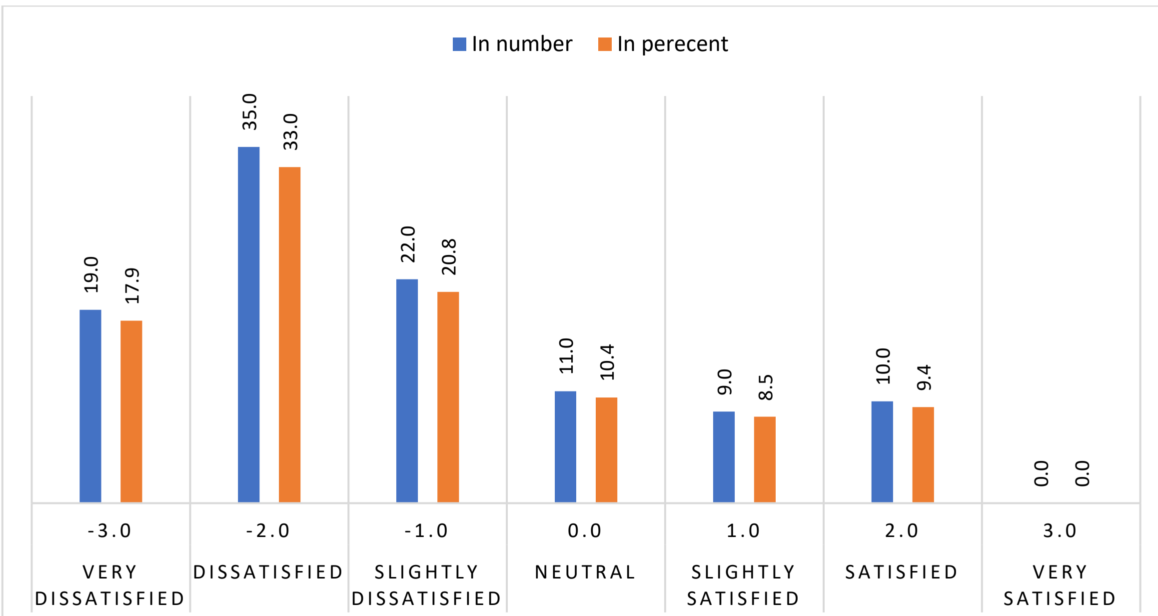

Figure 41 Thermal Satisfaction scale for modern house (field survey,2020)

Concerning to the traditional house satisfaction scale, few respondents n=22(20.75%) responded that as the traditional house satisfaction was not good and dissatisfied and above the half respondents, n=84(79.24%) the summation of slightly dissatisfied 23(21.70%), neutral 18(16.98), slightly satisfied 30(28.30%), satisfied 9(8.94) and very satisfied 4(3.77%) were under the comfort zone. Having this data, it is easy to generalize the satisfaction scale in a traditional house is good and standard comfort zone which is stated by ASHRAE thermal sensational scale indicates that the traditional house residents were satisfied with the indoor environment thermal comfort. Comparatively the old traditional house was comfortable than the modern house due to the satisfaction scale also. It is obvious to understand from the interview the residents were not satisfied with the modern house.

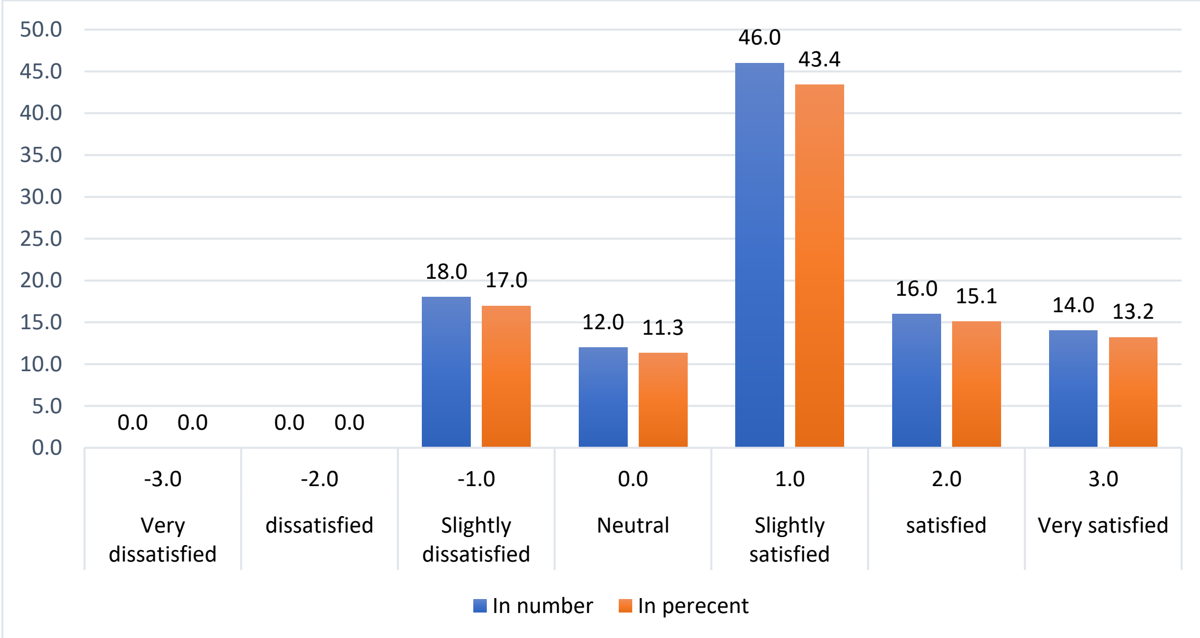

Figure 42 Thermal Satisfaction scale for traditional house (field survey,2020)

4.7. Comparative climatic comfort for both houses

Concerning to comfort for both types of houses almost all respondents, n= 98(93%) were responded traditional house is more comfortable than the modern house, n=6(5.7%) were responded that the comfort level of the houses are similar and few numbered n= 2(1.9%) were answered as the modern house is comfortable than the traditional houses. As it is understood form the response of the interviewee some residents who are lives in condominium house are becomes selling their houses to construct a traditional house.

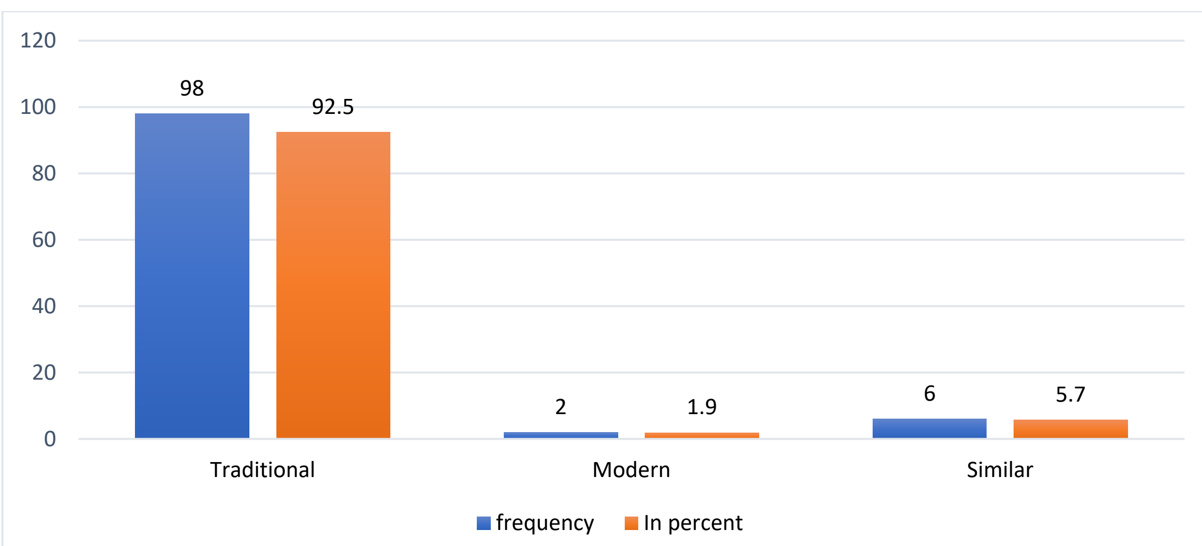

Figure 43 Comparative climatic comfort (field survey,2020)

4.7.1. The rationale behind for better comfort of a traditional houses

The data collected from the relevant respondents confirmed that the reason for the comfort of a traditional house, n=51(52%) responded as a construction material is the basic reason for the comfort, n=27(27.6%) responded as the size of the openings and type is the basic factor for the comfort and n=20(20.4%) were responded the construction techniques are the basic factor.

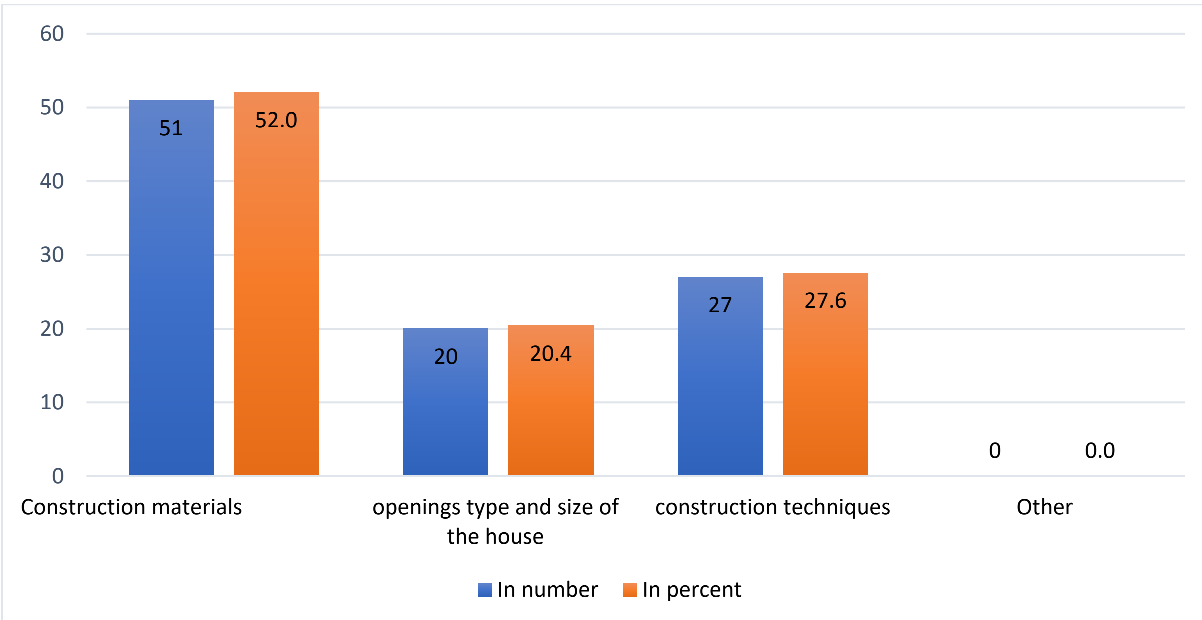

Figure 44 The reason for better thermal comfort (field survey,2020)

4.8. The analyses of thermal environments in both traditional and standards houses

During the survey, two environmental factors (variables) affecting thermal comfort have been collected from one traditional house and one modern house and the outside of the building during several days and times in three consecutive months at a certain assigned spot by using two digitals inferred thermometer and two hygrometers. The variables were air temperature and humidity.

A. Humidity and temperature data analysis in month one (February)

Figure A1 and A2 indicates that the temperature and humidity recordings of the traditional, modern houses and the external or outdoor environment as a comparison during February 2020 with the interval of three hours starting from 7:00 am – 6:00 pm

Figure A1 indicates that the temperature difference of the old traditional house, the modern house as well as the external environment. Accordingly, in this month a maximum temperature 36^0C and a minimum of 18^0C were recorded, from this, the highest number of temperatures was recorded from the external environment and the list number is from the traditional house. Concerning the comfort level according to ASHRAE standard, from 21^0C - 27^0C is a comfort zone (“Addendum a to Standard 55-2013,” n.d.). According to the standard, the recorded data indicates that the modern house was being in comfort zone only three weeks in a month such as Feb. 13,17,21,2020, and the rest moths were out of the standard comfort zone. Concerning the traditional house, a maximum 29.5^0C and minimum 18^0 C were recorded and in case of thermal comfort rather than the three months 1^{st} – 3^{rd} (Feb.01,05,09), the rest was on the comfort zone. The uncomfortable states of the modern house, which was caused by many reasons; the adapting of the new design styles which are incompatible with the Semra city environment, besides depending completely on the construction materials, which many studies proved that they are inappropriate for hot arid zones. Generally, the traditional house is preferable.

Concerning to the thermal sensational scale of the residents which is discussed above indicates that the residents are more sensational in the traditional house rather than the condominium (modern house). Generally, this indicates that the result which is obtained from the instrument is supported by the ASHRAE sensational scale.

Figure A2 indicates that the differential in indoor and outdoor humidity data for both types of houses. Concerning the modern house rather than Feb.02,2020, the rest were out of the range of thermal comfort (30RH – 60 RH) which is stated by ASHRAE, whereas in the case of the traditional houses the reading indicates that, all the recorded data quite close to the range of thermal comfort zone. The uncomfortable states of the modern house, which was caused by the method of construction, the size of openings, and orientation of the buildings was incompatible to the climatic condition of Semera city.

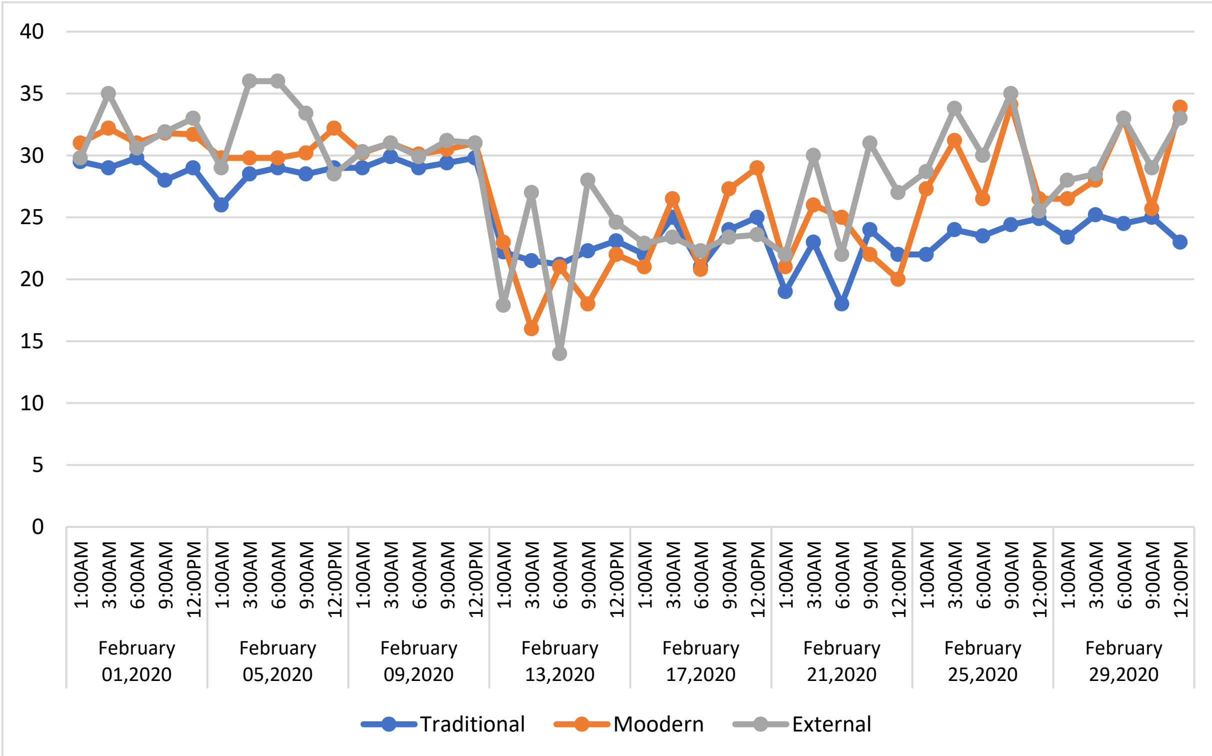

Figure 45 A1 Temperature data in February 2020 (field survey,2020)

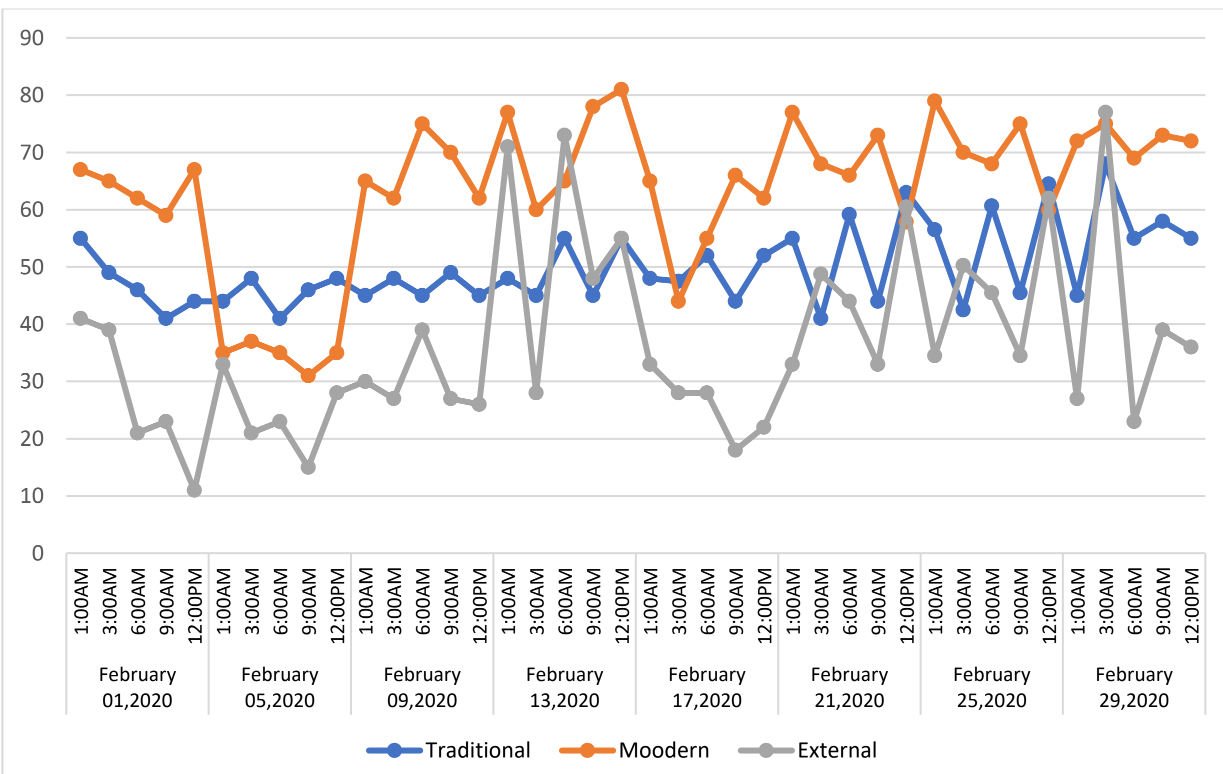

Figure 46 A2 Humidity data on February 2020 (field survey,2020)

B. Humidity and temperature data analysis in month two (March)

Figure B1 and B2 Represent the range of internal and external temperature and humidity which was recorded in the second month of the study period (March).

Figure B1 shows the temperature difference of the old traditional house, the modern house as well as the external environment. Accordingly, the maximum temperature recorded in the month was 38.5^0C by the external environment and the lowest temperature was recorded in traditional house 25.5^0C. Relative to the 1st month the second month has a high temperature. In the case of the modern house as shown below in figure all the recorded temperature was above 27^0C this indicates that the modern house is above the comfort zone throughout the month. Concerning the traditional house there some points which show in the thermal comfort zone but to the average, the traditional house was also out of the comfort zone. Relative to the modern house the traditional house is preferable because the recorded temperature in the traditional house was close to the comfort zone and the reding consistency is better than the modern house. The uncomfortable states of both types of residents were due to high temperature of the environment but for the uncomfortable state of the modern house, which was caused by the design by itself have a problem it was not designed due to the consideration of the climatic condition of the region

Figure B1 indicates that the Humidity difference of old traditional houses, the modern house, and the external environment. As shown below in the figure the recorded humidity indicates that to the average almost both buildings are out of comfort zone especially in the modern house and the external environment the range was very high and it has no regular consistency. uncomfortable states of the house were caused by poor design solutions. The moisture content of the air becomes dry when the temperature becomes higher. This result is also examined by thermal sensational scale of the residents and the result is the similar to the recording data indicates.

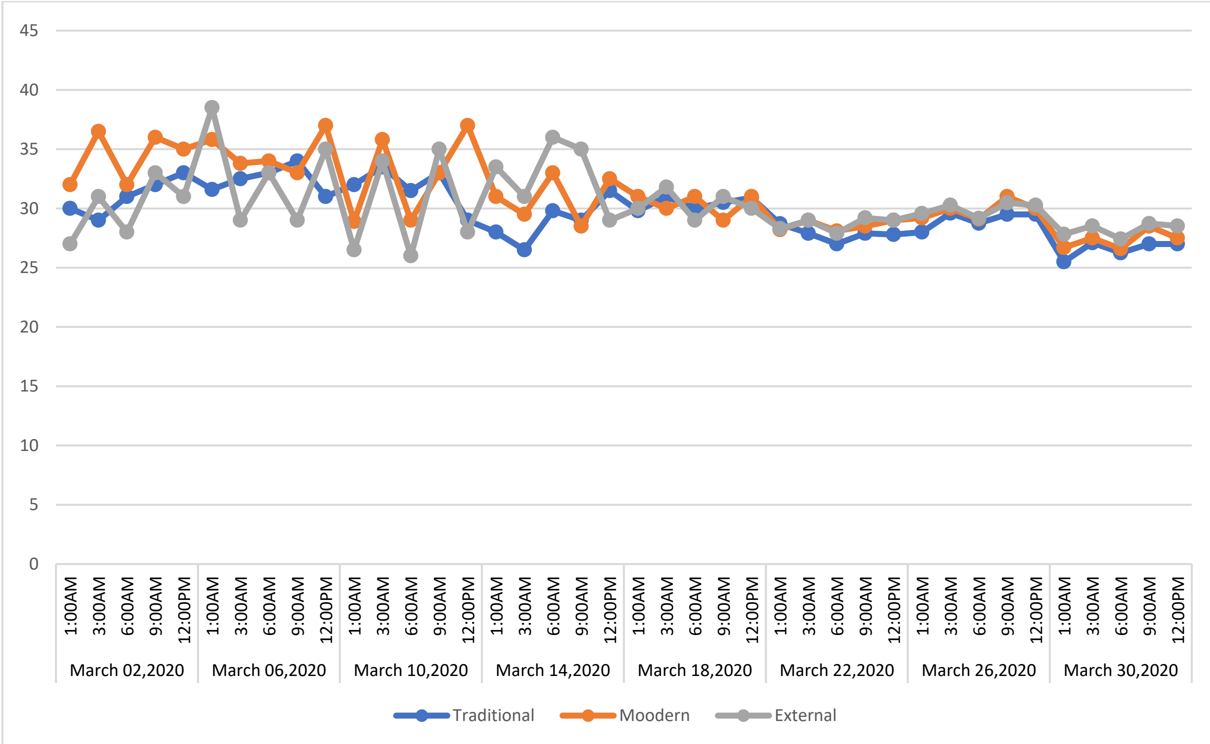

Figure 47 B2 Temperature data on March 2020 (field survey,2020)

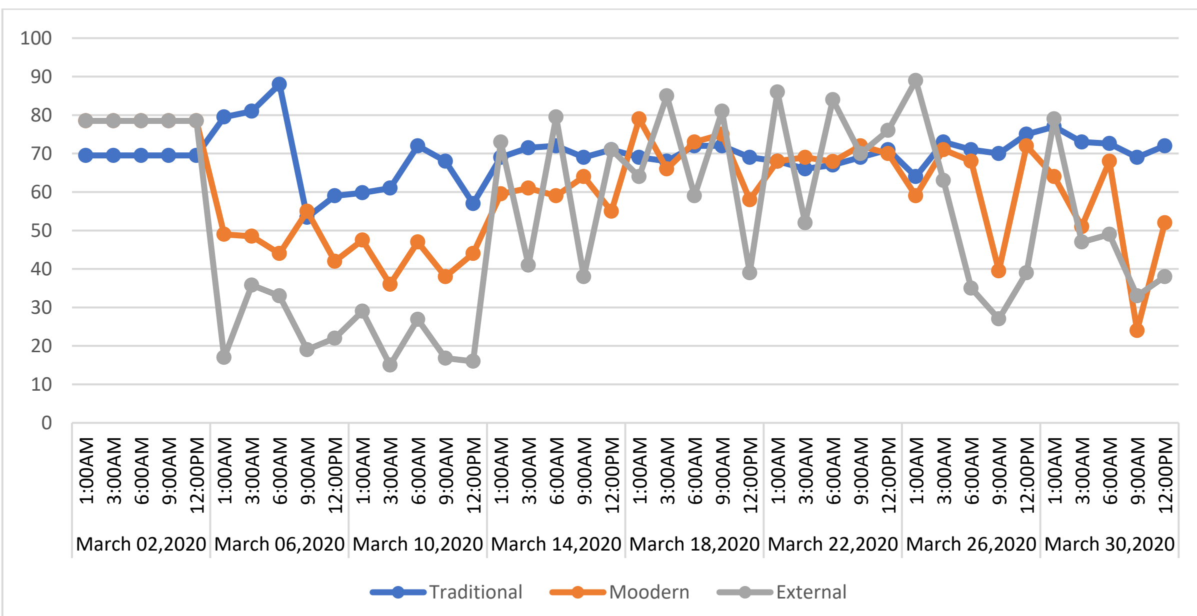

Figure 48 B2 Humidity data on March 2020 (field survey,2020)

C. Humidity and temperature data analysis in month Three (April)

Figure C1 and C2 Represent the range of internal and external temperature and humidity which was recorded in the second month of the study period (April).

Figure C1 shows that the temperature difference of the old traditional house, the modern house as well as the external environment. According to the collected data on month three of the study period, the highest temperature was recorded by the external environment which is 41^{0}C and minimum temperature recorded by the 6traditional house 24^{0}C. According to the collected temperature, the modern house temperature indicates that between 28^{0}C and 33^{0}C and this shows that the modern house is above the comfort zone but it was close to the comfort zone. Concerning the traditional house, the collected data indicates that the house was in a thermal comfort zone throughout the months. Constriction materials, building technique, cooling system, and building orientation enabled the room comfortable.

Figure C1 represents the Humidity difference of old traditional houses, the modern house, and the external environment. The figure below indicates that unlike the external environment both building types were under thermal comfort zone.

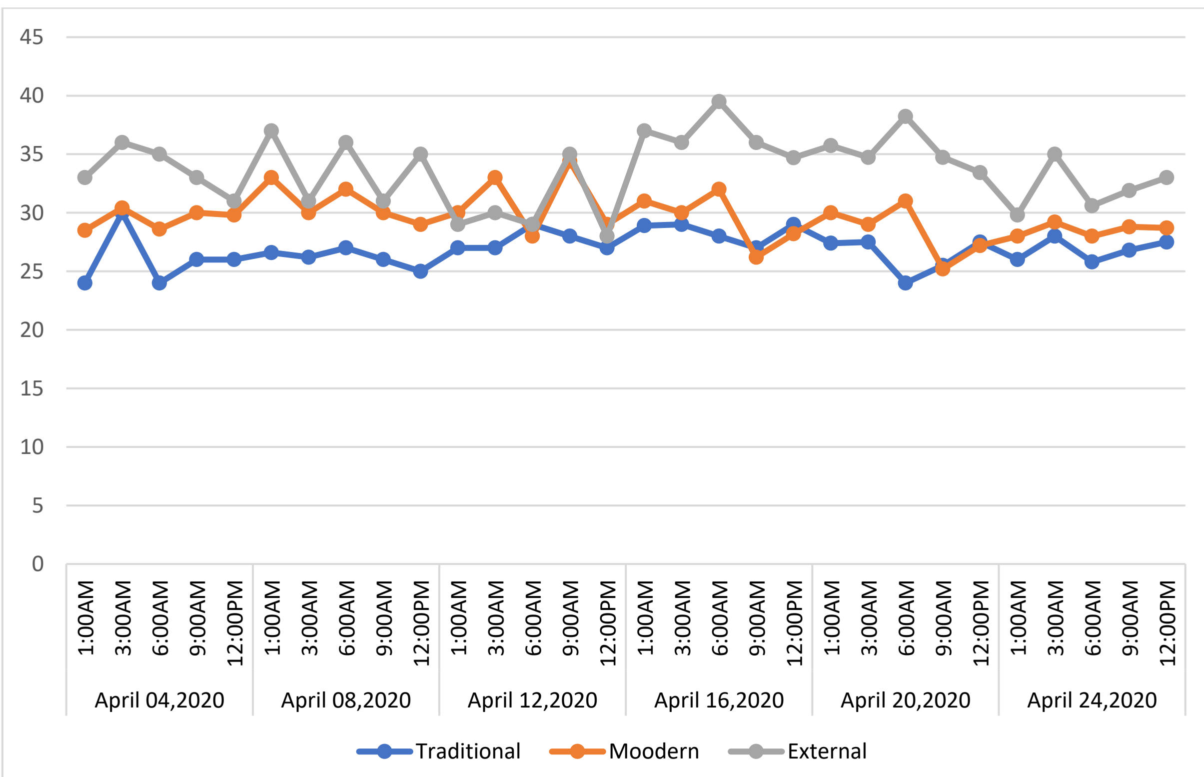

Figure 49 C2 Temperature data on April 2020 (field survey,2020)

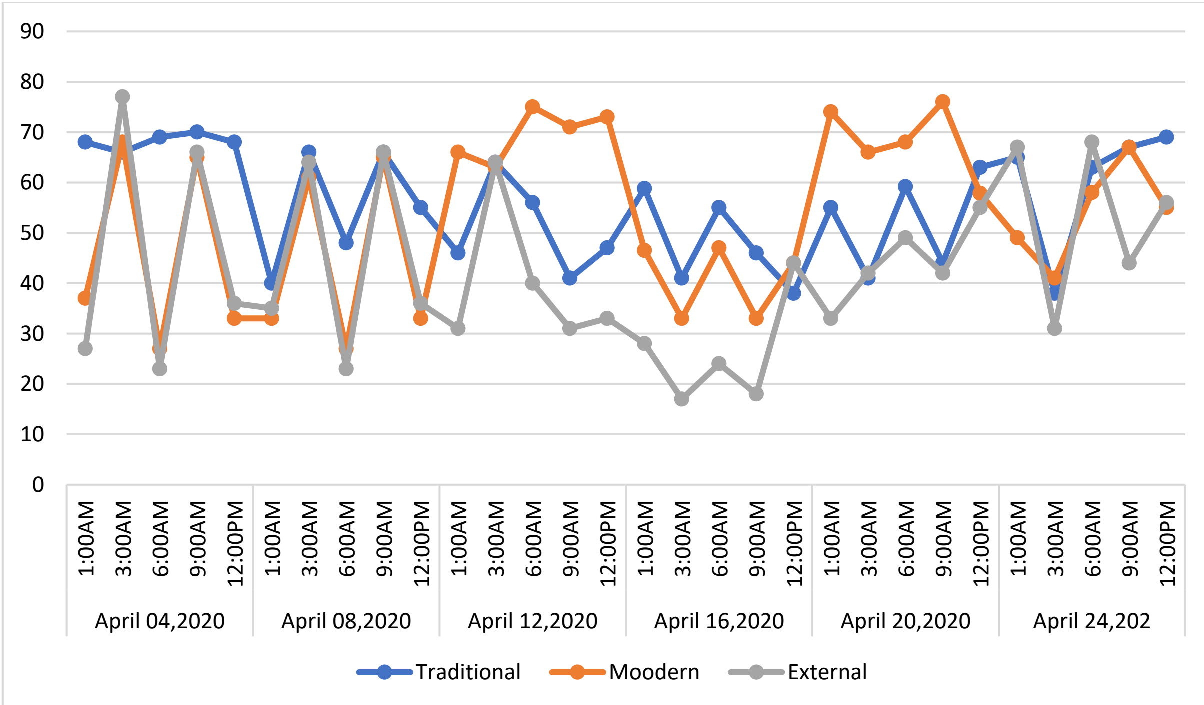

Figure 50 C 2 Humidity data in April 2020 (field survey,2020)

4.8.1. Comparative analysis on three month recorded humidity and temperature

According to the three consecutive moths recorded data there was a difference reading of temperature in all months. And concerning to the first month (February) relatively the list number of temperatures was recorded like maximum 36^{0}C and minimum 19^{0}C the maximum temperature was recorded from the external environment and the minimum was from the traditional house. In this month the traditional house was in comfort zone. In case of modern house partially it was on comfort zone but relative two the other months this month was preferable. The other two months are having a maximum temperature 32^{0}C for the modern house and minimum 22^{0}C traditional house in March and in April 37^{0}C Maximum from external environment and 24^{0}C minimum for traditional House. In total the traditional house was relatively best in all there months in the second month (March) in some spot the modern hose of temperature is above the external environment.

Regarding to the recorded humidity data comparatively the traditional house was better than the modern house in all three months. In the first month maximum 71RH and minimum 11RH were recorded and in the second month 85RH and 15RH maximum and minimum respectively and for the third month 77RH maximum and 17RH minimum were recorded. Regarding to the humidity data both the maximum and minimum data were recorded from the external environment.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATIONS

In this study a comparative analysis on bio-climatic thermal comfort of condominium (modern house) which is constructed by the government and the traditional (vernacular) houses which is constructed by the indigenous Semera peoples was carried out. The study was conducted using both subjective and objective evaluation method such as informal interview, structured questionnaires including ASHRAE 7-points of sensational scale and the questionnaires distributed to a representative sample who have experience living on both types of houses and objectively two important indoor thermal comfort factors such as Temperature and Humidity data were recorded for three consecutive months by using digital infrared Thermometers and Hygrometers. The key findings were summarized as follows.

5.1. Traditional House

Concerning to traditional house the thermal comfort of the indoor environment is suitable and the residents have a good sensational scale, their preference also good for their dwellings and they have a good satisfaction on the houses because of the indoor thermal comfort. Even if they used nothing mechanical cooling and ventilation system, they regulate the indoor environment using traditional method of cooling system and also, they used locally available material and eco-friendly building material this enables to protect depletion of natural resources.

5.1.2. Modern house

The study indicates that traditional houses residents had immigrated from their dwellings and adopted the concrete houses mainly for reasons of convoying with the modern era, obtaining better sanitary and electricity utilities and the lack of privacy. This immigration has exposed to negative results on the thermal comfort of the indoor environment. The residents have faced a lot of challenges even they spent their more time in outdoor such as the balconies and corroders the used the internal space for store of their goods .Concerning to thermal sensation, preference and comfort the residents were in a huge challenges and some residents also wants to return back the traditional house.

5.1.3. Thermal comfort

The results of the temperature & humidity data showed that the traditional house is much better than the modern house. Even if, living in modern house in the absence of such artificial air-conditioning is very difficult., recording data were taken inside the houses of both styles for comparison and to know the extent of reliability of the traditional houses in providing the thermal comfort. The results showed that the Traditional houses are the best in favor of the thermal comfort inside the house. The reasons were previously discussed in Chapter 4 of this study.

5.2. Recommendations

The following Are recommendations for improving indoor thermal comfort for residents.

A) The study is not intended to recommended that to return back to the traditional house rather to recommend so as to adapt some important benefits from the traditional house such as some important skills, method of construction and strategies. The preservation of the traditional buildings and renovating them by the same local materials besides improving it workability and performance, which will serve and rich the country culture.

B) Refining the properties of the local construction materials, and facilitate its productivity, marking and transferring; to provide an appropriate construction material to the local environment,

C) The bio-climatic condition of the environment is acritical element for designing a building there for it is important to investigate after designing.

5.3. Strategies for achieving thermal comfort

Strategies refers to methods or ways that we use to improve the indoor thermal comfort environment during designing and constructing the buildings. there are different methods and strategies are used for the optimal thermal comfort environment such as(Manzano-agugliaro et al., 2015).

A. Passive Design

'Passive design' is design that works with the environment to exclude unwanted heat or cold and take advantage of sun and breezes, therefore avoiding or minimizing the need for mechanical heating or cooling. The use of passive design principles in the tropics results in a building that is comfortable, energy efficient and results in substantial savings in running costs of both cooling and lighting. The main principles of passive design for buildings in the tropics are summarized below.

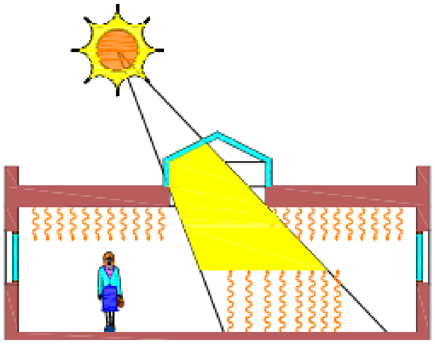

Figure 51 Roof openings for passive solar

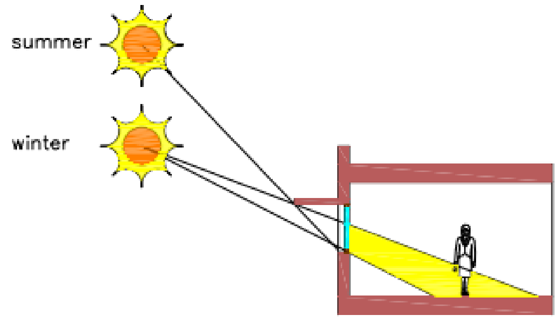

Figure 52 Passive solar heating solution

I. Avoid heat gain:

- Orient the building to reduce exposure to midday sun, particularly summer sun.
- Use materials with low thermal mass (as a general rule).
- Shade walls and windows, particularly any walls with high thermal mass.
- Use glazing on windows that cannot be effectively shaded.
- Use insulation, light colors and heat reflective surfaces.

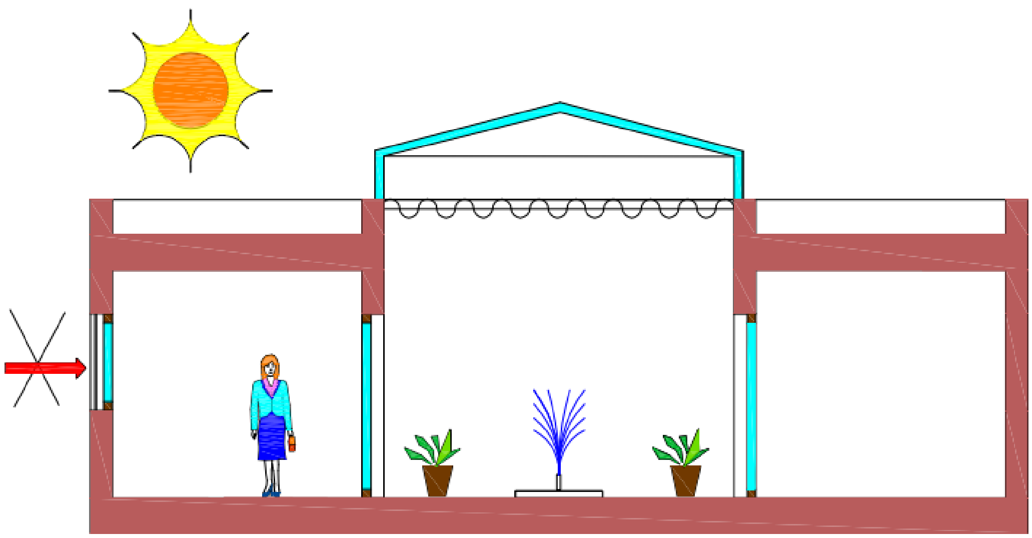

Figure 53 Avoids heat gains in the daytime

II. Encourage natural ventilation

- Orient the building and windows towards prevailing easterly winds.
- Include operable windows and ceiling vents that enable the building to naturally ventilate.

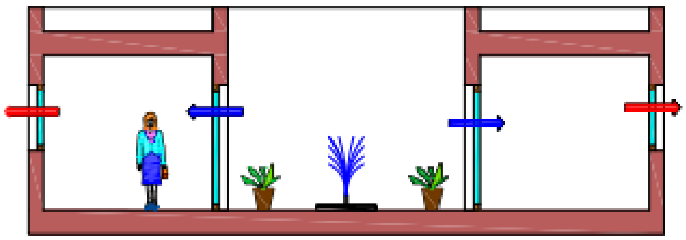

Figure 54 Natural ventilation cooling solution.

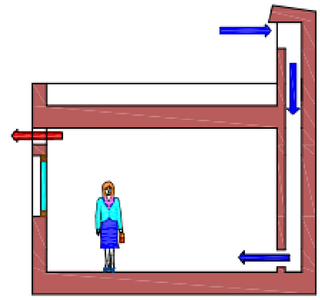

Figure 55 Wind tower

III. Make use of natural light

- Install shaded windows.
- Install shaded skylights, light tubes and other natural lighting devices.

IV. Create cool outdoor areas

- Use verandahs and deep balconies to shade and cool incoming air.
- Use planting and trees to reduce ground temperature and minimize reflected heat.

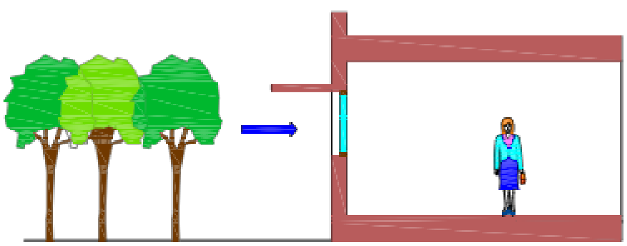

Figure 56 Exterior vegetation for cooling

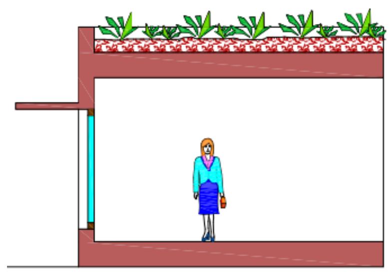

Figure 57 roof vegetation for cooling

The elements to consider for implementing these principles are orientation, thermal mass, insulation, ventilation and lighting. These are outlined below in more detail.

A. Orientation: Orientation concerns the position of the building on the site as well as the arrangement of the rooms within it. In the tropics, a building should be oriented so that the majority of walls and windows can easily be shaded from direct sun, while allowing maximum airflow and input of natural light.

B. Passive Ventilation: Designing a building in a way that maximizes natural ventilation will greatly reduce the need for energy intensive air conditioning. Air movement over the body, even if the air is not much cooler, creates a feeling of cool due to the evaporation of moisture from the skin.

C. Landscaping for a cool building: The hard surfaces of streets, driveways, parking areas and paving around buildings, absorb heat and then re-radiate it, creating a hotter microclimate. Reducing the extent of paving and other hard surfaces that reflect and or store heat and replacing these with vegetation will result in a cooler building and more enjoyable outdoor areas. Planting areas around the building creates a cooler environment due to a plant's ability to transpire, or lose moisture, which cools the air.

D. Thermal mass: Thermal mass refers to the ability of building materials to absorb, store and release heat. In tropical climates, the use of lightweight construction materials with low thermal mass is preferable, particularly on walls that are exposed to the sun. This is because lightweight construction materials such as timber, respond quickly to cooling breezes allowing the building to cool faster. These materials still require insulation to prevent direct heat transfer and to improve the efficiency of mechanical cooling if used. High thermal mass materials work best in temperate climates where there is a significant change in temperature between night and day. During summer, the heat stored in thermal mass during the day is flushed out by the cooler night temperatures, and the cool stored in the mass overnight is released into the building during the day. The elements to consider for implementing these principles are orientation, thermal mass, insulation, ventilation and lighting. These are outlined below in more detail.

E. Insulation: Insulation is one of the most effective ways to reduce heat input to a building and can be installed in the roof, ceiling and walls of the building. Insulation controls the rate at which a building loses or gains heat, keeping warmer air in during winter and excluding external heat in summer **R values:** Insulation materials are given an 'R' value, which rates the material's resistance to heat flow and therefore indicates its effectiveness. The higher the 'R' value the greater the insulating effect. However, an R value is not a measure of reflectivity and so is less effective as a measure of the capacity of insulation to reflect external heat.

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APPENDIX

A. General information about Inferred thermometer device

A. Introduction

This infrared thermometer is used for measuring the temperature of the object’s surface, which is applicable for various hot, hazardous, or hard to reach objects without contact safely and quickly. This unit consists of optics, Temperature Sensor Signal amplifier, Processing circuit, and LCD Display.

B. Warning and cautions

<u>1.Warning;</u>

1. Do not point laser directly at eye or indirectly off a reflective surface.

2. The unit cannot measure through transparent surfaces such as glass or plastic. It will measure the surface temperature of these materials instead.

3. Steam, dust, smoke, or other particles can prevent accurate measurement by obstructing the unit's optics.

<u>2. Caution;</u>

1. EMF (electromagnetic fields) from arc welders, induction heaters.

2. Thermal shock (cause by large or abrupt ambient temperature changes allow 30 minutes for the unit to stabilize before use).

3. Do not leave the unit on or near objects of high temperature.

C. Distance to spot size

When take measurements pay attention to the distance to spot size. As the distance (D) from the target surface increases, the spot size (S) of the area measurement by the unit becomes larger. The distance to spot size of the unit is 12:1 This unit is equipped with a leaser, which is used for aiming

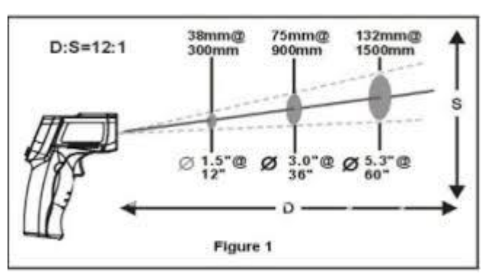


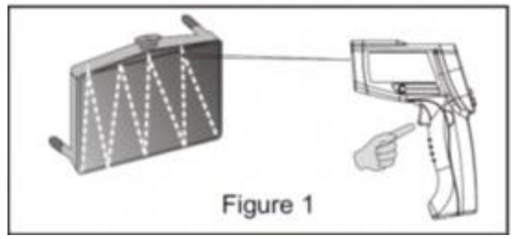
Figure 1

A. Emissivity

Emissivity; Most organic materials and painted or oxidized surfaces have an emissivity of 0.95(preset in the unit). Inaccurate readings will result from measuring shiny or polished metal surfaces. To compensate for this, adjust the unit's emissivity reading or cover the surface to be measured with masking tape or flat black paint. Measure the tape or painted surface when the tape or painted reaches the same temperature as the material underneath.

<u>Locating a hot spot</u>

To find a hot spot, aim the thermometer outside of interest, then scan across with an up and down motion unit you locate the hot spot(Figure 1)



B. LCD and buttons

1. LCD display
2. Diagram description;(Figure2)
3. A: measuring reading
4. B: measuring unit: laser on icon
5. D: backlight on the icon
6. E: battery power icon
7. F: scanning icon
8. G: data hold the icon
9. H: mode/emissivity indicator
10. I: data storage/read icon
11. J: low-temperature alarm icon
12. K: high-temperature alarm icon

Trigger; when turning on LCD VERXX software version for 1 sec. And turn to display reading with SCAN icon. Release the trigger, display reading with the HOLD icon. Built-in auto power off in 30sec.

H. specification

Temprature range	-50..700°C (-58 .. 1292°F)
Accuracy	0..700°C(32..1292 °F):±1.5 °C(±2.7 °F) or ±1.5% -50..0 °C(-58..32 °F):±3 °C(±5 °F) Which ever is greater
Resolution	0.1 °C or 0.1 °F
Repeatability	1% of reading or 1 °C
Response time	500 msec, 95% response
Spectrial response	8-14 um
Emissivity	0.10-1.00 adjustable (0.95 preset)
Distance to spot size	12:1
operatingtemperature	0 - 40 °C (32 - 104 °F)
Operating humidity	10-95%RH non condensing, up to 30 °C(86 °F)
Storage temperature	-20 - 60 °C(-4 -140 °F)
Power	9V Alkaline or Nicd battery
Typical battery life (Alkaline)	Non -laser model: 22hrs Laser model: 12hrs
Weight	222g
Dimensions	111*50*172mm

B .Questionery

The purpose of the questioner is to support the research with qualitative and quantitative data.

Questioner Nº: ___ Kebele: ___ Date: ___________Surveyor: Haven Hailu Sign: _______

o Please every one of you helps me by giving the correct answer to the questions and play your great role in this research (**mark /x**).

1.General Information:

1.1. City: ….

1.2. Age group: **A.** 30-40 **B.**41-50 **C.**51-60 **D.** Over 60

1.3. Level of education:

A. Elementary B. High School C. University D. Uneducated

1.4 Occupation:

A. Craftsman **B.** Employee **C.** Business **D.** Unemployed

1.5. Housing type:

A. detached **B.** row **C.** semi-detached **D**. other types

2. Information on Traditional House:

2.1 For how long you lived in the traditional house:

A. Less than 5 years B. 5-10 years **C**. More than 10 years

2.2 What is the total number of occupants in the house:

A. Less than 5 **B.** 5-10 **C.** More than 10 people (please mention the number of families)

3. Utilities in the Traditional House:

3.1 Availability of electricity: **A.** Yes **B.** No

3.2 Level of natural lighting: **A.** Weak **B.** Fair **C.** Good

3.3 Level of natural ventilation: **A**. Weak **B.** Fair **C.** Good

4. Environmental Comfort Level both House:

4.1. Thermal preference for both houses. (ASHRAE thermal sensational scale)

NO	General Thermal Comfort	Thermal Sensation Scale
1	Hot	1. + 3
2	Warm	2. + 2
3	Slightly Warm	3. + 1
4	Neutral	4. 0
5	Slightly Cool	5. – 1
6	Cool	6. – 2
7	Cold	7. – 3

4.2 Regarding thermal comfort which one is a preferable house?

A. Traditional **B.** Modern **C.** Similar

4.3 In your opinion, what are the reasons for differences between traditional and modern houses concerning climatic comfort:

A. Construction materials **B.** construction techniques

C. openings type and size of the house **D.** Other …………………………

4.4 What system was used for cooling during the Hot season:

A. Hand-held fans **B.** Electric fans

C. Nothing exists **D.** Other ………………………….

4.5 What system is used for heating during the cold season?

A. Cordwood heating **B.** Gas heating **C.** Coal heating

D. No heating **E.** Other ………………………….

4.6 In your opinion, what are the major reasons for leaving the traditional style in building, and adopting the modern style:

A. The modern ones are more comfortable

B. They are fashionable/ have more prestige value

B. Sanitary utilities are much better

C. Other …………………………….

4.7. In your opinion, the advantages of the traditional house are they:

A. Provide climatic comfort

B. Low cost

C. Use local construction material

D. Provide strong social relationships

E. Have special characters that distinguish them from other styles of traditional houses in other parts of the country.

F. Other ……………………………

4.8. In your opinion, the disadvantages of the traditional house are they have:

A. Problems of sanitary utilities.

B. Lack of prestige value (not fashionable)

C. Lack of privacy because many families are living in the same house **D.** Other ……………

C.Temperature and humidity data

Month One (February) Temperature data in ^{o}C				
Date	Time	Traditional	Modern	External
February 01,2020	1:00AM	29.5	31	29.8
	3:00AM	29	32.2	35
	6:00AM	29.8	31	30.6
	9:00AM	28	31.8	31.9
	12:00PM	29	31.7	33
February 05,2020	1:00AM	26	29.8	29
	3:00AM	28.5	29.8	36
	6:00AM	29	29.8	36
	9:00AM	28.5	30.2	33.4
	12:00PM	29	32.2	28.5
February 09,2020	1:00AM	29	30.2	30.3
	3:00AM	29.9	31	31
	6:00AM	29	30.1	29.9
	9:00AM	29.4	30.5	31.2
	12:00PM	29.8	31	31
February 13,2020	1:00AM	22.2	23	17.9
	3:00AM	21.5	16	27
	6:00AM	21.2	21	14
	9:00AM	22.3	18	28
	12:00PM	23.1	22	24.6
February 17,2020	1:00AM	22	21	23
	3:00AM	25	27	23
	6:00AM	21	21	22
	9:00AM	24	27	23
	12:00PM	25	29	24
February 21,2020	1:00AM	19.0	21.0	22.0
	3:00AM	23.0	26.0	30.0
	6:00AM	18.0	25.0	22.0
	9:00AM	24.0	22.0	31.0
	12:00PM	22.0	20.0	27.0
February 25,2020	1:00AM	22	27.3	28.7
	3:00AM	24	31.2	33.8
	6:00AM	23.5	26.5	30
	9:00AM	24.4	34.1	35
	12:00PM	24.9	26.5	25.5
February 29,2020	1:00AM	23.4	26.5	28
	3:00AM	25.2	28	28.5
	6:00AM	24.5	33	33
	9:00AM	25	25.7	29
	12:00PM	23	33.9	33

Month Two (March) Temperature data in ^{o}C				
Date	Time	Traditional	Modern	External
March 02,2020	1:00AM	30	32	27
	3:00AM	29	36.5	31
	6:00AM	31	32	28
	9:00AM	32	36	33
	12:00PM	33	35	31
March 06,2020	1:00AM	31.6	35.8	38.5
	3:00AM	32.5	33.8	29
	6:00AM	33	34	33
	9:00AM	34	33	29
	12:00PM	31	37	35
March 10,2020	1:00AM	32	28.9	26.5
	3:00AM	33.5	35.8	34
	6:00AM	31.5	29	26
	9:00AM	33	33	35
	12:00PM	29	37	28
March 14,2020	1:00AM	28	31	33.5
	3:00AM	26.5	29.5	31
	6:00AM	29.8	33	36
	9:00AM	29	28.5	35
	12:00PM	31.5	32.5	29
March 18,2020	1:00AM	30	31	30
	3:00AM	31	30	32
	6:00AM	30	31	29
	9:00AM	31	29	31
	12:00PM	31	31	30
March 22,2020	1:00AM	28.7	28.2	28.3
	3:00AM	27.9	29.0	29.0
	6:00AM	27.0	28.1	27.9
	9:00AM	27.9	28.5	29.2
	12:00PM	27.8	29.0	29.0
March 26,2020	1:00AM	28.0	29.2	29.6
	3:00AM	29.6	30.0	30.3
	6:00AM	28.8	29.1	29.2
	9:00AM	29.5	31.0	30.5
	12:00PM	29.5	30.0	30.3
March 30,2020	1:00AM	25.5	26.7	27.82
	3:00AM	27.1	27.5	28.52
	6:00AM	26.25	26.6	27.42
	9:00AM	27	28.5	28.72
	12:00PM	27	27.5	28.52

Month Three (April) Temperature data in ^{o}C				
Date	Time	Traditional	Modern	External
April 04,2020	1:00AM	24	28.5	33
	3:00AM	30	30.4	36
	6:00AM	24	28.6	35
	9:00AM	26	30	33
	12:00PM	26	29.8	31
April 08,2020	1:00AM	26.6	33	37
	3:00AM	26.2	30	31
	6:00AM	27	32	36
	9:00AM	26	30	31
	12:00PM	25	29	35
April 12,2020	1:00AM	27	30	29
	3:00AM	27	33	30
	6:00AM	29	28	29
	9:00AM	28	34.4	35
	12:00PM	27	29	28
April 16,2020	1:00AM	28.9	31	37
	3:00AM	29	30	36
	6:00AM	28	32	39.5
	9:00AM	27	26.2	36
	12:00PM	29	28.2	34.7
April 20,2020	1:00AM	27.4	30	36
	3:00AM	27.5	29	35
	6:00AM	24	31	38
	9:00AM	25.5	25.2	35
	12:00PM	27.5	27.2	33
April 24,2020	1:00AM	26	28	29.8
	3:00AM	28	29.2	35.0
	6:00AM	25.8	28	30.6
	9:00AM	26.8	28.8	31.9
	12:00PM	27.5	28.7	33.0

Month One (February) Humidity data				
Date	Time	Traditional	Modern	External
February 01,2020	1:00AM	55	67	41
	3:00AM	49	65	39
	6:00AM	46	62	21
	9:00AM	41	59	23
	12:00PM	44	67	11
February 05,2020	1:00AM	44	35	33
	3:00AM	48	37	21
	6:00AM	41	35	23
	9:00AM	46	31	15
	12:00PM	48	35	28
February 09,2020	1:00AM	45	65	30
	3:00AM	48	62	27
	6:00AM	45	75	39
	9:00AM	49	70	27
	12:00PM	45	62	26
February 13,2020	1:00AM	48	77	71
	3:00AM	45	60	28
	6:00AM	55	65	73
	9:00AM	45	78	48
	12:00PM	55	81	55
February 17,2020	1:00AM	48	65	33
	3:00AM	48	44	28
	6:00AM	52	55	28
	9:00AM	44	66	18
	12:00PM	52	62	22
February 21,2020	1:00AM	55.0	77.0	33.0
	3:00AM	41.0	68.0	48.8
	6:00AM	59.2	66.0	44.0
	9:00AM	44.0	73.0	33.0
	12:00PM	63.0	57.9	60.5
February 25,2020	1:00AM	56.5	79.0	34.5
	3:00AM	42.5	70.0	50.3
	6:00AM	60.7	68.0	45.5
	9:00AM	45.5	75.0	34.5
	12:00PM	64.5	59.9	62.0
February 29,2020	1:00AM	45	72	27
	3:00AM	68	75	77
	6:00AM	55	69	23
	9:00AM	58	73	39
	12:00PM	55	72	36

Month Two (March) Humidity data				
Date	Time	Traditional	Modern	External
March 02,2020	1:00AM	69.5	78.5	78.5
	3:00AM	69.5	78.5	78.5
	6:00AM	69.5	78.5	78.5
	9:00AM	69.5	78.5	78.5
	12:00PM	69.5	78.5	78.5
March 06,2020	1:00AM	79.5	49	17
	3:00AM	81	48.5	35.8
	6:00AM	88	44	33
	9:00AM	53.4	55	19
	12:00PM	59	42	22
March 10,2020	1:00AM	59.8	47.5	29
	3:00AM	61	36	15
	6:00AM	72	47	26.9
	9:00AM	68	38	16.8
	12:00PM	57	44	16
March 14,2020	1:00AM	69	59.5	73
	3:00AM	71.5	61	41
	6:00AM	72	59	79.5
	9:00AM	69	64	38
	12:00PM	71	55	71
March 18,2020	1:00AM	69	79	64
	3:00AM	68	66	85
	6:00AM	72	73	59
	9:00AM	72	75	81
	12:00PM	69	58	39
March 22,2020	1:00AM	68.0	68.0	86.0
	3:00AM	66.0	69.0	52.0
	6:00AM	67.0	67.9	84.0
	9:00AM	69.0	72.0	70.0
	12:00PM	71.0	70.0	76.0
March 26,2020	1:00AM	64.0	59.0	89.0
	3:00AM	73.0	71.0	63.0
	6:00AM	71.0	68.0	35.0
	9:00AM	70.0	39.5	27.0
	12:00PM	75.0	72.0	39.0
March 30,2020	1:00AM	77	64	79
	3:00AM	73	51	47
	6:00AM	72.6	68	49
	9:00AM	69	24	33
	12:00PM	72	52	38

Month Three (April) Humidity data				
Date	Time	Traditional	Modern	External
April 04,2020	1:00AM	68	37	27
	3:00AM	66	68	77
	6:00AM	69	27	23
	9:00AM	70	65	66
	12:00PM	68	33	36
April 08,2020	1:00AM	40	33	35
	3:00AM	66	61	64
	6:00AM	48	27	23
	9:00AM	66	65	66
	12:00PM	55	33	36
April 12,2020	1:00AM	46	66	31
	3:00AM	64	63	64
	6:00AM	56	75	40
	9:00AM	41	71	31
	12:00PM	47	73	33
April 16,2020	1:00AM	58.8	46.5	28
	3:00AM	41	33	17
	6:00AM	55	47	24
	9:00AM	46	33	18
	12:00PM	38	44	44
April 20,2020	1:00AM	55	74	33
	3:00AM	41	66	42
	6:00AM	59	68	49
	9:00AM	44	76	42
	12:00PM	63	58	55
Day 6	1:00AM	65	49	67
	3:00AM	38	41	31
	6:00AM	63	58	68
	9:00AM	67	67	44
	12:00PM	69	55	56