

**Indoor Thermal Analysis of Hospital Building in Dire Dawa,
Ethiopia**



Bethelhem Seifu shigaze

Thesis Submitted to the School of Civil Engineering and Architecture

Department of Architecture

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

Office of Graduate Studies

Adama Science and Technology University

August 2021

Adama, Ethiopia

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Approval

I, the advisors of the thesis entitled “ **Indoor Thermal Analysis of Hospital Building in Dire Dawa, Ethiopia**” and developed by Bethelhem Seifu, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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Declaration

I hereby declare that this Master Thesis entitled “**Indoor Thermal Analysis of Hospital Building in Dire Dawa, Ethiopia**” is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

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Recommendation

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled “**Indoor Thermal Analysis of Hospital Building in Dire Dawa, Ethiopia**” prepared under my guidance by Bethelhem seifu submitted in partial fulfillment of the requirements for the degree of Master’s in Environmental Architecture. Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

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ABSTRACT

Thermal comfort is a primary concept in human life and activity. In addition to the environmental parameters, the concept incorporate psychological and physiological aspects. The vulnerability of the occupants to elevated temperatures is one of a counting factor for thermal susceptibility. Thermal comfort is a sensitive issue in hospital buildings, indicating the necessity for a thorough study. Aside from that, due to their health-related consequences, patients are likely to have varied thermal requirements. This study, therefore, aims to evaluate the indoor thermal comfort of two hospital buildings in Dire Dawa. There wasn't any study done in Dire Dawa, Ethiopia on the thermal comfort assessment in hospital buildings. In this study, three environmental factors (indoor air temperature, air speed, and relative humidity) measured and analyzed to determine their level relative to ASHRAE 55 standard, The value of environmental variables compared with occupants (clinical staff, patients, and visitors) perception towards thermal comfort. The physical measurement and survey were carried in the warmest month of the year, from mid-April to May 2021 G.C. for six selected room of the case buildings. The data obtained from the survey was analyzed using SPSS version 24 and MS Excel. The result of the study revealed that almost all occupants are not comfortable with the indoor thermal condition and prefer cooler environment. Thermal perception of 57.3% of occupants is out of the comfort zone of ASHRAE 55. The average mean temperature is 29.8 °C and humidity is 38%. The air velocity data is also below the comfort range. According to the result high temperature and low air velocity highly affect the building space, with 62% and 75% probability of affecting the thermal perception of occupants. The building fail to modify the micro climate of the study area. Passive building techniques which can avoid excess heat and allow better ventilation system are suggested. In addition to that building, regulations need to incorporate thermal comfort requirements, Particularly in design and construction of medical environment.

Keywords: Hospital building, Indoor space, Thermal preference, Comfort zone, Bio-climatic

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ABBREVIATIONS

ASHRAE	American Society of Heating, Refrigeration and Air-Conditioning Engineers
CBE	University of California Berkeley Center for the Built Environment
DDAC	Dire Dawa Administration Council
DRH	Dillchora referral hospital
EBCS 12	Ethiopian building code standards 12
IAQ	Indoor air quality
IEQ	Indoor environmental quality
NMA	National Meteorological Agency
PMV	Predictive mean vote.
PNC	Post Natal Care
PCM	Phase change materials
SGH	Sabian general hospital
TC	Thermal comfort
TS	Thermal sensation
TP	Thermal preference
WWR	Window wall ratio

CHAPTER ONE

Introduction

This paper is written for the study conducted in the Administrative city of Dire Dawa, Ethiopia. In partial fulfillment of Degree of Masters in Environmental Architecture at Adama Science and Technology University. The study intends on contributing knowledge-based analysis on indoor thermal comfort in the hospital building. Thermal comfort is the optimum level of environmental variables within a space occupants referred to as comfortable to stay. It is a critical element to acceptable indoor environmental quality(IEQ). The concept of thermal comfort depends on climatic conditions. The world's climatic condition is changing at a rapid pace. As a result, the 21-century building revolution focused on sustainable design. Even though it had been considered low in developing countries like Ethiopia, Environmental sustainability is an urgent global concern. This study is conducted, in two hospital buildings found in the administrative city of Dire Dawa, Indoor environmental comfort is a critical need in medical centers. Medical strain and restricted physical environment influence the thermal tolerance of patients in medical centers. There is no research held on thermal efficiency of hospital buildings in Ethiopia, in particular in Dire Dawa. As an architect, 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 indoor thermal comfort investigations in hospital buildings. The study recommends Adaptation measurement to the local bio-climatic condition of the study area. That will help create a better indoor environment with fewer resources. This chapter includes the background of the study, statement of the problem, the objective, the significance of conducting the study, and limiting factors.

1.1. Background of the study

Thermal environment refers to the surrounding element affecting heat transfer at that specific point (Norbert,2015). Mounting research shows that comfortable occupants are more alert, have better energy levels, and use fewer sick days, more productive

and satisfied (Mcclurg, 2016). Most of modern society spent 80% of its life in an artificial environment and is physically and psychologically vulnerable to the effects of an uncomfortable indoor environment (Markov,2003). Thermal comfort is the combined effect of environmental and personal variables. Environmental variables are those which relate to the climate conditions. Human-induced climate change is feared to lead to an unprecedented level of global warming in the next few decades (Smene,2016).

The mid-twentieth century challenge of architects and engineers is avoiding the influence of changing climate in building functionality. Different researchers were dealing with the issues of thermal comfort. The Danish physiologist Povl Ole Fanger has played a significant role in the development of thermal comfort approaches. He combines personal and environmental variables with the rating scale of a perceived sense of well-being in Predicted Mean Vote (PMV) and Percentage People Dissatisfied(PPD) (Fabbri, 2007). The adaptive model also considers the ability of people to influence their thermal environment.

When it comes to the medical center need for a thermal environment became critical. Patients are generally delicate and are not like the population upon which the Standards are based (Hwang et al, 2007).The study conducted by Nahar(2019) indicates the thermal comfort in hospitals affects the healing process of the patient (p.29). A similar study revealed that high-temperature levels reduce the recovery rate of the patients in the wards. As a result, patients stay longer (Kameel and Khalil, 2003). According to Ormandy (2012), Chang in the indoor environment increase the level of the illness. Several authors have discussed the aspect of thermal comfort not only for patients but also for hospital staff. The medical staff feels warmer than the patient (Hashiguchi et al,2005). Sustainable design is the general reaction of the modern world to environmental crises. It is still highly desirable but hardly feasible to produce buildings that attain total comfort within the changing environment.

Developed countries made series of thermal comfort studies on hospital buildings to identify the degree to which thermal variables affect patients, visitors, and staff. But in developing countries, the studies are not far from the residential buildings (Karyono, 2000; Nematchoua, et.al.,2014). This situation is also true in Ethiopia. Few studies were conducted on expectations, acceptability, and preferences of indoor

thermal comfort in traditional and modern buildings (Yadeta et.al. 2019; Haven, 2021). There is a shortage of literature in Ethiopia that addresses the thermal comfort need in the hospital building. Therefore, it is essential to evaluate the thermal comfort efficiency of hospital buildings' design. In particular in hot areas of the country, like Dire Dawa. These help to come up with better strategies for sustainable design options.

1.2. Statement of problem

The climate change has caused an increment in temperature and a decrement in rainfall in Ethiopia (ekbom 2013). Temperature is expected to increase from 1.4°C up to 2.9°C by 2050s. The country is vulnerable to the impacts of changing climatic conditions. The city of Dire Dawa is one of the hot regions expected to be affected due to the change in surface temperature. The temperature, as well as the indoor thermal comfort will be affected. Most modern buildings in the city depend on space conditioning. The level of natural ventilation is low in which thermal adaptation is significant. The majority of the occupants in the hospital building were complaining about their thermal environment. Microclimate can significantly affect both patients and staff. On the other hand, thermal discomfort attracts, holds, and enhances the healing process of the patients. It enhances work efficiency (Sopian et al., 2013). Depend on the length of time spent within, the problem of indoor thermal comfort has negative implications on the performance of occupants (Seppanen et al., 2006).

According to international reports mentioned, Ethiopia is one of the least mention countries on quality health care provision and management systems. Many policies and research initiatives focused on improving physical access rather than the quality of the space provided (Tsegay et al.2018). The regulation regarding IEQ for hospital Building designs define the level of mechanical system only. Most buildings in hot regions maintain indoor comfort through the mechanical system. Dire Dawa is a city located in a semi-desert scrub ecosystem with an average temperature of 34.6 °C. One of the reasons behind the high energy consumption of hospital buildings is high space heating, cooling, and ventilation loads. (Augusto & Xavier, 2020). Indoor thermal

environment studies are part of indoor environmental quality assessment studies (Manzano-Agugliaro et.al., 2015).

However, to the best of the author's knowledge, no research has been conducted on the thermal efficiency of hospital buildings in Ethiopia in general and Dire Dawa city in particular. The concept of thermal comfort as relative to the effect on patients is an urgent topic yet to be analyzed in more detail (Jamal K, 2012). Therefore, this study is intended to carry out a more comprehensive thermal comfort analysis in Hospital buildings found in Dire Dawa, as hospital facility should be designed in such a way as to provide the maximum benefit to its inhabitants.

1.3. Objective

1.3.1. General objective

Main objective of the study is to analyze indoor thermal comfort of two Hospitals building in Dire Dawa, Ethiopia.

1.3.2. Specific objectives

- To investigate the occupants' (patients, staff and visitors) thermal comfort perceptions in indoor spaces.
- Analyse the thermal comfort level of the hospital buildings
- To examine three environmental factors(air temperature, air velocity, relative humidity) that affect thermal efficiency in different indoor spaces of Hospital Building .

1.4. Research question

The final output of these studies clarifies the questions listed below.

- What are the thermal perception level of patients, staff, and visitors?
- Do the measured variables are in Permissible level of ASHRAE 55 standard?
- Do the **environment parameters** and the **actual sensation vote** in different indoor transitional spaces are correlated?
- Do the indoor thermal environment of the hospitals is comfortable?

1.5. Significance of the study

The output of this study benefits the local community within cities under extreme temperature ranges DDAC in particular. The study helps to identify the existing challenge of hospital buildings regarding thermal comfort. The physical and mental benefit of a comfortable environment is priceless. It is hard to measure in monetary value. The Ethiopian standard for general hospital requirements formulated by ESA(Ethiopian standard agency) has no specification on passive measurements in the indoor environmental quality of hospital building design (Ethiopian standard, 2012). the study clarify the existing problem in which regulations need to address. The building industry needs clear guidelines on the level of exposure to environmental variables. The study helps on Improvement of indoor environment condition of health centers will facilitate the healing process of patients; avoid further disorder on nerves system, immune system, and endocrine system which will result from, external heat stress. The energy use of hospital buildings is more than twice as much as other general public buildings. Passive Solutions of the study maximize thermal comfort with minimized energy consumption.

This study will shed light on Knowledge development of thermal requirements on indoor space. Policymakers, urban designers, architects, and researchers use the finding of this research as input for innovative design and construction of comfortable living spaces. Especially those regions found in extreme temperature ranges.

1.6. Scope of the study

The spatial location of study area is in Dire Dawa town-Eastern Ethiopia. Two governmental hospital buildings are analyzed under the study. Distributed in 9 urban and 38 rural kebele (small administrative units of Ethiopia), these Institutions give service for the catchment of half a million people in different medical disciplines. It incorporates evaluations of basic thermal parameters with personal judgment of users. The study was conducted from mid April 2021 to the May 2021 G.C.

1.7. Limitation of the study

Undergoing these study the main challenge was getting permission to access patients. There were restrictions in the IPD ward regarding Covide19 pandemic. Due to some hospital regulations I was not allowed to access/study the most delicate space of the hospital environment. Most patients do not want to go through the questionnaire more than once. And measurements need to be done for three different times of the day. Because of the limited time and resources, only three environmental variables are selected for the study and data is collected only for 15 days.

There will never be any doubt that the concept of thermal comfort is critical in IEQ. After preliminary observation on sample units, The clothing and activity level of sample units has been identified from the standard table of ISO 9920 and ISO 8996. Studies on several pieces of literature's also magnify its importance on health care facilities. Merely there is no defined guideline on passive measurement of hospital buildings design and construction.

1.8. Report Organization

This study comprises four main chapters. Chapter one introduces the background of the study, objective, significance, scope, and limitation. Chapter two presents different literature on related topics. The discussion cover topics listed on specific objective. Chapter three explains the methodological structure of the Research. The source and size of the sample population plus The material used are specified. It also explains the climatic and geographical status of the study area. The chapter discusses the data analysis Techniques. Chapter four presents discussions on findings, conclusions, and recommendations of the study.

1.9. Operational definition of the study

Under the study on thermal responsiveness of hospital buildings in DDAC, the terms identified below defines thermal comfort.

Thermal comfort is satisfaction with the thermal environment of a given space. And it is assessed by a subjective assessment. (ASHRAE 55, 2017)

Comfort zone is the range of climatic conditions within which a majority of persons would feel thermal comfort.

Thermal physiology; is the condition or law in which the human body made an effort to attain efficient thermal regulation (Fabbri, 2015).

Predicted Mean Vote (PMV), PMV is based on a seven-point scale for thermal sensations, ranging from hot (+3) to cold (-3). Zero is the ideal value representing thermal neutrality. The PMV comfort zone defines the combinations of the six factors affecting thermal comfort. PMV is within the recommended limits $-0.5 < \text{PMV} < +0.5$ (ASHARE 55, 2017).

Percentage of People Dissatisfied (PPD) is an index to predict the percentage of people likely to feel thermally uncomfortable. PPD tolerates 5% dissatisfaction.

PNC(postnatal care)-is a unit in a maternity ward, in which new moms stay after birth with their babies. Most of the time room and bathroom is shared with other new moms and their babies. A team of midwives, nurses, and doctors will look after them until they're well enough to go home (Warren et al,2008).

Wound care is a medical facility for treating wounds. begins at the time of injury and lasts for days and weeks. If it Has not started to heal in 2 weeks, it might turn into a non-healing wound.

Air speed: the rate of air movement at a point, without regard to direction (Candido et al., 2010).

Adaptive opportunity: An opportunity that elements of the building design offer to the users to make themselves thermally comfortable.

Air Conditioned buildings: Buildings in which internal thermal environments are controlled by adjusting the air supply, ventilation, air humidity and air temperature.

ASHRAE scale: The seven point ASHRAE scale is a set of seven options given to people to tag their thermal comfort perception to a given environment (cold, cool, slightly cool, neutral, slightly warm, warm and hot).

Clo: The unit for evaluate the thermal insulation of clothing, where $\text{clo} = 0.155 \text{ mw.K.W}$.

Draught: Unwanted local cooling of the body caused by air movement.

Indoor transitional spaces: Spaces located within a building but which are also connected with the exterior environment.

Mean radiant temperature: The uniform surface temperature of a radiantly black enclosure in which an occupant would exchange the same amount of radiant heat as in the actual non-uniform space.

Metabolic rate: The rate used to express people physical activity, this rate is expressed in met units, where $1 \text{ met} = 58.2 \text{ W/m}^2$ (Norbert, 2015).

Naturally ventilated buildings: Buildings in which interior spaces are thermally operated without using any heating, ventilation and air conditioning (HVAC) system, but can use other operable building elements such as doors and windows to provide thermal comfort.

Operative temperature: The combined effect of the air temperature and mean radiant temperature, represented in a single value. It is a weighted average that depends on the heat transfer coefficients by convection and radiation at the clothed surface of individuals (Tanabe S, 1987).

Physical measurements: Refers to the measurements of air velocity, air humidity, air temperature and globe temperature.

Relative humidity: The ratio of water pressure to saturation vapor pressure at the

Thermal experience: People's previous thermal conditions that influence they current thermal perception of the environment.

Thermal preference: The thermal conditions people say they would prefer to experience, which may differ from their current state even if they express satisfaction with it.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Thermal comfort

Performance level of an existing building is evaluated to determine occupant's satisfaction and making recommendations for improving building design performance. Thermal comfort is one element of indoor environmental quality indicator used to assess the building performance (Mustafa,2017). Thermal comfort is an environmental condition in which humans attains physical and mental satisfaction. Even though it had had little influence on the practice of architecture, Thoughts on the climate suitability of a house flourished long ago. In 400BC, Socrates has suggested an idea on how buildings ensure thermal comfort. Vitruvius (1st century BC) wrote about the health and comfort benefits of considering the climate in a built environment. Through time industrial revolution has created some possible ways to the practicability of indoor thermal comfort. The concept of creating more comfortable indoor environment has been in progress till the present day (Ekici, 2016).

2.2. The Discipline of Comfort

The discipline of comfortable indoor environment has been born in the early decades of the twentieth century. Until then human had been using adaptive strategies related to behavior and clothing, to get along with the temperature. There was different researcher's dealing with the issues. Tense thermal conditions in his workplace triggered biophysicist and researcher Gagge AP to work on the concept of thermal comfort. He became the first one to work on the subject. He process experimental data on energy exchanges between human body and its environment. And found an application of the principles of thermodynamics for the human body. The "Two node model" of Gagge shows that the combination of the thermal exchange due to metabolic activity, the body's energy, evaporation, radiation and conduction is zero. The model elaborates the temperature control system, and the equation of heat balance of the human body.

The revolution on thermal comfort has begun after the Danish physiologist Povl Ole Fanger and other researchers promoted the study as a real discipline. Fanger PO who is an expert in the field of thermal comfort and perception of indoor environments had revised the equation of the two-node model. And expresses energy exchanges of the human body with a double equation. He has defined indexes of comfort and well-being following a series of experiments and tests. Fanger has tried to related physical parameters of the environment, physiological parameters of people and expression of wellbeing by people themselves. Predicted Mean Vote (PMV) and Percentage People Dissatisfied (PPD) are statistical approaches adopted to define and measure thermal comfort. Studies on these statistical approaches by Gagge, Fanger, and others researcher's led to the formation of standards. Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD; ISO 7730 and Thermal environmental conditions for human occupancy; ASHRAE 55, are the two widely mentioned standards. These standards have updated over time with further experiments (Fabbri & Focusing, n.d.).

2.3. Comfort zone

Comfort zone is a Map or diagrammatic representation of well-being. the graph represents basic parameters influencing the microclimate of the indoor environment with their acceptable range producing a comfortable situation (Fabbri & Focusing, n.d.). Olgyay was the first to outline the *comfort zone* in architectural terms, i.e. the range of environmental conditions within which the average person would feel comfortable (Auliciems & Szokolay, n.d.).

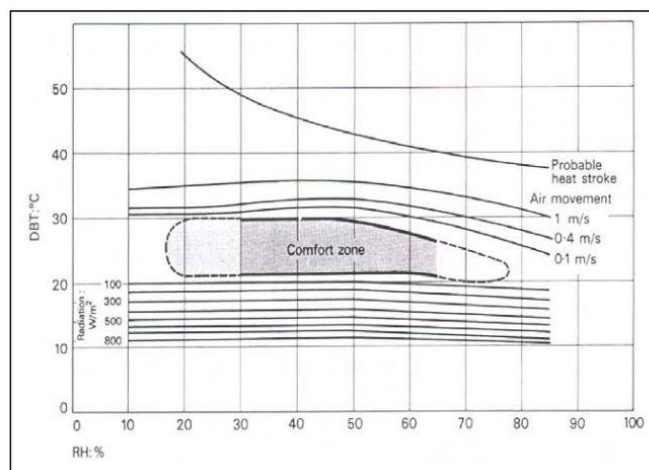


Figure 1. Metric version of Olgyay's bio-climatic chart

The chart manipulates magnitude of individual variables showing the contribution of each separately. And had get wide acceptance among architects. American Society of Heating, Refrigeration and Air-Conditioning Engineers has also traditionally refers to the Comfort Zone Method, which consists of an area on the ASHRAE Diagram: all micro-climatic conditions in which the Operating Temperature, Wet-Bulb Temperatures, Humidity Ratio and Relative Humidity, are within the Comfort Zone and ensure the condition of comfort.

Houghten FC and Yagloglou CP were the first to use psychometric chart, As a base for his 'equal comfort lines'. They simulate conditions in laboratories of ASHRAE in order to locate the comfort zone. They propose there line of comfort on the article, "Determination of the comfort zone" which has been published in 1923 (Fabbri & Focusing, n.d.).

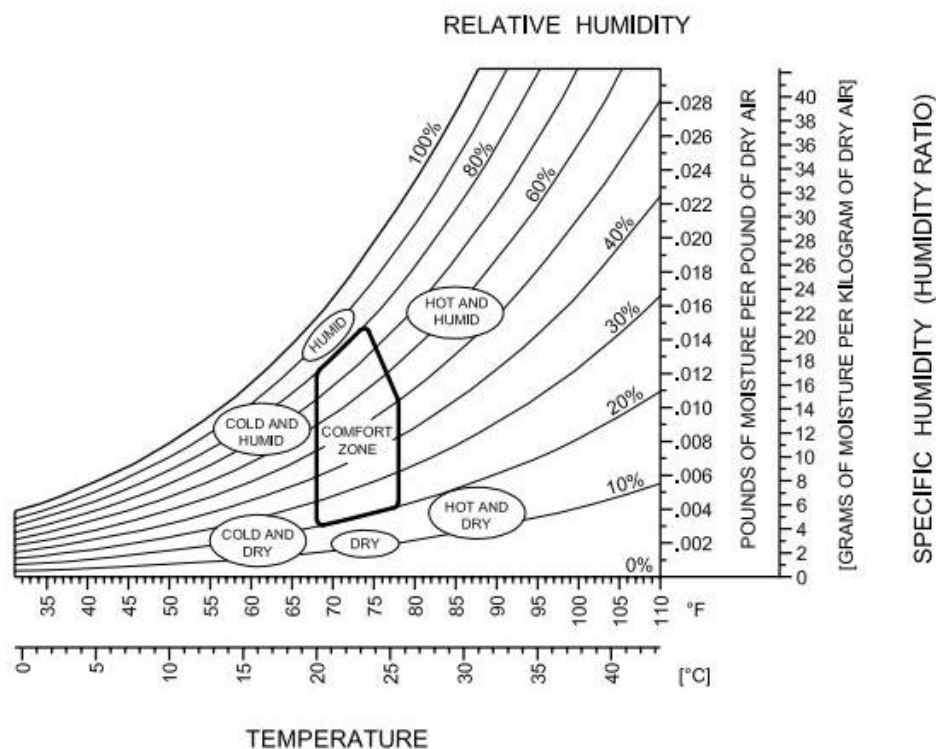


Figure 2. The comfort zone and various types of discomfort outside that zone are shown on this psychometric chart (Norbert.L,2015).

Satisfying all subjects is not possible, as the thermal perception vary with psychological, personal and present situation of an individual .The measurement for comfort zone comprise 90% of peoples, with 10% acceptable uncomfortable ratio (Kaynakli & Unver, 2003). The logic of the concept is created by comparison between the variables of any conditions of a standard environment, which can influence the thermal condition of a person. Therefore the energy exchange of human body with the environment is zero (Fabbri & Focusing, n.d.).

2.4. Use of effective thermal comfort

As one of the indoor environmental quality indicators, thermal comfort refers to the optimum temperature that building dwellers agreed as comfortable to stay. Within these environments, an individual feels healthy (ASHRAE, 2005).

The study of thermal comfort combines the features of physical and built environment with physiological needs and health of the human body. And it provides use full suggestion for medicine and architecture (Fabbri & Focusing, n.d.). As the type of physiological perception, thermal comfort relies on a subjective judgment that varies among individuals. An unfavorable indoor environment can affect physical and psychological well-being. In an extreme case, it might cause Death. Mounting research shows that comfortable occupants are more alert, have better energy levels, and use fewer sick days, more productive and satisfied employees (Mcclurg, 2016). Urban dwellers exposed to extreme temperature take thermally comfortable environment as grant. Regarding studies, the major goal of thermally comfortable environment, is health and well-being. In which energy use and productivity are the second and third prior topics simultaneously. As we know, building energy consumption has kept rising during the past few decades. Hospitals alone account for approximately 6% of total energy consumption in the public service sector (Augusto & Xavier, 2020). Parallel study investigated that due to desperate comfort need has increased the energy consumption of hospitals (Hwang et al., 2007). That will make the concept of thermally comfortable environment expensive.

2.5. Thermal comfort and climatic zone

Building microclimate is defined as “a type of microclimate which involves indoor spaces and spaces surrounding the indoor spaces in a particular building”. (Du ,2019.) The idea of relating architecture with climate is and has been developed long ago. Designing according to the climate needs understanding on micro climate of the site. Average weather or Climate is the result of the sun. The word “climate” comes from the Greek *klima*, expressing the slope of the earth with respect to the sun. After realizing that the climate results from sun angle (latitude) variation, the Greeks divided the world into the tropic, temperate, and arctic zones. Before hundred years ago, the atmosphere is fueled through contact with the solar heated ground with in the natural process.

Until human causes global warming, the annual energy absorption by the earth equals the energy radiated back in to the space, in the summer there is gain in the winter there is loose. Extreme climatic zones found around the world, in which architects are responsible for heating and cooling load of the space provided. Building design in temperate climate need both heating and cooling concern. Through the process a lot of money and energy will be invested

For better energy efficient building design, it is important that architects figure the dominating load between heating and cooling. Some aspects of building design are equally valid for both the heating and cooling loads (Norbert, 2015). For example, high ceilings are appropriate for a cooling-dominated climate while low ceilings are better for a heating-dominated climate.

2.6. Parameters of thermal comfort

Different factors can affect the thermal comfort of indoor space. It is the combined effect of environmental and individual variables. Environmental variables are those which relate to the climate conditions in the environment. They include the air temperature (t_a), mean radiant temperature (t_{rm}), air velocity (v_a), and relative humidity (HR). Personal variables include metabolic rate and the clothing thermal insulation (Eduardo et al., 2019).

These factors may be independent of each other, but their combined effect will define thermal comfort (De Dear & Brager, 1998). Extensive research held by the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) and the University of California Berkeley Center for the Built Environment (CBE) has found that these six variables can predict a person's thermal comfort.(Mcclurg, 2016). Even though it is one of the variables, Air temperature has been used as the only indicator of thermal comfort.

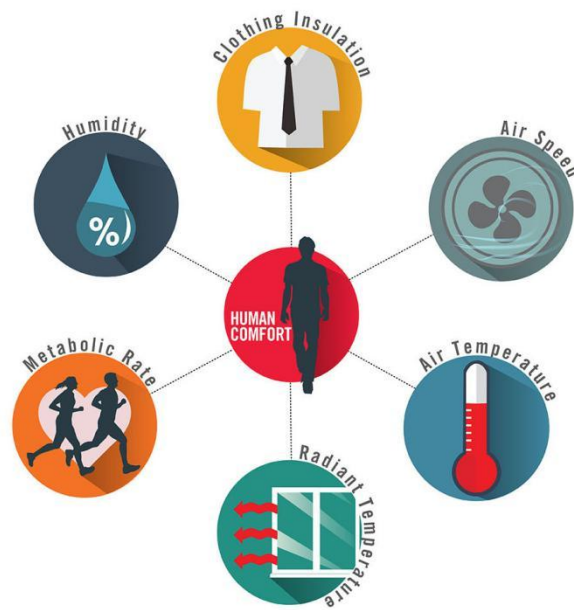


Figure 3. Six Variables in Thermal Comfort as listed by ASHRAE and CBE

For the best interaction between humans and the thermal environment that surrounds them, Understanding the necessary variables is the first step. The present-day design focus on passive solution for a sustainable environment. Most designs are concerned about how the building can best meet all six variables without a mechanical system. (Mcclurg, 2016).

2.7. Environmental factors

Usually, the concept of Thermal comfort is related to air temperature. Other environmental parameters are omitted, such as radiant temperature, humidity, and air velocity. These variables are those which relate to the climate conditions in the

environment. These factors are created environmentally due to different reasons such as the high emission of gases and any other pollution which may have an impact on the environment. Such as air temperature, Humidity, Air Velocity (Mamo & Worku, 2013). The location, orientation, and type of Building design decide the level of thermal comfort in which the building produces relative to those environmental parameters. In general environmental factors are natural elements affecting the indoor environment you are in.

2.7.1. Air Temperature

Air temperature is the temperature, surrounding your body in terms of location and time, usually measured in degrees Celsius. This is what is measured using a thermometer. It Determine the rate of heat loss, primarily through convection. Above 37 ° C, the flow of heat reverses and the body receives heat from the air. The higher temperature may cause increased out gassing of toxins from building materials, and low temperature can cause occupant discomfort including shivering, in attentiveness and muscular and joint tension. The comfort range for most people (80%) ranges from 20 ° C in winter to 25 ° C in summer. (Tanabe S, 1987)

2.7.2. Humidity

Relative humidity is the ratio between the actual amount of water vapors in the air and the maximum amount of water vapor that the air can hold at that air temperature. Its main function is the evaporation of moisture from the skin.

The more relative humidity in the air (i.e. the higher the ratio), the harder it is to sweat as humidity prevents the evaporation of sweat from the skin, which reduce heat reduction. Relative humidity between 40% and 70% do not have a major impact on thermal comfort. (Eddy et al., 2017).

Relative humidity affects occupant comfort both directly and indirectly. Low humidity or very dry environments (RH < 20-30%), affects comfort and health in ways such as drying nose, throat, eyes, and skin. The suggested level of indoor humidity in air-conditioned buildings is between 30-60%. Thermal sensation is an

indicator of overall thermal comfort and acceptability at lower levels of humidity. (Tanabe S, 1987)

2.7.3. Air Velocity

Air velocity an important factor of thermal comfort which describe the average speed of air moving across an individual. It can affect convective and evaporation heat losses from the human body, and thus influences thermal comfort conditions. Cooler air moving at a faster rate may cool occupants down, while still, heated air may make people feel stuffy. If the air temperature is less than skin temperature, it will increase heat loss through the skin, even when the system is in heat mode. Air speed has a very pronounced impact on heat loss. The comfortable airspeed range is between 0.1 m/s and 0.3 m/s, with 0.3 m/s to 1 m/s tolerable limit depends on the activity performed. Exceeding 1 m/s, the air movement can be uncomfortable and disruptive. 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. (Candido et al., 2010)

2.8. Personal factors

Comfort also depends on behavioral actions such as the nature of clothes and activity level of an individual.

2.8.1. Clothing insulation

The clothes are the main factor in climate adaptation of man to the environment. Types of clothing preference depend on individual behavior. The combination made of one or more sweaters, shoes or boots, or shirt and jacket instead of a single sweater, etc depend on personal habit by possibility to adapt their clothing in relation to climate and microclimate during the day. 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. So 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 (Fabbri & Focusing, n.d.). Studies on people's clothing by using thermal manikins have been developed over the past few years: These studies, however, do not show a method for determining the clothing surface temperature (t_{cl}) (Eduardo et al., 2019).

In the international standards for the evaluation of the isolation of garments and/or clothing ensembles (I_{cl}) uses a manikin with the following characteristics.

- ✧ Manikin height 170 ± 10 cm,
- ✧ Manikin surface area 1.8 ± 0.3 m²,
- ✧ Position standing during test, with Mean Skin Temperature between 32–34 °C,
- ✧ Room Operative/Air Temperature greater than 12 °C respect to the manikin,
- ✧ Heat loss from thermal manikin more than 20 W/m²,
- ✧ Relative Humidity 30–70 % (preferably 50 %) and
- ✧ Air Velocity less than 0.2 m/s, for a Test Period greater than 20 min

The unit of measurement of thermal resistance is the 'clo'. It expresses the relative thermal insulation values of various clothing assemblies. The clo expresses the resistance to the passage of heat and is equal to 0.155 m² °C/W, or for each square meter of surface of clothing, and for each degree of temperature difference between the skin and outer clothing, allows the passage through the clothes of 0.155 W (Fabbri & Focusing, n.d.).

Insulation values of typical clothing ensembles have been listed in the standard table of ISO 9920.

2.8.2. Metabolic rate (met) - Internal Heat Production

Knowledge of metabolic rate is necessary to measure metabolic heat production for the evaluation of human heat regulation (Norbert, 2015).

The internal heat production of our body depends on the state of health, age, sex, and type of diet. Its value depends on Human Body Metabolism (M) and of External Mechanical Power, expressed per unit surface area of the human body. Mechanical work is any physical activity performed by an individual. It might be Running or

lifting things. Depending on the motion of our body, we segregate activity as low moderate and heavy. The mechanical efficiency of the human body is zero or equal to 20%. For 0.20 units of work, we invest 20% of our metabolic energy. The Internal Heat Production in the Human Body is a magnitude that depends on Human Body metabolism (M) and of External Mechanical Power (W), expressed per unit surface area of the human body. The Metabolic Rate is expressed in W/m², or met. Its value can be calculated or can be identified from the standard table of ISO 8996(Fabbri & Focusing, n.d.).

There are different methods used for the calculation of the metabolic rate. Which consider the level of our heart beat rate and oxygen consumption rate. Most of them are sophisticated methods. PMV index should be used only if the metabolic rate ranges between 46 and 232 W m⁻² (Eduardo et al., 2019).

Table 1. human body metabolic rate relative to different activity's (Norbert, 2015).

Activity	Heat Produced (Btu/h)	Heat Produced (Watts)
Sleeping	340	100
Light work	680	200
Walking	1020	300
Jogging	2720	800

Notes:

1. The numbers given are approximate.
2. 1w = 3.412 Btu/h.

2.9. Design factors

The architectural design of the house is one of the factors that affect the thermal comfort within the space. The architectural elements play a great part in influencing the thermal comfort of the house. The urban design of a settlement can also be listed as primary elements which have an essential impact on the thermal performance of the buildings.

Design is needed to permit accurate control of environmental conditions. Through elements listed below. A well designed building envelop can dramatically reduce the need for mechanical system required to ensure thermal comfort simultaneously reducing carbon foot print. Solar gain is influenced by the building insulation level, its shape and orientation, the window to opaque wall ratio, the type of glazing and shading devices used. Thermal inertia varies according to the mass and the material of the building. High inertia envelops remain relatively stable in the face of temperature change. Air tightness and ventilation enable the control of air exchange with the outside. Insulation levels and an east-west building orientation reduce energy requirements in both summer and winter. However, other aspects of building design favor one season over another. A north-facing space might require heating, while a south facing space in the same building requires cooling. A west-facing room might require heating in the morning and cooling in the afternoon. (Norbert, 2015).

2.10. Humans thermal physiology

Through the physiological system, the human body can perceive the outside world. The Therm-Regulatory allows ensuring the proper metabolic activity. Meanwhile, the Respiratory system detects the air quality and pollution load. Physiology is the discipline that studies the conditions and the laws living organisms use to determine and regulate vital phenomena. The sense of comfort occurs when our bodies use minimum physiological effort for thermal regulation. Human beings try to adjust its thermostat through changing body posture or place, changing clothes, activities. The human body losses heat by exhaling warm or moist air from the lung. Hair is also a device that controls the rate of heat loss. But thermo regulation is sensed through the skin. The skin contacts the external environment through a dead cell called the epidermis. The living part of the skin consists of nerve receptors and glands called the dermis (Fabbri & Focusing, n.d.).

Human body reacts to increasing temperature. So thermo regulation tries to balance the heat generated and heat loss. In which human body attain thermal equilibrium. The Eccrine Gland (Thermoregulatory Sweat Gland) is composed of 99 % water and 1 % from the electrolyte, amino acids, and other vitamins. Which are distributed throughout the body and allow secretions of sweat, or lipid materials, triglyceride

ester and cause a bad smell (smell of sweat). Hypothalamus; a part of our brain adjust body temperature at about 98.6°F (37 °C) with a change of ± 0.5 °C. Further deviation creates severe stress (Norbert, 2015).

Our body can't be able to transfer heat to the outside if the temperatures exceed 40 °C. That will create heat stroke. If the temperature falls below 33°C, the body struggles to raise the temperature through shivering. Our bodies may also lose consciousness and die (Fabbri, 2007).

2.11. Thermal comfort in hospital building

Health and comfort are related concepts. A comfortable indoor environment improves sleep quality, decreased incidence of delusion, hope, positive interaction, decreases error, and increased work satisfaction (Markov, 2003). Thermal comfort is a critical element of successful building operations, particularly in health care facilities where it has a direct impact on patient care. The world health organization define comfort as; "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (Fabbri & Focusing, 2015).

In other side the standard of ASHRAE 55 define comfort as condition of mind which expresses satisfaction with the thermal environment depending on subjective evaluation. The interaction between Physiological, psychological and physical factors affect the condition of comfort (Norbert, 2015). The state of comfort can be affected when one of the parameters interrupted. Studies have showed that the relative humidity and air temperature can inhibit or promote the growth of bacteria and viruses. So the temperature and humidity should be in a particular range as specified, to control infection and provide thermal comfort. It also has been defined low humidity could increase exposure to respiratory disease as well as affect comfort (Nahar, 2019). Every physiological strain applied to the patient will induce extra stress on top of stress related to the disease or injury of the patient which is undesired unless medical treatment requires so (Verheyen et al., 2011).

Medical treatment and the use of drugs can also affect thermal sensation and comfort perception. The aged are more likely represented in hospitals than the other part in overall demographic composition. Relative to younger counterpart, they generally

experience thermoregulate decreases, they prefer slightly higher temperatures, are attributed to lower activity levels (Verheyen et al., 2011). For these and other reason patients will be abnormally sensitive to high or low temperatures. The bigger challenge of Hospital buildings is its diverse occupants, with different thermal need. Patients, clinicians and nursing staff, support staff (administrators, cleaners, etc) and visitors, inhibiting the hospital for more days or years than the patients. All of these may occupy a certain space at time. Even though greater harbor of Hospitals are concentrated with vulnerable individuals. On the time of high ambient temperature, especially during heat waves hospitals are expected to provide safe haven for those at large who are suffering. Patients are the first priory for hospitals, the environment around boosts patients satisfaction and influence there the healing process. Evaluating the temperature mainly on wards which are not mechanically cooled is a key aspect (Hwang et al., 2007).

- ✧ Guidelines and recommendations for thermal environmental conditions of patient rooms. Different standards have fixed limits on environmental factors, which should be attained in patient room.

Table 2. Thermal comfort ranges in some standards and guidelines.

Thermal comfort ranges in some standards and guidelines.

	RH [%]	Design temperature [°C]	Maximum air velocity [m/s]	
ASHRAE; 2008 [4]	Max. 60	21–24	–	Inpatient nursing: patient room
ASHRAE; 2007 [5]	30 (W)–50 (S)	21–24	–	Hospital and outpatient facilities: nursing: patient room
ISIAQ; 2003 [6]	<60%, preferable <50%	–	–	Healthcare: patient rooms
College Bouw ziekenhuis-voorzieningen; 2002 [7]	–	22.5–25.5	–	Uses $-0.5 < PMV < 0.5$ for acceptable comfort range
VIPA; 2002 [8]	40–65	23.5–25.5/21–23	0.18/0.15	Optimal (summer/winter)
	30–70	23–26/20–24	0.22/0.18	Normal (summer/winter)
	30–70	22–27/19–25	0.25/0.21	Minimal (summer/winter)

(W, S) = Winter, Summer.

According to international standard Thermal comfort requirements should be considered on an individual basis for people with physical disabilities (Verheyen et al,2011).

2.12. Thermal comfort model

Thermal comfort first has been studied as phenomena to human scale. This helps to identify common criteria to describe the perception of different human beings and there level of interaction with the external environment (Fabbri & Focusing, n.d.).

As humans, our thermostatically system modifies our temperature through involuntary responses. For example, by sweating in high temperatures or shivering in cold temperatures to keep us thermally balanced and to avoid local discomfort. The human body can adapt to the external environment up to a certain range, but as soon as the limits are reached, the body's responses are perceived as uncomfortable. There were different research's held to combine quantitative environmental variables with individual variables. In 1970 P.O. Fanger evolved a theory through his climate chamber experiments. And he declared that thermal comfort could be found from evaluating the metabolic rate, clothing insulation and environmental conditions of an individual (Sebastian, 2020)

The experiment tries to control confounding variables like age, weight, and gender, It has been held in the Denmark University includes the participation of 128 subjects. After five years experiment Fanger proposes ways on the rating scale of a perceived sense of well-being. 1967, he published the equation in an article called "Calculation of Thermal Comfort" (Fabbri & Focusing, 2015). As the result of "Fanger's comfort equation", indicates how the occupants judge the climate. Using PMV, the Percentage of People Dissatisfied (PPD) can be predicted (Ekici, 2016).

2.12.1. Predicted Mean Vote (PMV),

PMV is an internationally accepted model. Fanger had developed the model to predict the mean thermal comfort of occupants. And he tries to predict how they feel towards the indoor climate (Ekici, 2016). Even though the model is popular method to evaluate thermal sensation of a group of people, some discrepancies shown when it's compared to people's real thermal sensations. Different studies have been made to evaluate the accuracy of the PMV. Most researchers agreed that the discrepancies have resulted from clothing surface temperature (t_{cl}), which is one of the components for the calculation of PMV. Researchers conducted in different climatic conditions

have proven that the PMV value is overestimated or underestimated relative to actual thermal sensation. Lately, different methods have been proposed to avoid incorrect estimation of clothing surface temperature (t_{cl}). The modified model of thermal prediction, named as PMV2, was obtained by a multiple linear regression considering the thermal sensation votes, the metabolic rate and the six heat exchange mechanisms. The application of the multiple regression increased the potential of PMV2 to obtain responses closer to those provided by the occupants of the thermal environment studied (Eduardo et al., 2019).

PMV of 0.5 can be interpreted as 90% of people in the space will vote they are comfortable, which is the translation of all six variables in to single output (Mcclurg, 2016).

2.12.2. Percentage of People Dissatisfied (PPD).

PPD is an index to predict the percentage of a large group of people likely to be dissatisfied with their thermal environment. 5% dissatisfaction level is tolerable in any environment, ASHRAE Standard 55 allow PDD up to 20%. For a given space to be comfortable 80% of the occupants need to be satisfied in the existing environment.(ASHARE 55, 2017).

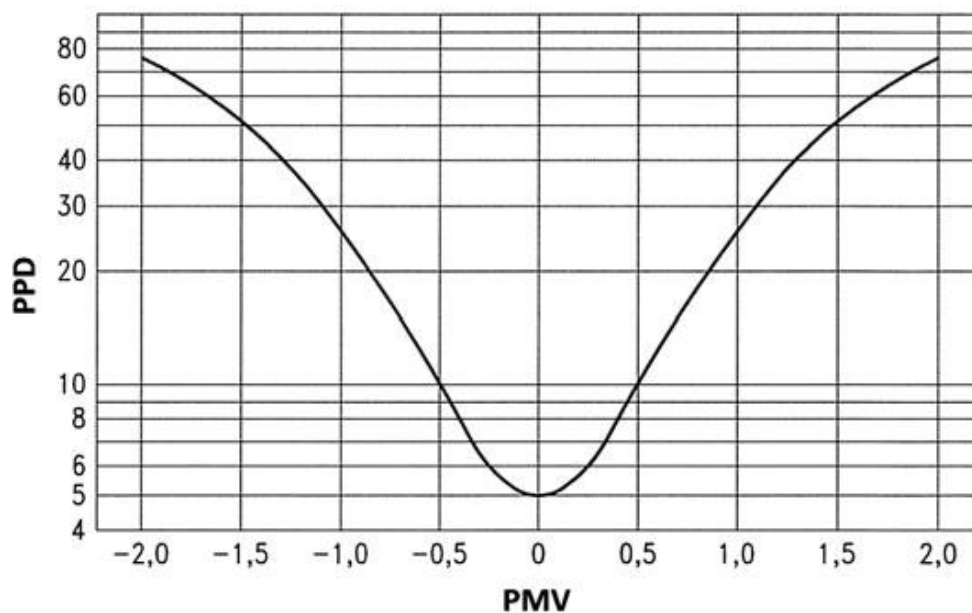


Figure 4. Relationship between PMV and PDD (ISO 7730)

2.13. HVAC systems

Through thousand years of civilization human race have been on progress to build better life on earth. Adapting the environment was the first challenge, in which humans came up with simple but sophisticated systems. After Industrial Revolution the applicability of Mechanical ventilation system became popular. The current energy crisis commingled with the inefficiency of mechanical systems in practice has led to a paradigm shift looking back on historical practice.

The general purpose of heating, ventilation and air conditioning (HVAC) systems is to provide more comfortable Indoor areas and acceptable indoor air qualities. Rather than creating controlling the heating and cooling process, the HVAC systems that create this excessive heating or cooling are also generating significantly higher carbon emissions than necessary. Not only are inefficiencies within our built environment impacting our own health and wellbeing, they are suffocating our planet too.

2.14. Standards on thermal comfort

Building standard and regulations have helped the progress of designing thermally comfortable living environment. Architects are working on ensuring residents thermally comfortable space and energy saving option (Hwang, & Shu, 2010). The first extensive scientific studies on thermal comfort held on fully controlled climate chamber. As well as consulting results of those field studies, provides a universal design criterion for thermal comfort across all building types and occupants. Gives clue for researchers on methods of thermal comfort evaluation. Depending on relevant researches held on indoor thermal quality local and international standards has been developed (Markov, 2003).

These standards' aim at presenting methods to evaluate thermal sensation and discomfort level of individuals exposed to moderate thermal environment. And define the acceptable thermal condition. Different countries have developed different standards for thermal comfort efficiency specification on building. Nevertheless most of them are derived from the three most frequently used international standards. ISO

Standard 7730, ANSI/ASHRAE Standard 55 and European standard EN 15251 are the three most used (Du, 2019).

Since comfort is the outcome of interaction of all possible factors. The standard addressed the possible environmental and personal parameters in detail. Gives definitions, makes a classification of the parameters and provides information for the conditions for an acceptable thermal environment. And specify the measuring range, accuracy, and response time of instruments measuring thermal environment parameters with in defied position and period (Markov, 2003).

As the standard was originally based studies of North American and European subjects, the discipline still presents uncertainty margins in its application. There are some ethnic and national-geographic deviations. Even if the standard is expected to apply with good approximation in most parts of the world, require further studies different microclimate is essential. Another area of uncertainty is regards the understanding of the art of comfort by different users such as children, the sick, the elderly, etc. ISO 14415 is meant for application in addition to ISO 7730 for determination and interpretation of thermal comfort in the case of people with special requirements, such as people with physical disabilities, pregnancy, sickness or normal aging (Fabbri & Focusing, n.d.).

This standard contains general considerations concerning thermal comfort perception as well as specification of conditions for thermal comfort. Also changes in mother-physiology and therm-sensation, therm-regulatory responses or thermal comfort perception are discussed and summarized for some specific disabilities in relation to thermal environments of concern (Verheyen et al., 2011)

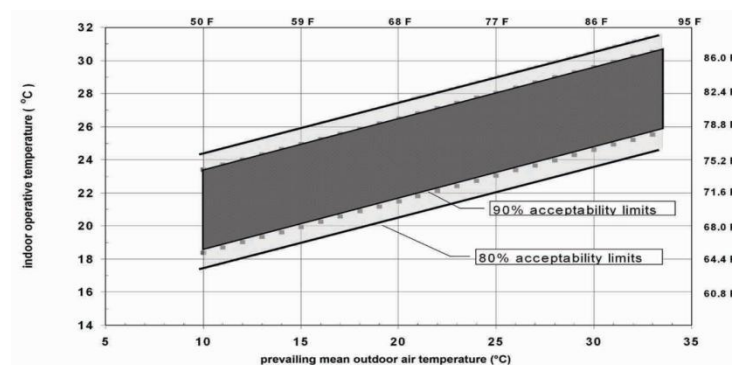


Figure 5 Acceptable operative temperature ranges for naturally conditioned spaces (ANSI/ASHRAE, 2017) (Du, 2019).

2.15. Measurement of thermal comfort

In recent years, researchers' interest in the adaptive theory of thermal comfort has led to qualifying and improving thermal environment, **subjectively** and **objectively** (Sopian et al., 2013). In order to estimate the thermal comfort level, accurate information on the thermal environment is essential. Acceptable thermal range can be achieved by objective measurement on environmental variables and subjective measurement of thermal perception.

2.15.1. Subjective measurement

Thermal comfort is subjective issue which depends on individual preference. It is hard to regulate the thermal environment to satisfy the whole crowd. Basically, People intuitively know these factors affect their comfort, it is up to each person to gauge their thermal comfort, but they have not been translated into metrics building designers can use. So the measurement focus on the following issues like Demographic factors, Thermal sensation, Thermal preference, Thermal acceptance, Thermal tolerance, Control ability of thermal conditions (Sopian et al., 2013).

Thermal sensation; is on a traditional ASHRAE 7-point scale. (+3 = hot, +2 = warm, +1 = slightly warm, 0 = neutral, -1 = slightly cool, -2 = cool, -3 = cold) is used to describe how they feels. (6)

Thermal preference; refer to the evaluation of preferable conditions compared to current conditions. The thermal preference scale asked respondents: "Right now, I prefer to be: cooler, no change, warmer".

Thermal acceptance; Acceptability was measured by directly asking respondents whether their current thermal environment was acceptable or not.

2.15.2. Objective Measurement

There are six physical factors affecting human thermal comfort, Four environmental factors and two personal factors.

Physical data for determining the level of thermal comfort and IAQ will be measured using appropriate equipment's. This measurement includes four environmental factors

- ◆ Ambient temperature,
- ◆ Mean radiant temperature (MRT),
- ◆ Humidity (RH),
- ◆ Air velocity (V),

All measurements were taken at a height of 1.0m above the ground and calibration was done prior to measurement. Two personal factors clothing insulation value and activity level (MET) will be estimated in accordance with the standard table of ISO 9920 and ISO 8996 respectively (Sopian et al., 2013).

2.16. Adaptive thermal comfort theory

Adaptive theory is different from the static heat balance model of PMV/PPD. It incorporate all opportunities used to adapt. And sensor signal shift the reaction of human body towards maintaining thermal equilibrium, due to past experiences and future expectations. Gradually the original reaction for the same and repeated environmental stimuli will be diminished. Most researches and study's explains that, healthy human being can resist the environmental thermal state through the three methods explained through Adaptive thermal comfort theory (Verheyen et al., 2011).

2.16.1. Behavioral adaptation

Most commonly used behavioral action is adjusting windows. Operating windows and fans, adjusting blinds/shades, changing clothing, and consuming food and drinks are some of adaptive strategies used by occupants, when the indoor conditions drift towards discomfort (Nicol, 2001). Adjustment includes personal, technological and

cultural responses that can change the heat and mass flows reining the thermal balance of the human body.

2.16.2. Physiological adaptation

For human body to be adjusted to extreme temperatures, of a few days to six months, may result in cardiovascular and endocrine adjustments. Vasoconstriction is the first physiological mechanism of human body. In cold environment it reduces blood flow to the skin, skin temperature and heat dissipation. The reverse is true for warm environment. If the temperature is too high human body produce Sweat for evaporative cooling. If it exceed a certain limit, it might cause heat stroke. If the temperature is too cold the muscles are forced to produce heat as a result of shivering.(Szokolay,2010)

2.16.3. Psychological adaptation

Thermal comfort is a condition of mind, which strongly relate to psychological term. Including the altering of perception of sensor signals due to past experiences and future expectations that in turn alters reaction of the human body in order to maintain thermal equilibrium (Verheyen et al, 2011).

when it came to hospital environment it's so hard to go through this theory. People with physical disabilities have confined adaptive opportunity and special attention should be paid to them. Particularly in conditions away from thermal neutrality as uncomfortable conditions bear on patients both physically and mentally. Within restricted mobility, Low cognition to thermo regulation, within severely restricted environment and clothing, And different medications. The influence of disease, treatment or other influence specific to the hospital setting is makes it difficult to reconcile the needs concerning the thermal environment of the different hospital users (Verheyen et al, 2011).

2.17. Experience of developing and developed countries on thermal comfort

Within the development of globalization human kind came to believe that all problems could be solved by high technology and that it was no longer necessary to

live in harmony with nature. Nevertheless the threatening crisis of global warming has persuaded the whole world to reconsider its relationships with nature (Norbert, 2015). The building industries have been tiring to face the challenge through sustainable design. The phenomena of temperature rise or overheating question the performance of the building in terms of thermal comfort (Getachew, 2020).

In addition, the energy demand of buildings has increased rapidly due to both the improvement of living standards and the globalization of modern architecture. The building sector covers almost half of the energy consumption of the society. And Much of that energy is used to cool and/or heat buildings. Air conditioning accounts for 44% of a building's energy consumption (Raish, n.d.). And finally, cooling a building is especially a challenge in countries where few resources are available. As result developed country's conducted studies on thermal comfort and identify the degree at which thermal variables affect human thermal comfort under specific climatic conditions (Yanget *al.*, 2014).

Modern world architects and engineers are applying passive systems not only residential buildings but to super-skyscrapers and medical facilities. Through advanced technology with regards to materials and the relearned lessons of the past, the built environment is prepared to endorse a ventilation revolution. Looking at the construction industry in developing countries; it is very fragmented and underdeveloped with inadequate capacity for the planning and design (Heilman, 2016). The progress of creating thermally comfortable environment doesn't go further than awareness creation stage (Subramanian *et al.*, 2017).

At first developing countries were moving with “***growing at any cost***” slogan, but through time these movement results diminutions of the environment. The forecast made by UN-habitat indicates that developing countries will consume 65% of the world's energy by 2040. About 57% of global greenhouse gas emission originated in developing countries. Accordingly, climate change presents this region with marvelous challenges probable more so than any other region on the whole world (UN Report, 2008). Developmental priorities as well as the cultural context within which design and construction will take place (Heilman, 2016).

Exploding the concepts and principles of vernacular trends on any way possible. The use of local material, construction techniques and harmony of building elements need to be analyzed according to their surrounding local climate. These can lead to such a building not only warm in winters and cool in summer but are also more economical to build and maintain.

2.18. Summary and gap

Throughout the review relevant studies related to the concept of thermal comfort have been discussed. Basic factors, measurement methods, and standards have been clarified. Each of these studies was relevant for this study or has been used in this study. There is different progress made to sustain the thermal challenge globally. The studies imply the need of passive design for health and productivity of occupants of indoor environment. The demand of air conditioning is affecting the energy consumption of buildings mainly on hot regions. That makes the concept of thermal comfort expensive.

In Ethiopia also there are a number of studies held in office building in Addis, Ababa city and residential buildings in Jimma and one of the hot regions Semera. Regardless of there is no research held on thermal efficiency of hospital environment.

CHAPTER THREE

3. RESEARCH METHODOLOGY

3.1. Description of study Area

3.1.1. Geographical location

The study was conducted in Dire Dawa Administrative city from mid of April to March 2021. Dire Dawa is located in the Eastern part of Ethiopia, 515 km from Addis Ababa and 47 km from Harar town. It is enclosed by Ethiopian Somalia and the State of Oromia. Dire Dawa moved out of federal administration to become a chartered city in 2004 after the federal parliament approved the city charter in proclamation 416/2004 (Asnake,2014). It is located with in a latitude and longitude of 9°35'35," N,41°51.967' E The city was an impressively planned city with central straight avenues and quarters (Kapil & Brajesh. 2019).

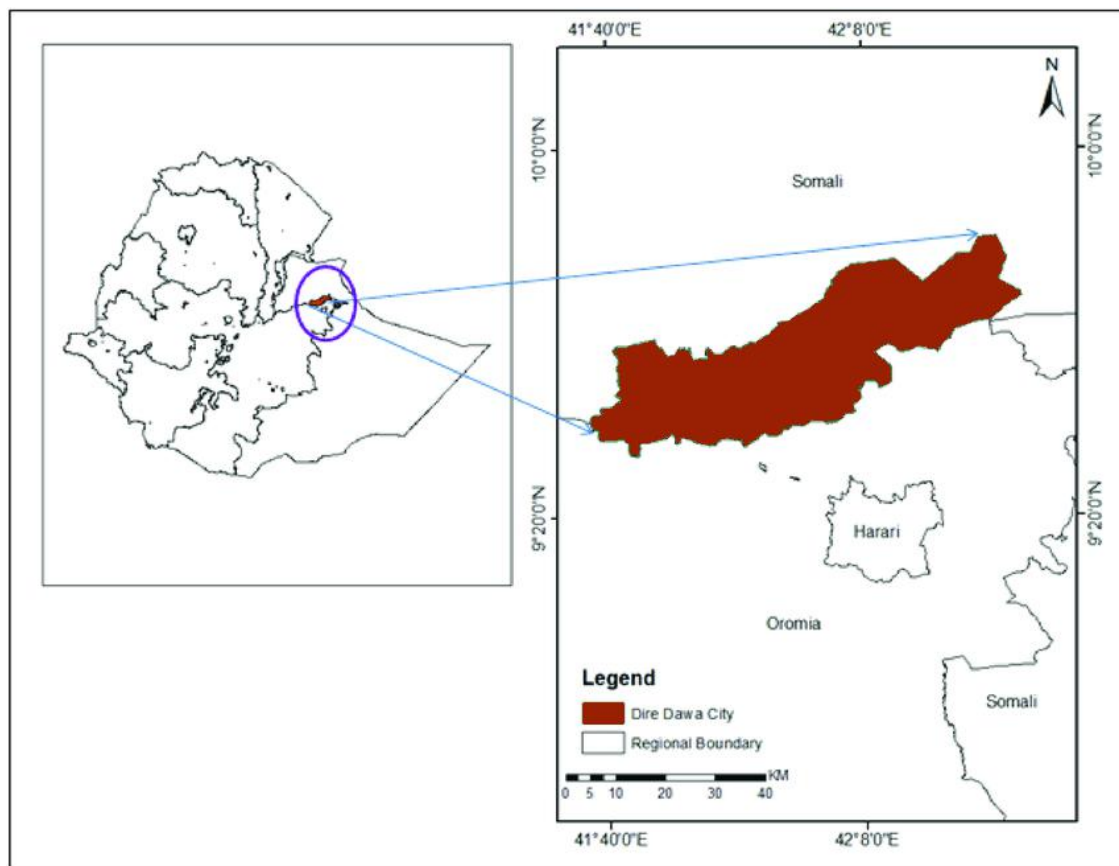


Figure 6. Location map (Ethio-GIS data)

3.1.2. Climatic data

Ecologically, the city lies within a semi-desert scrub ecosystem. It has a hot temperature with average maximum temperature and rainfall of 32.8 °C or 91.0 °F and 637 mm, respectively. According to Ethiopian National Meteorological Agency (NMA), the mean minimum temperature has been increasing throughout the country, particularly during the cool months, by 0.37 °C per decade in the last 60 year. The maximum temperature has been increasing by about 0.67 °C every 10 year (Kuo et al, 2015).

Table 3. Annual climatic data for administrative city of Dire Dawa (source; NMA)

Climatic Data For DDAC												
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Record high °C	38.0	42.0	42.0	37.8	39.9	39.5	38.2	37.3	37.4	38.4	36.4	42.0
Average- high °C	28.3	29.5	30.9	30.9	33.7	33.7	32.3	31.0	32.3	32.1	29.9	28.3
Daily mean °C	22.1	23.2	25.2	26.0	27.8	28.5	27.0	26.3	26.6	25.9	23.3	22.3
Avg , RH%	55	56	55	55	47	44	50	53	52	45	51	51

3.1.3. Socioeconomic analysis

DDAC is the third-largest city covering a total area of 1,558.64 square kilometers with an estimated density of 237.2 people per square kilometer. It has 9 urban kebeles (small administrative units of Ethiopia) and 38 rural kebeles. Based on the 2020 Census, the total population of Dire Dawa Administrative city is more than 500,000 of which females account 51.6%, with a 4.42% annual growth rate. Most of its inhabitants are Oromo, Somali, or Amhara people.

The City has given health care services for the catchment population in different disciplines. Two public hospitals, 15 health centers and 34 health posts provided services. Out of these health facilities, two hospitals and seven health centers are located in the central part of the administration while the rest are located in the peripheries of the city (Cultures, 2018).

The city is an industrial centre, home to several markets and the Diredhawa Airport. The economy of Dire Dawa has grown significantly. The new industrial park, named for various industries, includes textiles and clothing, car assembly, food processing, fertilizers, electronic and paper, in action, creating many jobs. In 2019 (T, 2015).

3.2. Research design

The study used a cross-sectional study design. Quantitative and qualitative data were collected on environmental variables and occupants perception levels regarding the thermal comfort performance of selected case buildings, From mid-April to May 2021G.C. Under the cross-sectional study, Environmental variables and occupants' thermal perception is measured relative to the standard of ASHRAE 55.

The effect of each variable is correlated with the thermal perception level of occupants using the multivariate method. The study identified the Permissible level of environmental variables and their influence on occupants thermal perception level. Environmental variables are physically measured. Thermal perception level is measured using a standard questionnaire formulated based on ASHRAE 7 sensation measurement scales.

3.3. Types and sources of data

To achieve the major objective, the study has used hybrid data from secondary and primary source. Primary data were collected through field survey, observation, direct instrumental measurement, captured photos, structured questionnaires and interviews. Structured questionnaires address patients, clinical staff and visitors who have stayed on the sample space. Physical measurement includes air temperature, humidity and air velocity. Secondary data was collected from floor and structural plan, books, journals, internet web sites and related literature's.

3.4. Sampling techniques and procedures.

In this study, two public hospitals (Dillchora referral hospital, Sabiyan General Hospital) were selected purposely from the total 15 health centers. These two institutions are the only public hospitals rendering health service to majority population.

Stratified samplings have been used to identify three functional space from each institutions. Patient room, examination room and waiting area are selected to address three group of hospital user, patients, clinical staff and visitors. Environmental variable and thermal perception level is measured in three sample rooms from each hospitals. Both subjective and objective measurement were taken in three different hours of the day. Sample population for subjective measurement have been selected Based on the accommodation capacity, more than half of occupants in each room have been participated in the study. In which the study addressed 48 occupants .

The type of ward and patients have been selected purposely by the researcher in regarding the tolerance to attain the study requirement, to decrease the confounded relationship, which may result from the type of illness and medication effect. Depending on the suggestion of medical professionals, the study select PNC ward and wound care unit.

Clinical staff and visitors are selected using simple random sampling. Sample rooms are oriented in different orientation, the study have tried to consider the relative outcome. The objective and subjective requirement of the study is consider under mixed sampling procedure.

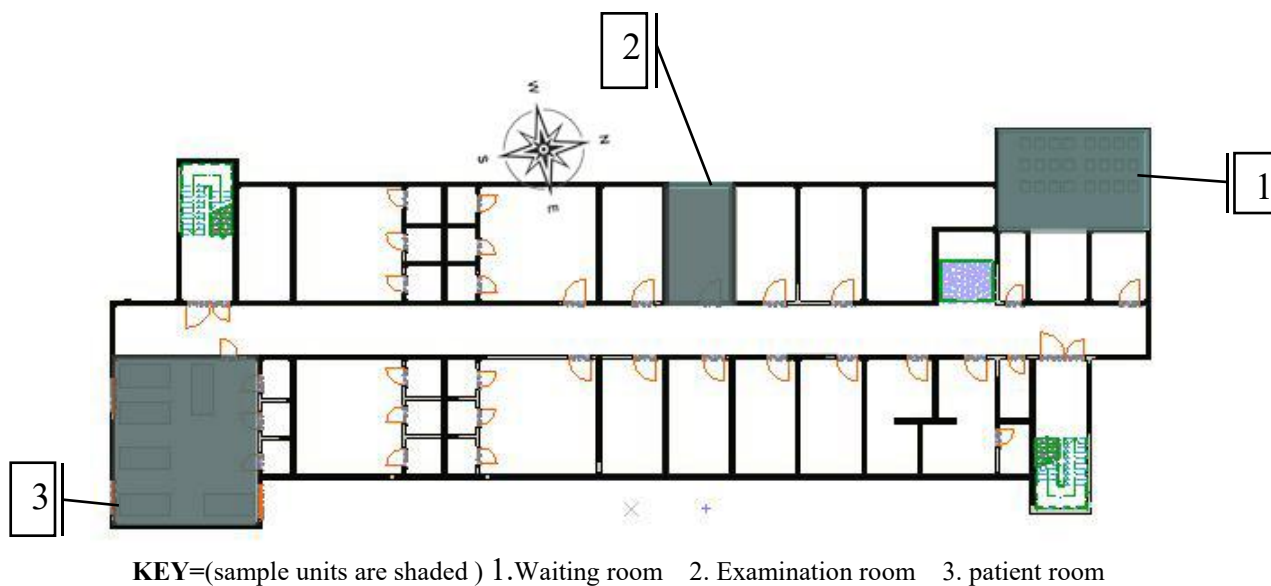


Figure 7. Floor plan/ level two/ Dillchora hospital



Figure 8; PNC and Examination room/Dillchora hospital.

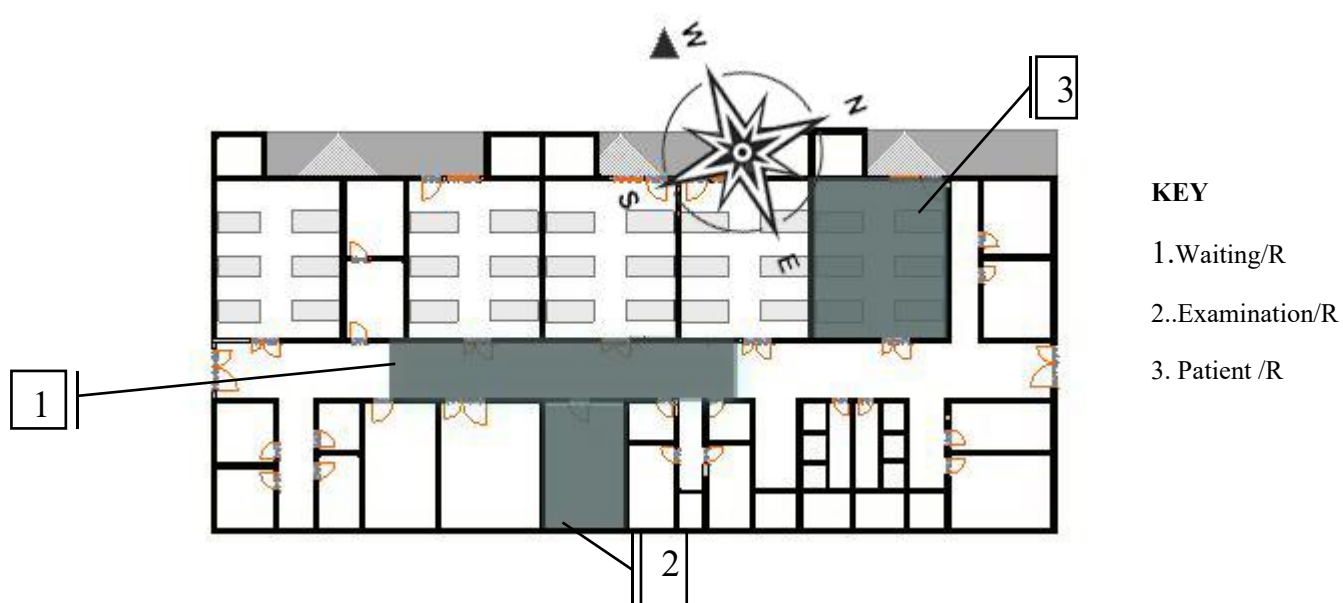


Figure 9 Ground floor/ IPD -Sabian General hospital



Figure 10. IPD ward in sabian general hospital

Table 4. Orientation of sample spaces

Sample hospital	Sample space	Orientation Relative to the solar radiation.
DillChora Referral Hospital	Examination room	West
	Patient room(PNC Ward)	South-East
	Waiting area	North-West
Sabian General hospital	Examination room	East
	Patient room(wound care)	West
	Waiting area	South

3.5. Methods of data collections

This study analyzes the thermal requirement of patient's staff and visitors at two hospitals building in Dire Dawa town. Three different types of rooms were selected from each hospital. Objective physical measurements and subjective assessments of the thermal environment were performed for selected room. While personal variables related to metabolic rate and clothing insulation will be determined with tables and data found in international norms.

3.5.1. Physical measurement of environmental variable

Temperature, humidity, and air velocity are the main environmental parameters listed as the first three factors affecting the thermal capacity of a given space in international standards like ASHER and CBE. The study measures these three parameters during the survey using three Digital thermo-hygrometer, and one digital anemometer respectively. Measurement is held According to the standard of ISO 7726 (Ergonomics of the thermal environment - Instruments for measuring physical quantities). The instruments have been calibrated before measurement. Based on the standard parameters were measured at a height of 1.1m on the center of the room away from any heat source. Depend on the respond time; the instruments were set inside the room before the record to ensure acclimatization of the space thermal environment. Special care was taken in order to ensure that the instruments would not disturb patients comfort. The record has been held with two day interval in sample functional rooms, For 15(fifteen) days within April and May warmest time of the year. For each sample institutions, Three environmental data is collected in three different room in three different time of the day, based on the ASHRAE 55,2013.

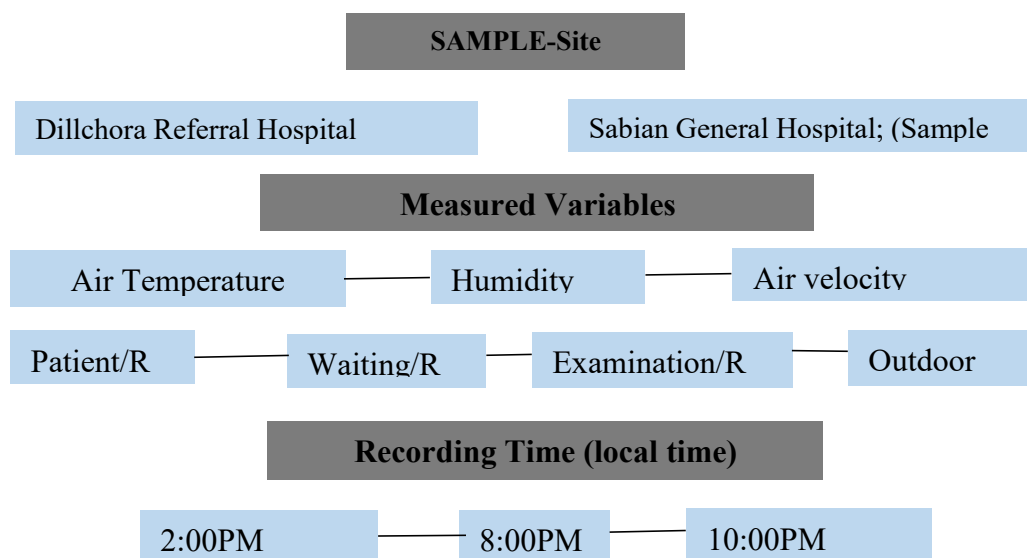


Figure 11. physical data distribution of sample



Figure 12. Sample examination room



Figure 13. Sample Patient room .

3.5.2. Standard questionnaire

Structured questioner is formulated based on ASHRAE 7 sensation measurement scale. Volunteer subjects hospitalized in wards, staff and visitors were target populations. Demographic information (age, gender, length of hospitalization), and other related information's were surveyed first.

Depending on the effect of sun angle on thermal condition of the day, questioners were released within three-hour interval starting from 2:00 PM – 10:00PM local time. Considering medical status of sample patients are asked to rate their thermal environments by thermal sensations, thermal sensation, preference and thermal satisfaction level. The questioner includes a checklist filled by investigator for

clothing worn at the time of visit. A total number of 48 questionnaires were completed, a total of 144 surveys has been made. The structured questionnaire is attached in Appendix B,

ASHRAE 7 point sensation scale is listed below,

Table 5. ASHRAE 7 point sensation scale.

ASHREA Standard							
Perception scale	-3	-2	-1	0	1	2	3
thermal sensation	Cold	Cool	Slightly cool	Neutral	Slightly warm	Warm	Hot
Thermal preference	Much cooler	Cooler	Slightly cool	No change	Slightly warmer	Warmer	Much warmer
Satisfaction scale	Very dissatisfied	Dissatisfied	Slightly dissatisfied	Neutral	Slightly satisfied	Satisfied	Very satisfied

3.5.3. Field survey

The existing physical structure of sample rooms has been analyzed. Orientation, space size, window ratio building material and other design elements affecting the thermal sensitivity of dweller's have been included. The extent of thermal condition, methods used to maintain the indoor environment and the reaction of occupants have also been observed under the survey. Pictures have been taken to depict the existing physical condition of the space with the occupants with their full permission.

3.5.4. Informal interview

Informal interview has been held with physicians to better understand the type of illness and medication the sample population, are taking, regarding there thermal status. The physicians were selected relative to their specialization on the field.

3.6. Method of data analysis

In indoor comfort evaluation great prediction end result can be achieved from combination of subjective and objective measurement (Verheyen et al., 2011). environmental and thermal perception data have been analyzed using SPSS version 24.

and excel spread sheet. Indoor thermal environment parameters found in the building (air temperature and relative humidity and air velocity) were compared with the comfort zone defined in ASHARE 55 Standard as discussed in the literature review section 2.7. The study identified the relation between measured environmental variables and thermal perception level using multivariate correlation. The result of the study was presented using descriptive statics, table, chart and figures, with meaning full interpretation.

3.7. Materials

3.6.1. Digital thermo hygrometer,

The thermo-hygrometer measures both air humidity and temperature. The model of thermo hygrometer used in this study measure humidity and air temperature within the range of 10%-99%and 10⁰c-70⁰c(14⁰F-15⁰ F) respectively.The thermo hygrometer is versatile in that it can take non-destructive measurements. The device 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.

A **hygrometer** is an instrument used to measure the amount of water vapor in air, in soil, or in confined spaces. Humidity measurement instruments usually rely on measurements of some other quantities such as temperature, pressure, mass, a mechanical or electrical change in a substance as moisture is absorbed.



Figure 14. Digital ThermoHygrometer

3.6.2. Air velocity meters

Commonly called **anemometers**, are used to measure the speed and/or volume of air movement. The study have used AS836 model a high-tech air velocity measure, digital anemometer using sensor.



Figure 15. Smart sensor Anemometer.

Informative Appendix 1(one) explains the description, features, and specification Thermo hygrometer and anemometer. Structured questionnaire is also attached in Appendix 2 (two).

3.8. Data quality assurance

Even if there are different confounding variables regarding the nature of the topic this study tries to use methods that can enhance better quality data. Sample populations have been selected with extensive study for less manipulation regarding their medical status; it has been arranged for investigators to approach mainly patients as medical staffs. The value of measuring instruments has been cross checked with the standard temperature. The questionnaire first developed in English version has been translated to local languages of the study area (oromifa). Back translated to English version to ensure its consistency. The interview has been conducted using local version of a questioner.

Through determining users perception of the existing thermal climate Questioner has been disposed simultaneously for all samples.it reduce fluctuation depending on time

and situation. One-day intensive training had been given to data collectors and supervisors, about the purpose of study, and the device also an overall data collection procedure to be eminently maintained by them during data collection time.

3.9. Ethical Considerations

For quality output the study has given prior concern on awareness creation on purpose and objectives of the study. Consent from each study participants have been obtained, before data collection. The anonymity and confidentiality of information have been secured. Legal permission has been attained from Dire Dawa health bureau and selected Hospitals management. All material used throughout the study have been acknowledged. The measuring equipment has been located in a way that doesn't disturb hospital user. The researcher has analyzed the data relative to standards without manipulation.

CHAPTER FOUR

4. RESULT AND DISCUSSION

The study analyzes the thermal performance of two governmental hospitals. Subjective and objective Measurement is taken in six selected spaces, the Patient room, Examination room, and Waiting Area. Temperature, humidity and Air velocity has been physically recorded and scientifically analyzed. Digital devices is used to measure the three environmental parameters. The recording has been held for 15 days with two days intervals. A total of 924 data sets were obtained between the heating season of April and May 2021GC.

Subjective data is analyzed according to ASHARE 55. The data set contains an equal number of samples from each hospital. In general basic thermal Parameters are identified and correlated with the thermal satisfaction scale of occupants (patients clinical staff and visitor).

According to the study result most environmental data are out of the comfort rage stated in ASHARE 55. According to the correlation result, the variables influence thermal perception in different level.

4.1. Characteristics of Target population

4.1.1. Sample distribution

Table 6. sample population distribution

Sample size	Sample size of hospitals	Study population		Gender
48	24=50%, Dillchora	18=37.5%	9=Post Natal	50%
	Referral Hospital	(IPD)	9=Wound Care	Female
	24=50% Sabina	Patients		50%
	General Hospital	18=37.5%Clinical Staff		Male
		12=25% Visitors		

The sample population contains 48 volunteers, 24 from each hospital. In which patients, clinical staff, and visitors participated in a 0.37:0.25:0.37 ratio. The

percentage ratio is assigned as controlling variables for confounded variables resulting from patients' medical status and emotional stress of the hospital environment.

Nine female Patients in PNC ward attending treatment in dillchora referral hospital and nine male patients in wound care unit from sabian general hospital have been analyzed. The study contains a total number of 18 patients. 12 visitors and 18 clinical staffs are also participated.

4.1.2. Admission Period

The majority of patients and visitors have stayed within the space for days. 27% of patients respondents stayed for weeks. 88% clinical staff stayed for years. Depending on the duration of sample characters, the thermal environment can be surely felt, which will support the accuracy of thermal sensation measurements.

Table 7.the percentage duration of patients, clinical staff, and visitors.

Range	Days	Week	Month	Year
Patients	10	5	3	0
Clinical Staff	0	0	2	16
Visitors	8	3	1	0
Percentage contribution	30%	16%	12.5%	33%

4.1.3. Age of the Respondents

The age group of the total population n=48(100%) ranged from 18 to 67 years old. As shown in the figure below n=12(25%) of the respondents are within an age group of 25-40.

The sample contains equals a number of respondents within the range of 15-25 and 40-60 age group n=6 (12.5%) and n=7(14.5%), respectively. n=3(6%) of the total sample population is above 60.

Table 8. Table, the percentage age distribution of patients, clinical staff, and visitors within the sample group.

Range	Patients	Staff	Visitors
15-25	4	2	3
25-40	9	11	4
40-60	3	3	4
60+	2	2	1
Total	18-37%	18-37%	12-25%

In the past decades, studies have argued that the thermal sensation of the elderly is different from that of the young. Thermal sensitivity decreases with advanced age. Fanger adopted (PMV) index to predict the thermal difference between different age groups. Comparing the result 0.5-point difference between the actual mean thermal sensation of elders and comfort meter and the Fanger Comfort Equation. Most of the researches confirmed the thermal sensitivity of elderly people was low and they were not sensitive to changes in temperature. The thermal adaptation behavior of the elderly exhibited seasonal differences (Jiao et al., 2017).

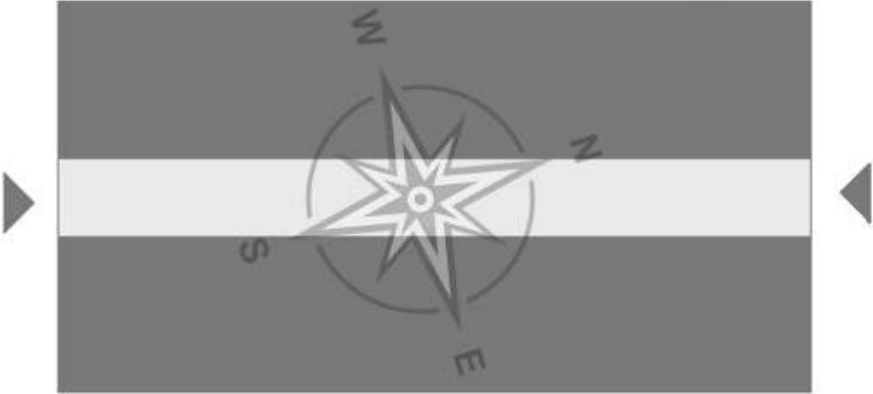
As we see in table 8 the age group of sample respondents contains different age groups, the objective of the study is to identify the overall thermal perception of all occupants with a different character.

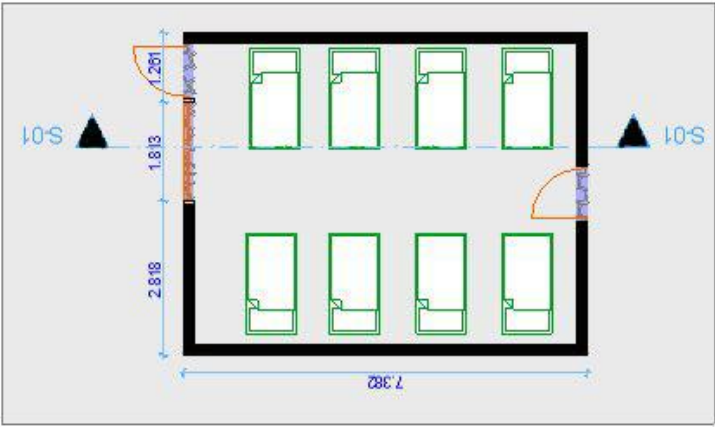
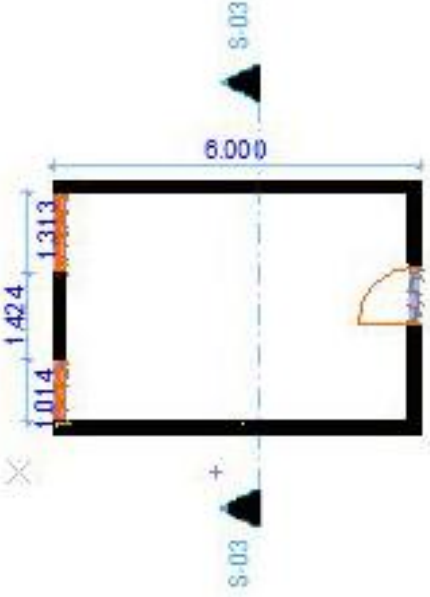
4.2. Physical characteristic of sample units

The concept of sustainability is the synergy between design and construction solutions. Architectural design use passive techniques to optimize the use of natural resource. which help for energy consumption drop-off and better satisfaction on indoor climate.

A. Sabina Hospital

Table 9. Physical characteristic of sample spaces in sabian hospital.

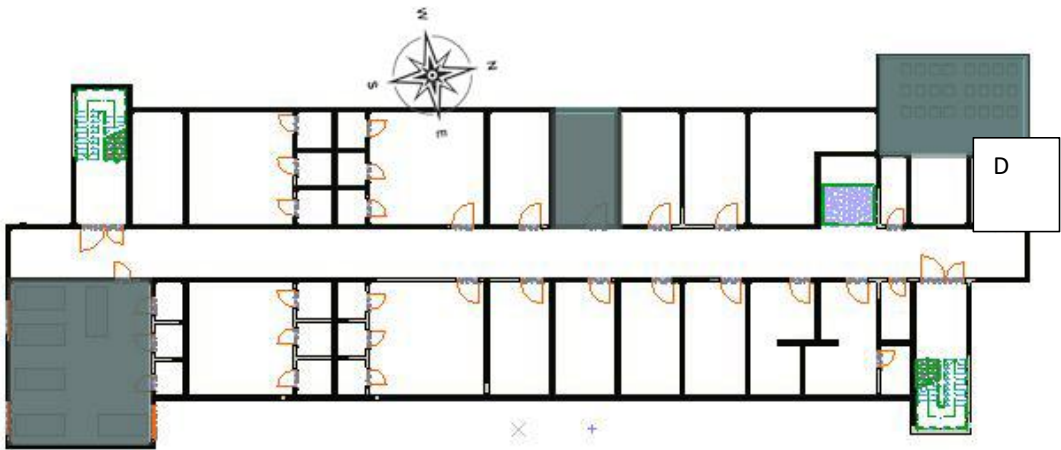
Sabian general hospital ; was established in 1934, by a rail way company. IPD ward contains two maternity, one wound care and a general rooms facing towards west north. The opposite side of the block contain two isolation room, one procedure room, and one examination room including rest rooms facing towards east. The corridor used as waiting area for visitor and patients. The longer side of the building is oriented west-north receive more solar radiation in the summer. 	
Patient Room	In IPD ward there are five patient rooms including the sample room. Each accommodates 8 individuals including family and clinical staff. The main face of the room is oriented towards west. ◆ The area of room is 43.2 m²(6m*7.2m), ◆ volume of 138.2 m³. 2.63m from floor to ceiling with a 0.87 m deep space above (floor to floor height 3.2 m). ◆ The window area was 2.59 m² (4mm thick glazing), covering 6 percent of the floor area of the room. The minimum glazed area of a space intended for human occupancy shall not be less than 15 percent of the floor area of the room served (EBCS 12) ◆ The window is oriented towards west West is a crucial orientation. Since the high intensity of solar radiation is received during evening hour. The window wall ratio WWR is 7.33%.

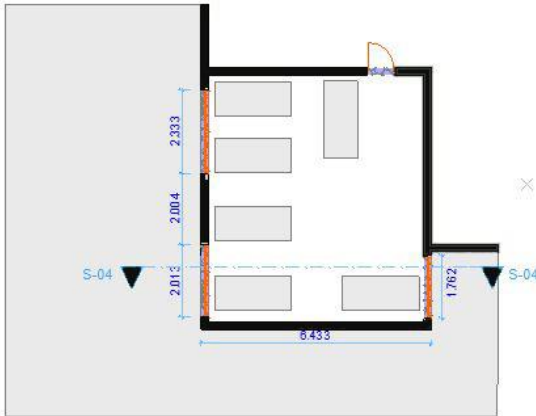
	
Examination Room	In IPD ward there are two examination rooms including the sample room. Each accommodates 3 clinical staffs and patient The main face of the room is oriented towards east. ◆ The area of room is 23.7 m^2 ($6\text{m} \times 3.95\text{m}$), ◆ volume of 75.84m^3. 2.63m from floor to ceiling with a 0.87 m deep space above (floor to floor height 3.2 m). ◆ There are same type and sized two windows found in opposite corner of the room. window area of each windows was 1.29 m^2 (4mm thick glazing), covering 11% of the floor area of the room. It is below the standard. ◆ The window is oriented towards east. receive max radiation during summer. The window wall ratio WWR is 4.89%. 

Waiting area	In IPD ward have no separate space for visitors to wait. The corridor used as the waiting area for patients and visitor. The average accommodation level with in the study period is 7 individuals at a time. The space had no opening there is door in the two opposite side, Oriented towards south and north. ◆ The area of room is 45 m²(2.5m*18m), ◆ volume of 144m³. 2.63m from floor to ceiling with a 0.87 m deep space above (floor to floor height 3.2 m). ◆ There are same two metal doors found in opposite corner of the corridor. The area of each door was 33.6 m² (4mm thick glazing), quality clear sheet glass glazed to metal bend.
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B. Dillchora referral Hospital

Table 10. physical characteristic of sample spaces in sabian hospital.

Dillchora referral Hospital IPD ward contains five maternity, four examination rooms, one waiting area and three nurse stations with different orientation. The longer side of the building is oriented west. 	
Patient Room	The sample room is PNC unit accommodating 8 patients visitor. The room is oriented towards south and east, the wall with windows is

	oriented towards the south. ◆ The area of room is $32.25 \text{ m}^2 (6.45\text{m} \times 5\text{m})$, ◆ volume of 103.2 m^3. 2.63m from floor to ceiling with a 0.87 m deep space above (floor to floor height 3.2 m). ◆ There are three windows, $(1.53\text{m} \times 1.73\text{m})$ two pieces oriented towards the south covering 5.93 m^2 and 1.73×0.75 sized window towards the north. Covering a total area of 7.23 m^2 (4mm thick glazing), covering 22.4% of the floor area of the room ◆ The window is oriented towards south The south part of the building facade orientation receive max solar radiation during winter which is preferable in which the summer season need protection ◆ The window wall ratio WWR is 5.94%. 
Examination Room	Examination room oriented towards west. ◆ The area of room is $15 \text{ m}^2 (3\text{m} \times 15\text{m})$, ◆ volume of 48 m^3. 2.63m from floor to ceiling with a 0.87 m deep space above (floor to floor height 3.2 m). ◆ There are same type and sized two windows found in opposite corner of the room. $(1\text{m} \times 1.5\text{m})$ the total window area was 3m^2 (4mm thick glazing), covering 20% of the floor area of the room. It is below the standard. ◆ The window is oriented towards west. receive max radiation during summer. ◆ The window wall ratio WWR is 9.6%.

Waiting area	Waiting area facing to north The average accommodation level with in the study period is 18 individuals at a time. The space had no opening there is door in the two opposite side, Oriented towards south and north. ◆ The area of room is 18.49 m²(4.3m*4.3m), ◆ volume of 59.16 m³. 2.63m from floor to ceiling with a 0.87 m deep space above (floor to floor height 3.2 m). ◆ There are three windows, (1.53m*1.73m) two pieces oriented towards the north covering 5.93 m² and 1.73*0.75 sized window towards the south. Covering a total area of 7.23 m² (4mm thick glazing), covering 22.4% of the floor area of the room the same but opposite side of patient room
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Building orientation is basically the positioning of building with respect to the sun. Usually done to maximize solar gain in appropriate time of the year. when required in cold climate and minimize solar gain in hot climate (A. Eljojo, 2017).

- North or south facing wall offer the best opportunity for shading sun on window and wall by the use of eave over hangs which don't obstacle breezes.
- In warmer climate orientation east of north can allow better capture of cooling breezes. Poor orientation and lack of appropriate shading can exclude winter sun and cause overheating in summer by allowing low angle east or west sun to strike glass surface at more direct angle, reducing reflection and increase solar gains.

The major problem here is direct sunlight entering the window creates Excessive brightness or overheating or lack adequate lighting depending on seasonal variation.

4.3. Thermal Perception Level of Indoor Environment

predicting the thermal perception of a population is an important step in determining what conditions are comfortable. Thermal perception of the indoor environment is analyzed using the seven-point thermal sensation scale of ASHRAE. The analysis has identified the thermal sensation, thermal preference, and satisfaction level of patients, staff and visitors in the hospital buildings.

4.3.1. Thermal sensation

Thermal sensation describes the perception of occupants about the existing indoor environment (Eduardo et al., 2019). PNC and wound care patients, clinical staff, and visitors participated. ASHRAE 7 point sensation scale is used. The figure below shows the mean thermal sensation of sample population from the two institutions.

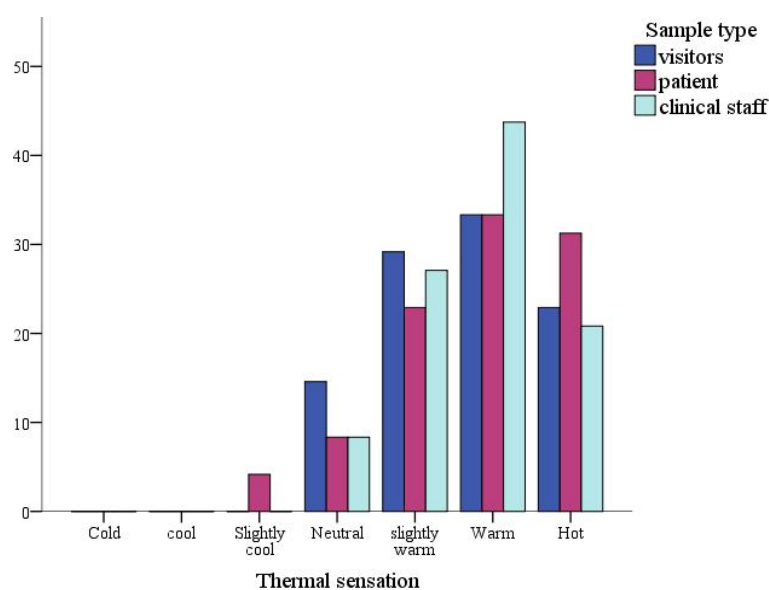


Figure 16. Thermal sensation of different sample populations,

Table 11. Thermal sensation of different sample group from the two institutions.

According to the above table, 64.5% of sample patients are out of the ASHRAE standard comfort zone (slightly cool, neutral ,slightly warm).

Patients in wound care unit and visitor prefer the outdoor space. Research's shows that hot weather is one of the factors affecting wound healing (Protocol, 2018).The

exposure to the outdoor environment create infection and increase the level of contamination.

Sample Type	Cold (-3)	Cool (-2)	Slightly Cool (-1)	Neutral (0)	Slightly Warm (1)	Warm (2)	Hot (3)
Visitor	0.0%	0.0%	0.0%	14.6%	29.2%	33.3%	22.9%
Patients	0.0%	0.0%	4.2%	8.3%	22.9%	33.3%	31.3%
Staff	0.0%	0.0%	0.0%	8.3%	27.1%	43.8%	20.8%

The indoor environmental quality, directly and indirectly, affects PNC patients. The first two days in PNC ward are critical for patients. (Protocol, 2018).



Figure 17. wound care patients in sabian general hospital.



Figure 18. visitors in outdoor space

43% and 20.8 % of Clinical staff also had voted “warm” and ‘hot’. According to ASHRAE sensational scale, three central options (-1 to +1), indicates comfort zone (ASHRAE, 2017), based on this 64.6% respondents were not on the comfort zone. Relative to the two sample groups the percentage of visitors in the discomfort

zone is lower, 56.2%. From the total sample population, only 38.2% of them are in the comfort range.

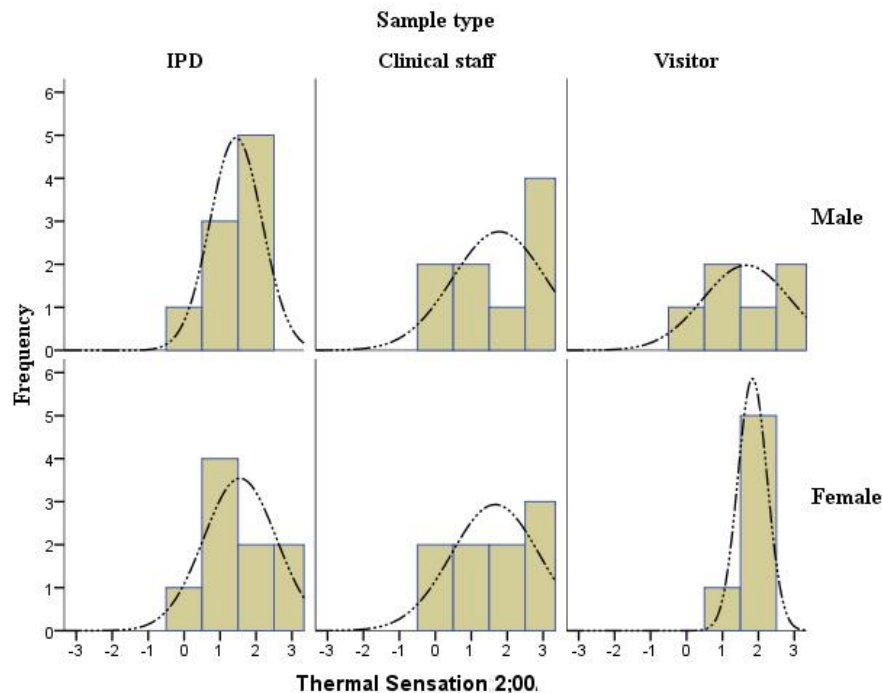


Figure 19. Thermal sensation of different gender correlated to different sample type.

We can see from figure 21 that patients voted higher temperature. The indoor temperature has been felt slightly higher in male patients. Female staff and male visitors have voted lower temperature than male staff and female visitors.

Depend on recent research, Even if there are average differences, thermal comfort preferences between sexes seem to be Small. Balancing the heat loss and gain, the Human body attain core internal body temperature. These minimize the heat exchange with the environment. According to studies, males feel discomfort earlier than females in rising temperatures. They have high levels of discomfort sensation than females (Wyon, et.al, 2009).

Termo-regulation capacity differs between women and men due to biological reasons, Hormone, body surface to body mass ratio, fat content, are some of them (Kaciuba-Cecilio & Grucza, n.d.).

As we observe from the above figure, the reaction of the sample population has shown a slight difference between men and women. Mentioned as one confounding

variable the study has tried to control its effect by contributing an equal amount of samples from both genders to each sample type.

✧ **Thermal discomfort time (for patients, in Dillchora referral hospital)**

As shows in table 12, the thermal sensation of building occupants is affected by the indoor environment in the afternoon, especially from 6:00-10:00. 64.6 % of the occupant felt uncomfortable during that time. The physical measurement of environmental data shows higher temperature range in the after noon.

Table 12. over all Thermal sensation in different time of the day.

Thermal Sensation	Cold (-3)	Cool (-2)	Slightly cool (-1)	Neutral (0)	slightly warm (1)	Warm (2)	Hot (3)
2;00	0.0%	0.0%	25.0%	27.1%	31.3%	16.7%	0.0%
6;00	0.0%	0.0%	4.2%	8.3%	22.9%	33.3%	31.3%
10;00	0.0%	0.0%	0.0%	6.3%	29.2%	43.8%	20.8%

Source: Data survey April and May, 2019

The morning condition is relatively comfortable for more than half of the respondents. The thermal sensation scale is distributed evenly among the sample population with no extreme high or low reaction.

4.3.2. Thermal Perception

Most of the time, thermal comfort phenomena are studied from a thermal sensation perspective on the immediate environment from people's perception. But thermal preference scale is also a measuring scale, which helps us explore thermal perception on the individual appreciation base. While the TS values imply a tolerable thermal range scenario, the TP analysis offers the idealization of thermal pleasing conditions.

The table below shows the mean thermal perception of sample population from the two institutions.

Table 14. over all Thermal preference of different sample populations

Sample type	Much cooler (-3)	Cooler (-2)	Slightly cool (-1)	NO change (0)	Slightly warmer (1)	Warmer (2)	Much Warmer (3)
Visitors	16.7%	29.2%	37.5%	12.5%	4.2%	0.0%	0.0%
Patients	35.4%	31.3%	16.7%	2.1%	14.6%	0.0%	0.0%
Clinical staff	16.7%	41.7%	22.9%	4.2%	14.6%	0.0%	0.0%

Concerning the thermal preferences, 37.5% of the visitors prefer to have ‘slightly cooler’ temperature, while 12.5% prefer ‘no change’ condition. 29.2 % and 16.7% of visitors were preferred to have a cooler and much cooler condition, respectively, if they had an opportunity to change the thermal environment. 4.2% of visitors voted slightly warmer option (table 14). Based on the finding, 45.9% were out of the comfort zone of the preference scale and 54.2% were between the standard of ASHRAE.31.3 and 35.4% of patients prefer cooler and much cooler indoor environment. 33.4% were in comfort rage of preference scale. 66% of patients were out of the range. Concerning clinical staff 16.7% and 41% voted prefer cooler and much cooler indoor environment. 41.7% of clinical staffs are out of the comfort zone.

✧ **Thermal perception in different time of the day (for patients, in Dillchora referral hospital)**

Table 15. Thermal preference on different time of the day.

Thermal Preference	Much cooler (-3)	Cooler (-2)	Slightly cool (-1)	NO change (0)	Slightly warmer (1)	Warmer (2)	Much Warmer (3)
2:00	6.3%	14.6%	43.8%	27.1%	6.3%	2.1%	0.0%
6:00	35.4%	31.3%	16.7%	2.1%	14.6%	0.0%	0.0%
10:00	16.7%	41.7%	22.9%	4.2%	14.6%	0.0%	0.0%

The problem of the indoor environment is significant in the mid-day. More than half of the daytime needs a critical solution according to (table 15).

The thermal preference of patients shifts to “cooler” and “much cooler” in the afternoon session especially from 6:00 am to 10:00 am, 35.4% and 31.3%. 77.1 % of patients were in the comfort range in the morning section. This implies the fluctuations in the room temperature during the day had a direct impact on the thermal behavior of the building.

4.3.3. Satisfaction Level

Several psychological variables, such as expectation levels, use of controls, behaviors, and thermal background, influence thermal satisfaction of indoor parameters (Simons, et.al. 2012). Based on the finding of this study, about 22.9% of visitors voted ‘very dissatisfied’ while 25.92% felt ‘dissatisfied’ with the comfort of the hospital buildings. On the other hand, about 29.2%, 20.8%, and 2.1% hospital visitors voted slightly dissatisfied, neutral, slightly satisfied, respectively (Figure, 25 and table 15). According to figure 52.1% patients voted “Dissatisfied”, 18.8% were very dissatisfied. Only 29.2% were satisfied. 45.8% of Clinical staff voted “dissatisfy”, 12.5% “very dissatisfied”. 41.8% were within the comfort range. The figure below shows the mean thermal satisfaction of sample population from the two institutions.

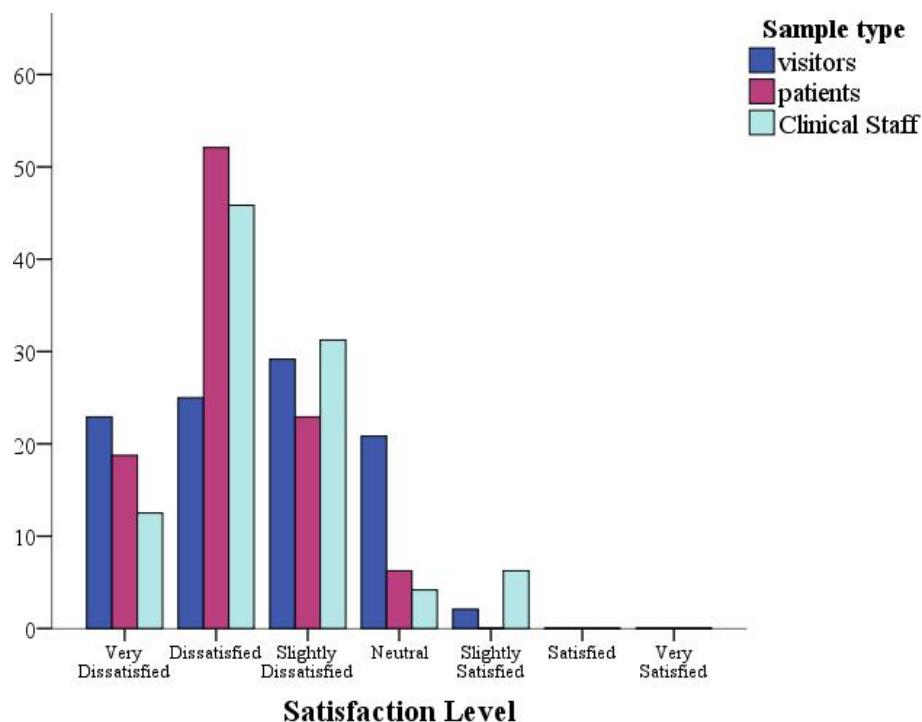


Figure 20. Satisfaction level of different sample populations .

Table 16. Over satisfaction level of different sample populations

Sample type	Very Dissatisfied (-3)	Dissatisfied (-2)	Slightly Dissatisfied (-1)	Neutral (0)	Slightly Satisfied (1)	Satisfied (2)	Very Satisfied (3)
visitors	22.9%	25.0%	29.2%	20.8%	2.1%	0.0%	0.0%
Patients	18.8%	52.1%	22.9%	6.3%	0.0%	0.0%	0.0%
Clinical staff	12.5%	45.8%	31.3%	4.2%	6.3%	0.0%	0.0%

The standard of ASHRAE stated the occupants' satisfaction level of 80% for a given space to be comfortable. With a 20% tolerable limit. According to figure 22, 93% and 89.6 % of patients and clinical staff are dissatisfied in different levels. 59% of them are out of the thermal comfort range (table 16).

As discussed in section 4.4 the level of three measured environmental variables exceed the standard limit affecting the satisfaction level, to avoid those variable the design need to control the level in which they are introduced in the indoor space.

4.4. Cooling Facility provision and natural ventilation

Currently, both hospitals are using a hybrid ventilation system Mechanical system (ceiling fans and AC), and a manual system of windows. Natural ventilation taps naturally available forces to supply and remove air into a given space. Natural airflow is a critical passive method to preserve thermal consolation in indoor space (Candido et al., 2010). It can also be used as an energy-conserving design strategy to reduce building cooling loads by eliminating heat stored within the building's thermal mass.

From figure 22, the researcher concluded that the level of natural ventilation is weak. But the majority of rooms have a ceiling fan. Natural ventilation is weak in most sample rooms, the Availability of fans has a critical impact on the thermal sensation.

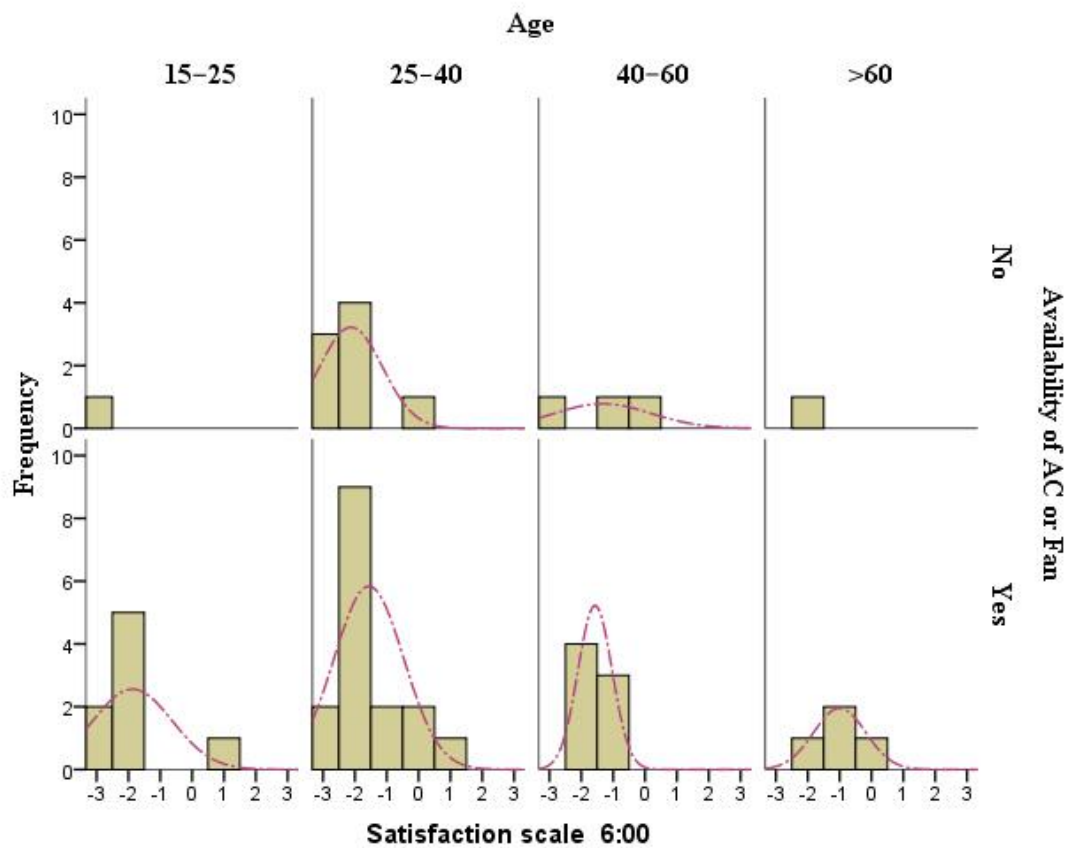


Figure 22. Over all satisfaction level in different time of the day



Figure 23 Existing cooling facility used.

During the physical survey, researcher has observed that most of the ceiling fans are in place. Almost all of the ceiling fans are not working due to maintenance and power disruption problems. The other challenge in inpatient rooms is as the rooms are multi-bed, not all patients are interested in the fans due to personal reasons. Numerous researchers have revealed that occupants of naturally ventilated buildings accept and

even prefer a wide range of temperatures than their counterparts in sealed, air-conditioned buildings because their preferred temperature depends on outdoor (Candido et al., 2010).

The satisfaction level of respondent with in age range of 25 to 40 changes with the availability of fan. When the age exceeds sixty, people will have low reactions on fans. According to different studies, the ability to sense hot and cold surface commonly decline with age. The effectiveness of human body thermo-regulation is reduced gradually when the age exceeds sixty (Lenzuni, 2009).

According to the data level of natural ventilation is weak in Dillchora referral hospital. Especially patients and clinical staff voted high. The natural ventilation of Sabian general hospital has been voted “fair” relatively.

4.5. Temperature, Humidity and Air velocity data analysis.

4.5.1. Temperature

Extreme temperature range increase physiological strain applied on patient, that will induce extra stress on top of stress related to the disease or injury of the patient which is undesired unless medical treatment requires so (Verheyen et al., 2011).

Section A and B Presents the temperature recordings in patient room, examination room, waiting area and out door environment in the two sample institutions. The data shows the temperature range from mid April to May 2021. measured for 15 days with the interval of three hours starting from 2:00 am – 10:00 am

A. Dillchora Referral Hospital temperature data

The results of air temperature are presented for the month of April and May in Figure 31 and 32 below, respectively.

According to, Figure 31 the maximum temperature of April and May is 35⁰C and 38⁰C and the minimum temperature of 27⁰C and 18⁰C were recorded. from this, the highest number of temperatures was recorded from the external environment and the list number is from examination room. The highest and the lowest temperature is recorded in May.

The temperature flow has the same pattern for the three spaces including the external temperature. The morning temperature is relatively low at 2:00 rising at 6:00 and stayed till 10:00 with a slight decrement. The external temperature for May is relatively low. The high temperature of the spaces was caused by many reasons. Patient rooms are sophisticated by patients and visitors, examination rooms are also occupied by clinical staff and patients. electronic materials also emit heat. the waiting area is relatively better.

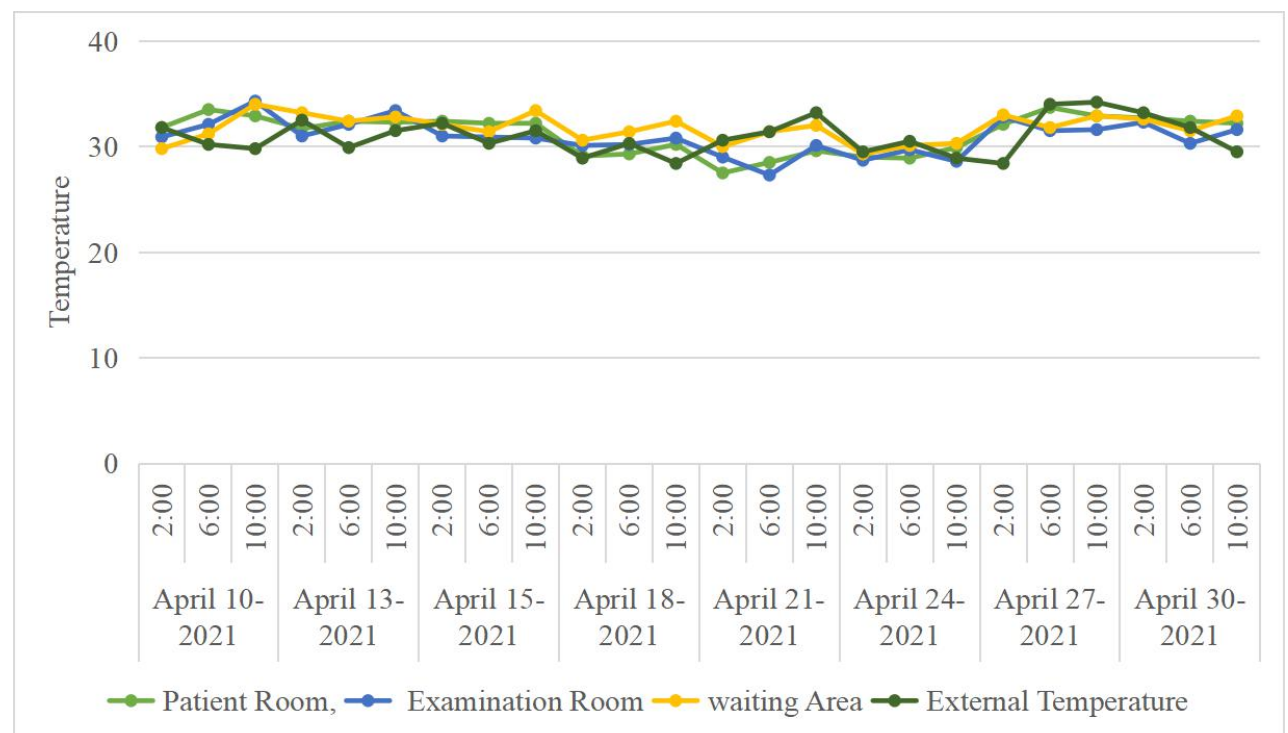


Figure 27. Temperature data of three indoor space and out door environment in April 2021 (field survey,2021)

Relative to the comfort standard of ASHRAE, ranging from 21⁰C to 27⁰C. these comfort range is stated for Three rooms were totally out of the range most of the records are far from the comfort range. Indicating the spaces are uncomfortable. which was caused by many reasons,

The thermal conductivity of building material used and the excess occupants within the space cause the rise in temperature. The opening orientation in examination allow excess solar radiation in to the room.

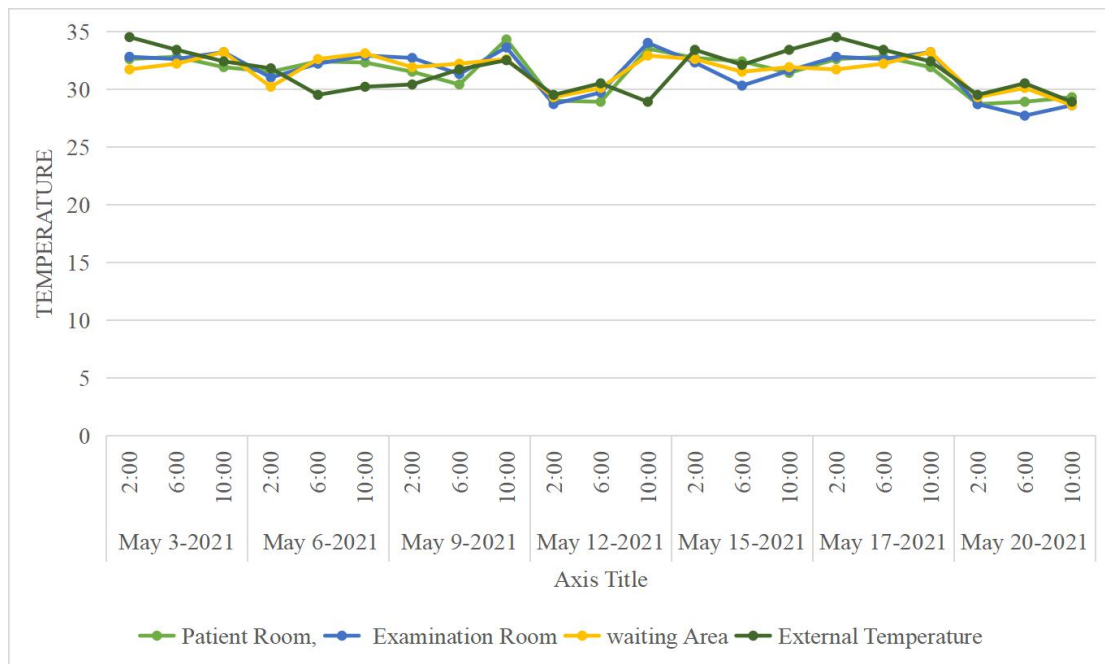


Figure 28. Temperature data of three indoor space and out door environment in May 2021 (field survey,2021)

B. Sabina General Hospital temperature data

The temperature of Sabina general Hospital, was also measured in April and May. The temperature of the building in the morning was rising with time, as shown in Figures 33,34. Fluctuation of temperature throughout the daytime is with a certain limit, without extreme high and low variation.

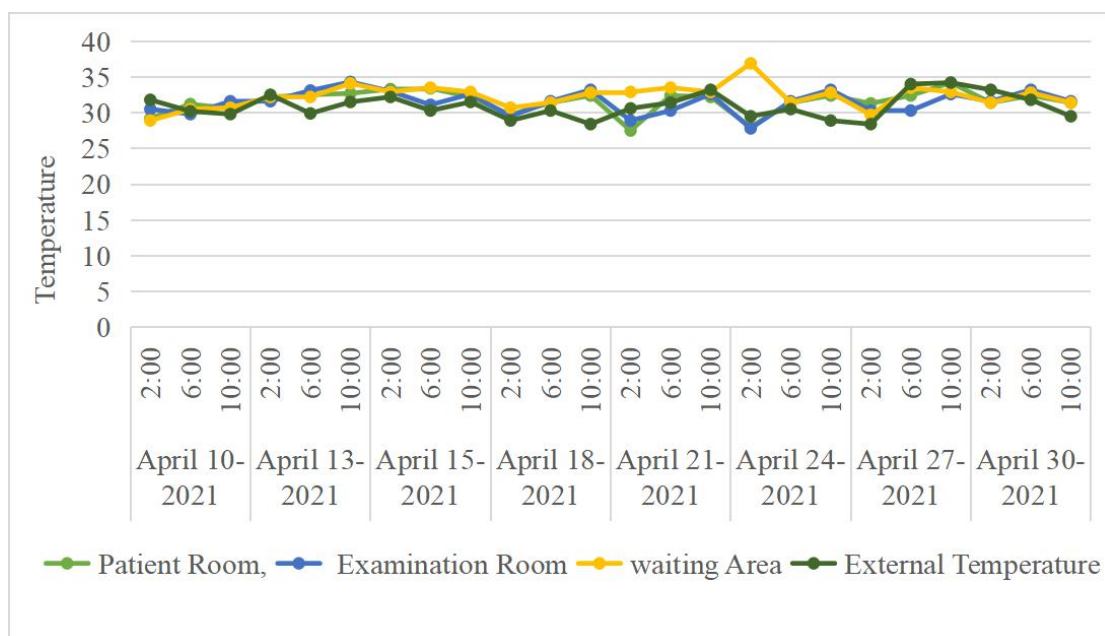


Figure 29. Temperature data of three indoor space and out door environment in May 2021 (field survey,2021)

Based on the results obtained from the subjective analysis, the thermal perception of occupants in the morning is in comfort range relatively. We can relate that to the low temperature range measured in the 3:00 AM.

As shown in Figure 27, occupants' discomfort levels began to rise in the afternoon. Implying the degree of discomfort has a positive relation with room temperature and time variation. The room temperature range affects the thermal perception of occupants. The room temperature is affecting the thermal perception of occupants negatively. This implies the building needs appropriate passive strategy to mitigate the temperature in the indoor environment.

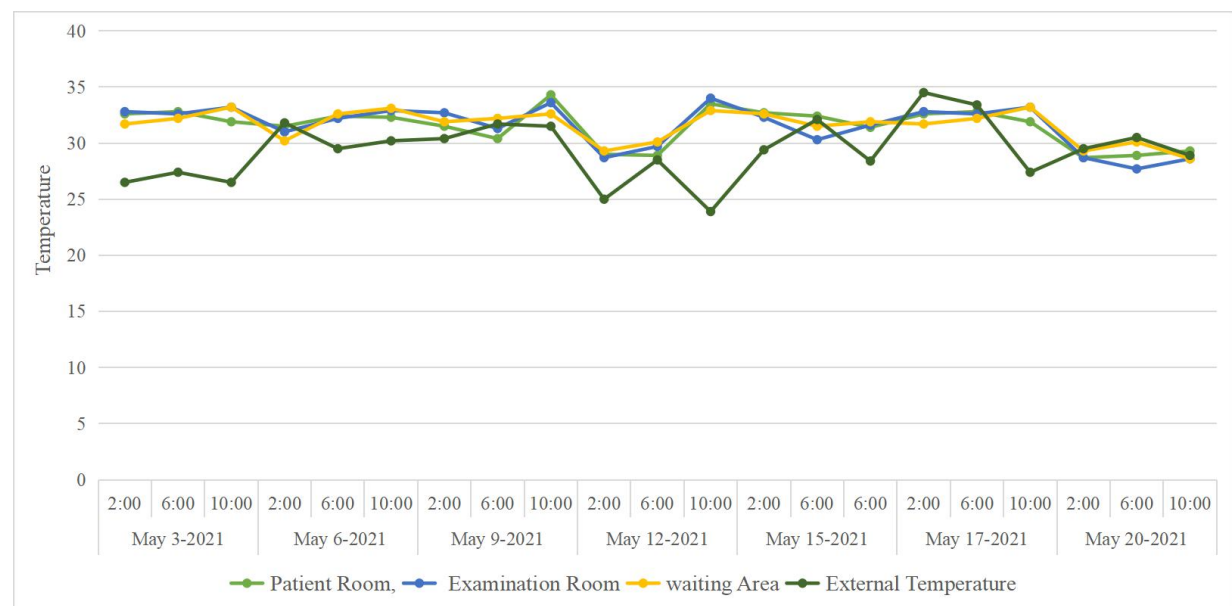


Figure 30. Temperature data of three indoor space and out door environment in May 2021 (field survey,2021)

4.5.2. Humidity

Low humidity or very dry environments ($RH < 20-30\%$), affects comfort and health in ways such as drying nose, throat, eyes, and skin. The suggested level of indoor humidity in air-conditioned buildings is between 30-60%. Thermal sensation is an indicator of overall thermal comfort and acceptability at lower levels of humidity. (Tanabe S, 1987)

A. Dillchora Referral Hospital humidity data

Figure 35 and 36 Represent the range of internal and external humidity which was recorded in April and March.

According to the figure the recorded humidity indicates that to the average almost all buildings spaces are out of comfort zone especially in the examination room and the range was very low and it has no regular consistency with in the 15 recording days also within three recording times of the day.

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 similar to the recording data indicates.

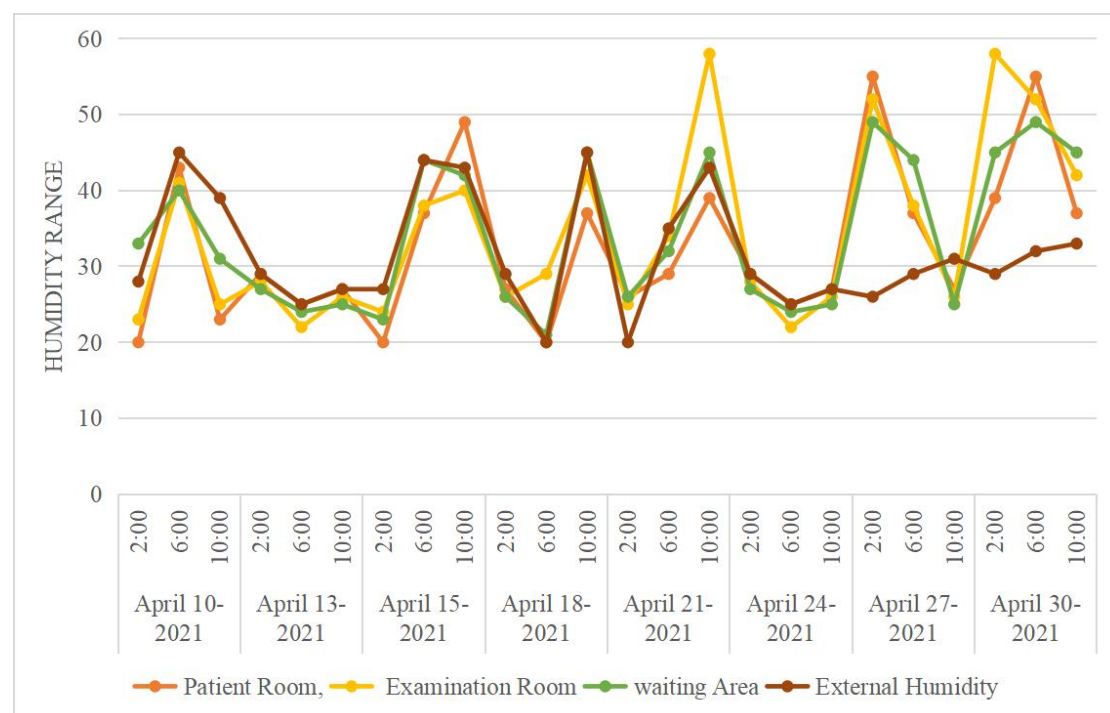


Figure 31. Humidity data of three indoor space and out door environment in April 2021 (field survey,2021).

38% of the data is within the ASHARE 55 allowable limit which is between 30-60%. Sample rooms performed well in the morning session accordingly, these results from lower temperature range in the morning, the air stay moist.



Figure 32. Humidity data of three indoor space and out door environment in May 2021 (field survey,2021)

B. Sabina General Hospital Humidity data

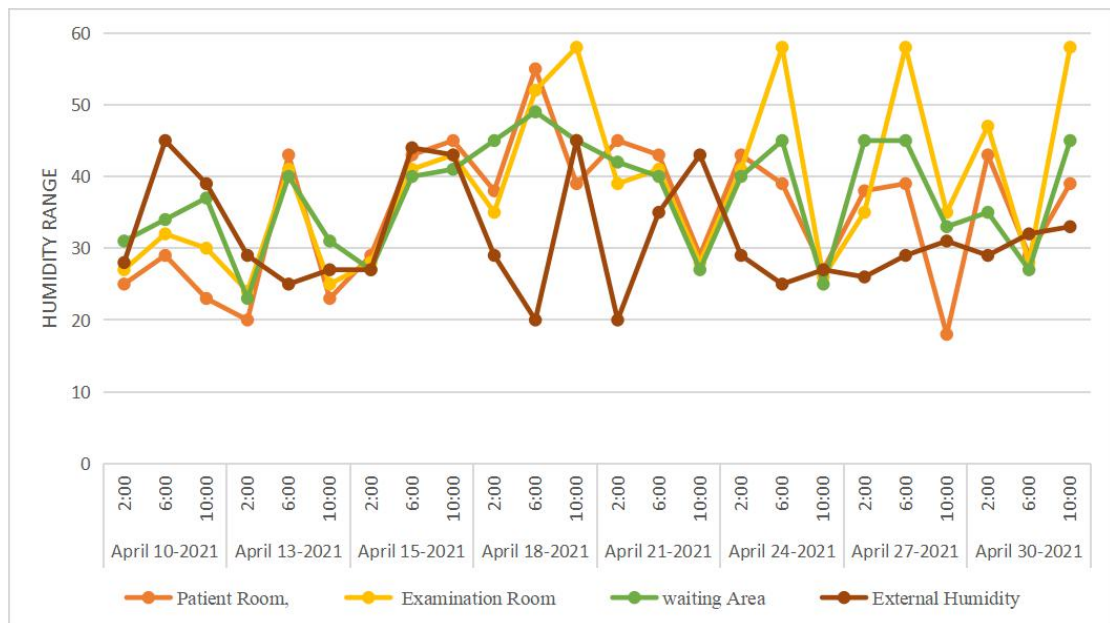


Figure 33. Humidity data of three indoor space and out door environment in April 2021 (field survey,2021)

Figure 33 and 34 indicates the humidity level In sabian is better to that of dillchora. 41% of the recorded data is in comfort range, April 15 to May 6 the humidity level in the three rooms were in the allowable limit. The maximum 58RH and minimum 21 RH were recorded in the study period. The pattern of the recording has the same consistency with in the three sample rooms. A suitable level of RH prevents excessive skin, eye, and respiratory tract dryness. This allows for the patients and personnel to breath and perspire more easily (Khodakarami and Nasrollahi, 2012).

Even if the level of humidity affect the thermal environment, high humidity level is not desirable in hospital environment. Research shows that in a room with a relative humidity (RH) below 40%, water molecules can rapidly lose 90% of their volume, causing airborne bacteria to float and possibly reach other hosts. droplets will retain their size and spread much faster, which will prevent the formation of airborne bacteria (Khodakarami et al, 2012).

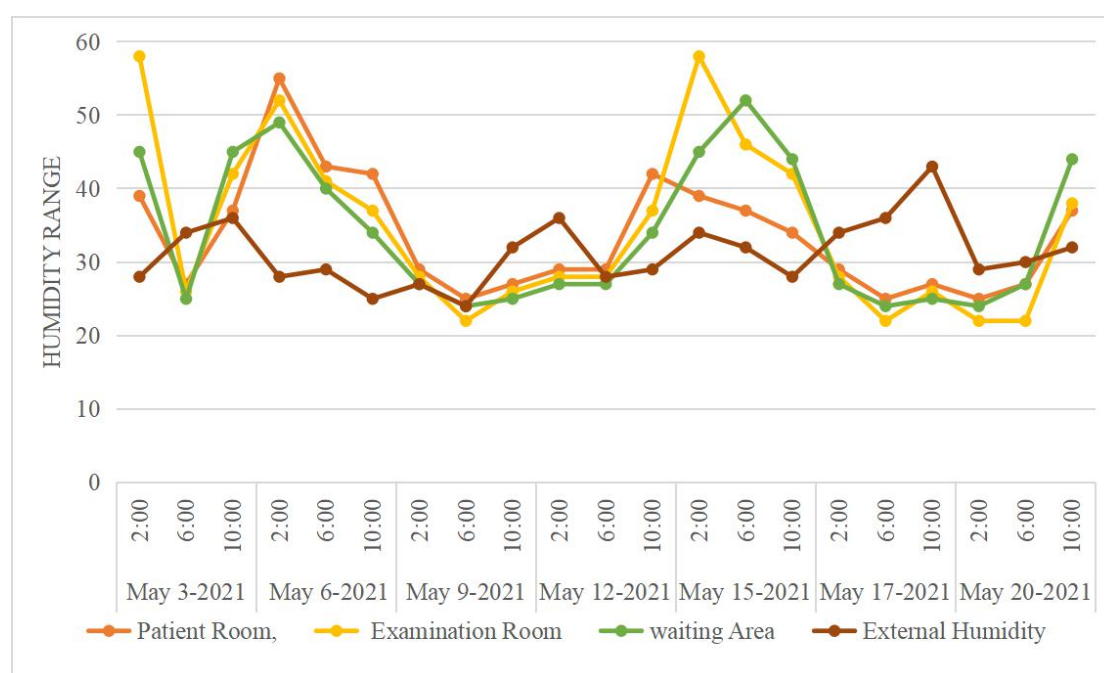


Figure 34. Humidity data of three indoor space and out door environment in May 2021 (field survey,2021).

4.5.3. Air velocity

Air movement is an essential element to attain thermal comfort within a building. A direct cooling strategy reduces building cooling load and energy consumption by mechanical systems. 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 (Candido et al., 2010).

A. Dillchora Referral Hospital Air velocity data

Based on the figure below, we can see outdoor air velocity is high. And the indoor air velocity is low, waiting area ranging between 0.012m/s to 0.27m/s. examination room ; 0.01m/s to 0.19m/s, patient room ; 0.01m/s to 0.17m/s.

According to ASHRAE 55, most of the data is out of the comfortable range. Indoor airspeed in hot climates exceeds the normal comfort range of 0.1 m/s and 0.3 m/s to 0.2 and 1.50 m/s.

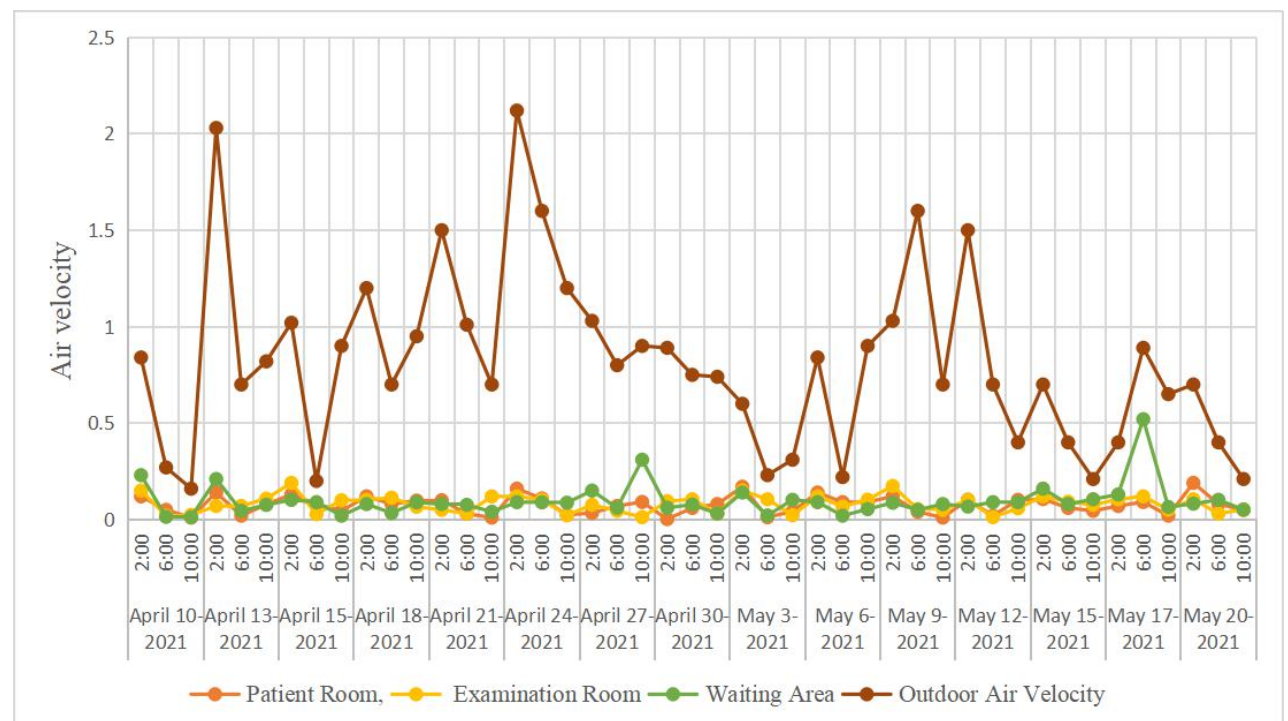


Figure 35. Air Velocity data of three indoor space and out door environment in April and May 2021 (field survey,2021)

These resulted from poor orientation of the openings. Also the size of the openings didn't allow the external air in to the indoor space. This implies the building needs appropriate passive strategy to mitigate the the external air in the indoor environment.

B. Sabian General Hospital Air velocity data

The figure below presents the air speed recorded with in April 10 to March 20. According to the figure, outdoor air velocity range from 2.89m/s to 0.21 m/s. the indoor air velocity ranged from 0.019m/s to 0.22m/s for examination room, 0.01m/s to 0.18m/s patient room and 0.03m/s to 0.29m/s for waiting area.

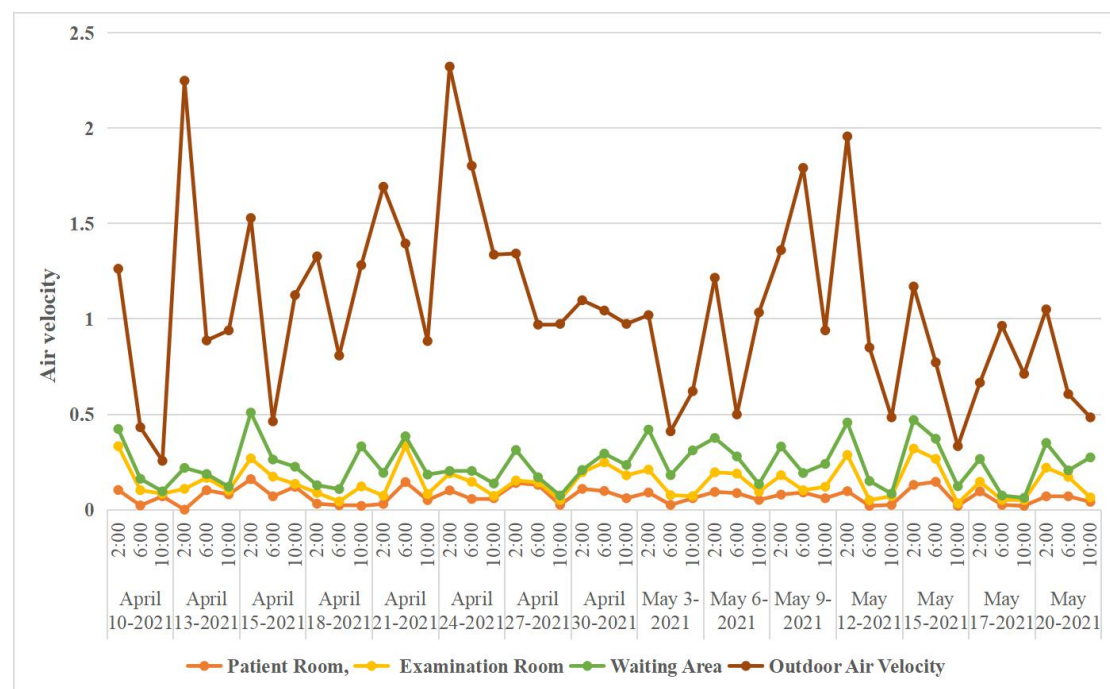


Figure 36. Air Velocity data of three indoor space and out door environment in April and May (field survey, 2021).

According to ASHRAE 55, the three sample rooms are out of the comfortable range. The rooms indoor temperature is high (section 4.4.1, B). increasing the indoor air velocity regulates the temperature.

During high- indoor temperatures, Higher air velocities help occupants to remove sensible and latent heat from the body. In the process, body temperature is restored to its comfort set-points (Candido et al., 2010).

4.6. Correlation of environmental variable to perception scale.

Outdoor humidity ranges from 22% to 58%, air velocity(0.04m/s to 2.89m/s) and temperature ranges from(17°C to 41°C). According to the recorded data humidity and air movement level fluctuate to a large level than that of temperature. The temperature variation is relatively low. The combination of high temperature and high relative humidity reduces thermal comfort (Fang, 2004), According to the climatic data recorded the indoor temperature of the sample space is high, with fluctuating low humidity. This implies the building needs appropriate passive strategy to mitigate the the external temperature or increase the level of humidity.Its obvious that decreasing the level of indoor temperature is preferable, especially in hospital environment.

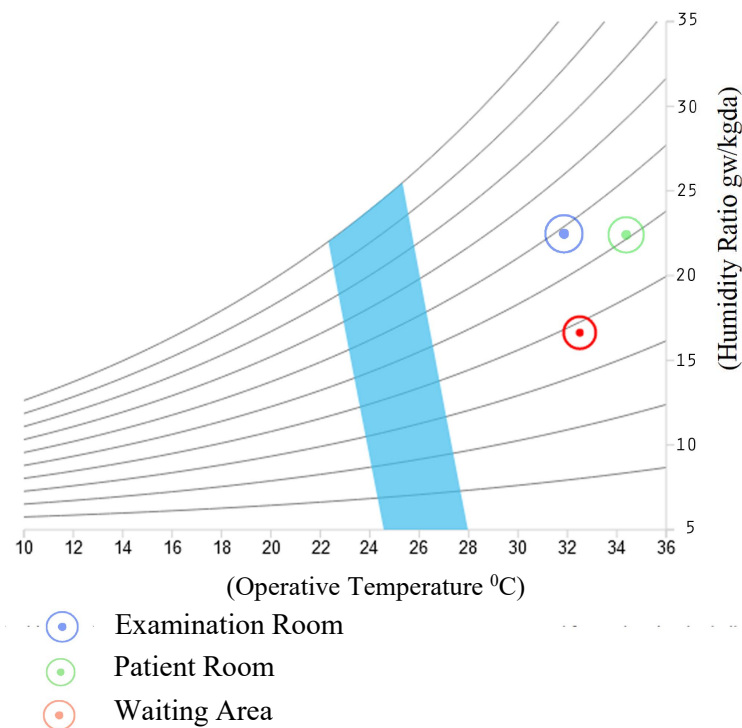


Figure 37; environmental variable relative to the comfort range of ASHRE 55

The psychrometric chart above shows the the environmental variables relative to the the ASHRE 55 standard comfort range. The mean environmental variable for three selected spaces has been summarized.

The most important impact that relative low air humidity has in hospitals and medical facilities is the protection of patients from bacterial attacks. There are normally tons of pathogens hospitals, and preventing the spread of these microorganisms is beneficial to a patient's health. As the relative humidity increase the probability of producing bacteria also increases. The temperature, humidity, and Air velocity data recorded in the six sample space is in within the same range , so the mean thermal preference (thermal sensation, preference and satisfaction level) is correlated with the mean temperature.

4.6.1. Temperature

A. Indoor and outdoor temperature

According to fig 38, outdoor and indoor temperature had a weak positive correlation. As discussed in section 4.4.1(A and B) The temperature range of the in door and out door environment vary through out the day. Relatively low in the morning and high in the afternoon session. Even if the magnitude of the indoor and out door temperature vary, they are related. The Significance level of the correlation is 0.28. 28% chance of difference is expected. the correlation coefficient is 0.317, the level of variation between indoor and outdoor temperature is low. high accommodation levels and different medical devices are additional heat sources for the indoor environment. The buildings materials and openings allow excess heat in to the building in door space.

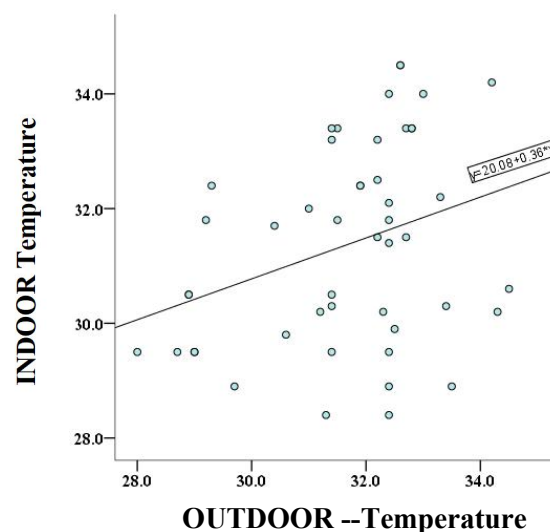


Figure 38. correlation percentages of indoor and outdoor temperature

B. Indoor temperature and thermal perception

The figure below shows the relation between indoor temperature range and perception level. The correlation of temperature has a positive value, concerning the mean thermal sensation of occupants.

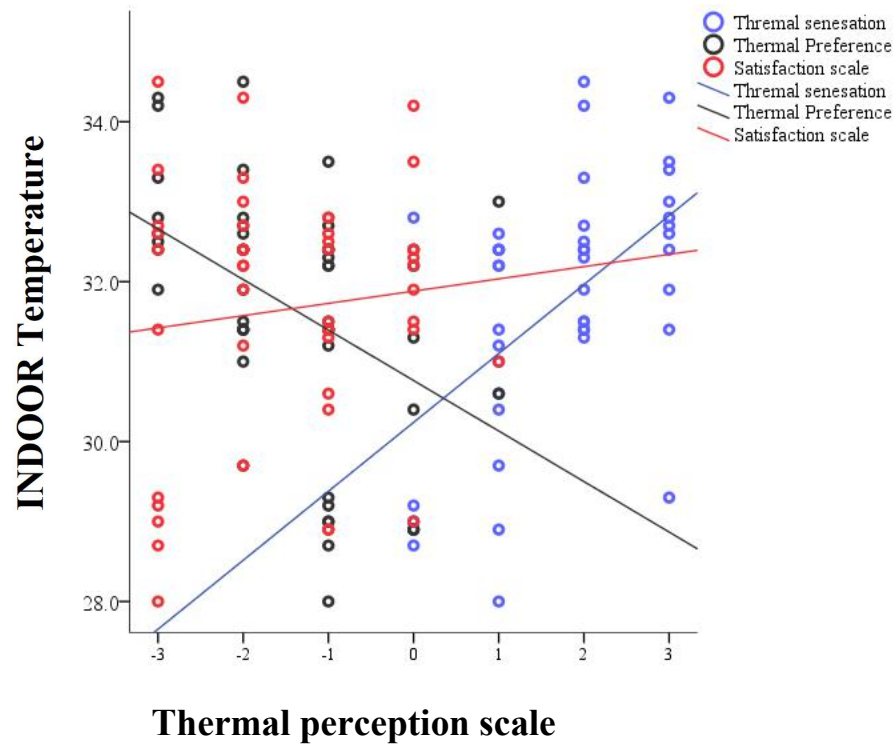


Figure 39. correlation percentages of preference scale with temperature

Correlation coefficient (r)=0.543, shows weak positive relationship with no chance of difference. The reverse is true for thermal preference weak negative correlation. As the temperature increases, the thermal preference level increases between -1 and -3. It indicates a high level of cooling is expected.

$R = 0.11$ close to zero, The temperature had a slight correlation with satisfaction level. The two variables had a 45.6% of probability of finding the difference.

4.6.2. Humidity

A. Indoor and outdoor humidity

The figure 40 shows the relation between indoor and outdoor humidity range. Outdoor humidity levels did not correlate with indoor temperature. As discussed in 4.4.2 the average humidity level of indoor spaces in both sample institution is below

the standard range. Affected by the high indoor temperature. The out door humidity level is not consistent with low effect on indoor humidity level.

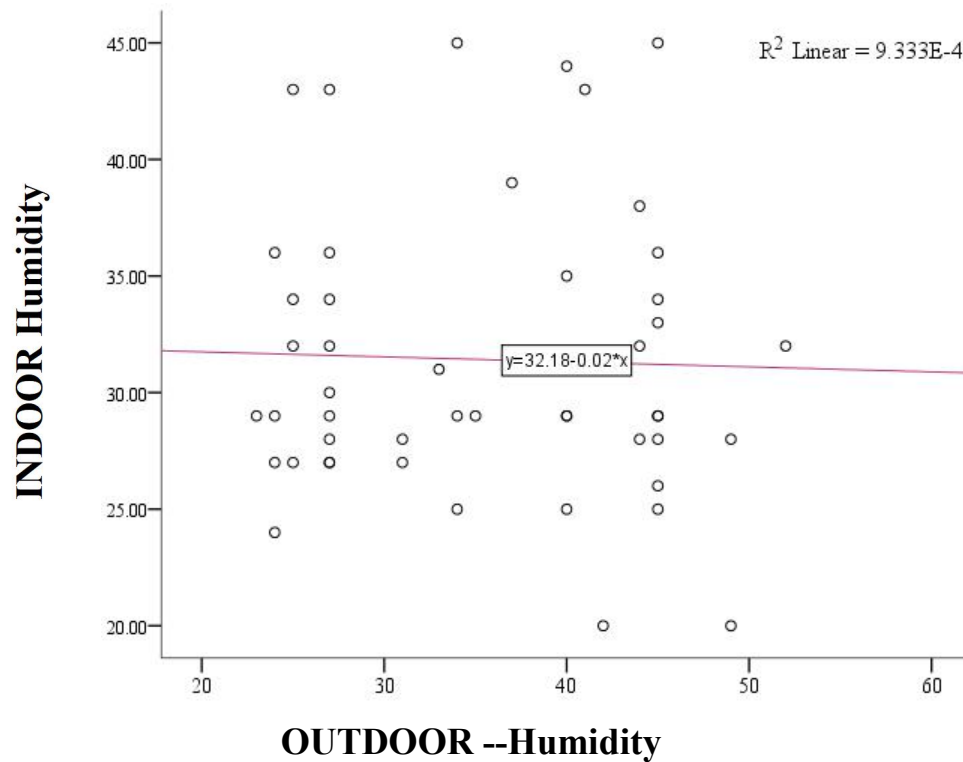


Figure 40. correlation percentages of indoor and outdoor humidity

B. Indoor humidity and thermal perception scale

The figure below shows the relation between humidity range and perception level. The correlation coefficient of $r=0.12$, explains the relation between the indoor humidity and thermal sensation scale had weak or no relation.

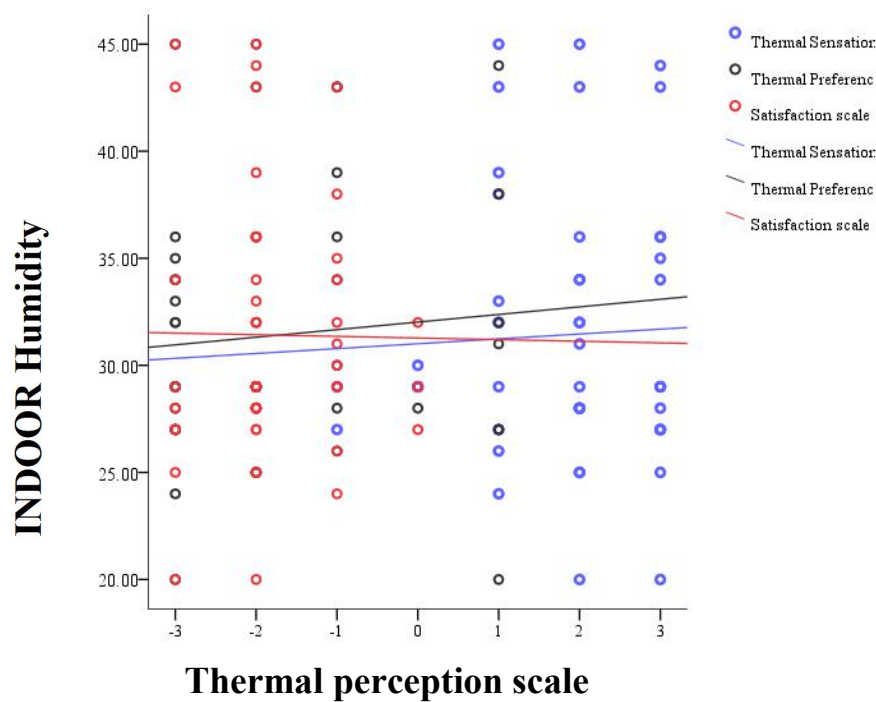


Figure 41. correlation percentages of preference scale with humidity

The same correlation level is recorded regarding thermal preference and satisfaction level, $r=0.36$, and $r=-0.148$. The average chance of difference is 50 %. these might result from consistency of humidity level within the study period.

4.6.3. Air velocity

A. Indoor and outdoor Air velocity

The figure 42 shows the relation between indoor and outdoor air velocity range. The Outdoor Air velocity score a 0.101 correlation coefficient with the indoor environment. The chance of finding a difference is 0.493. As discussed in section 4.4.3 the out door air velocity of Dire Dawa is high for 7 month of the year. Merely the indoor air velocity is extremely low. The correlation graph shows the same. The average chance of difference is 49%. These result from poor design in size and orientation of opening.

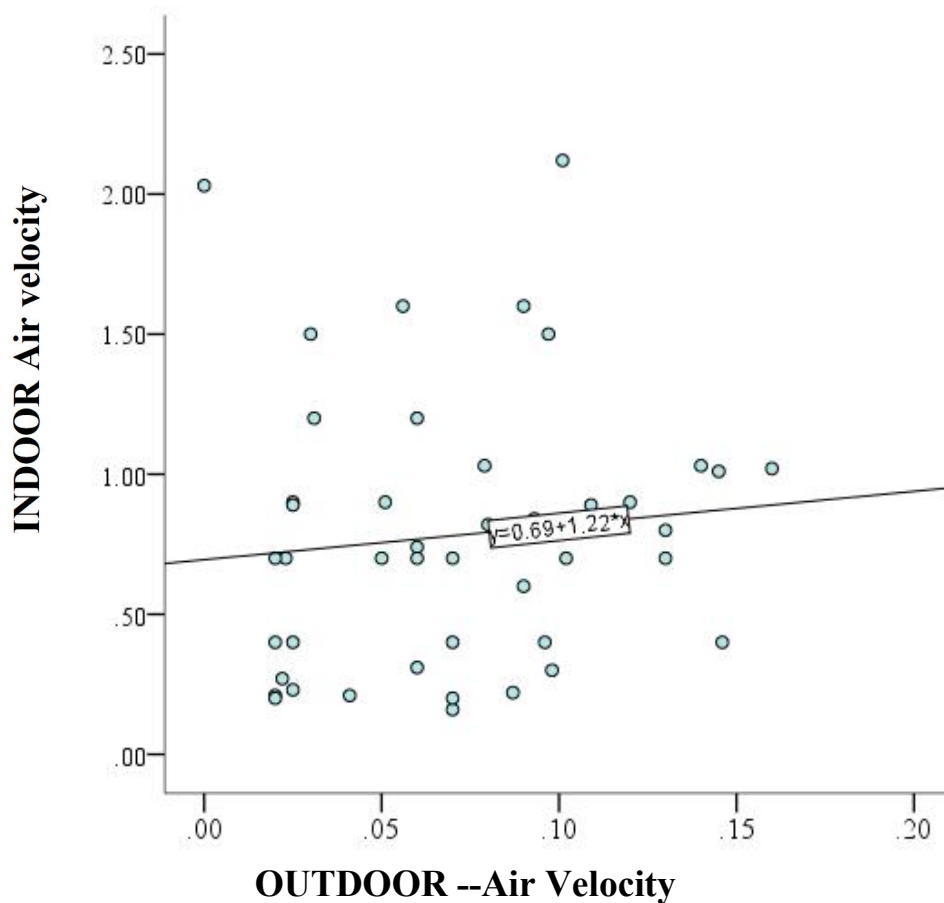


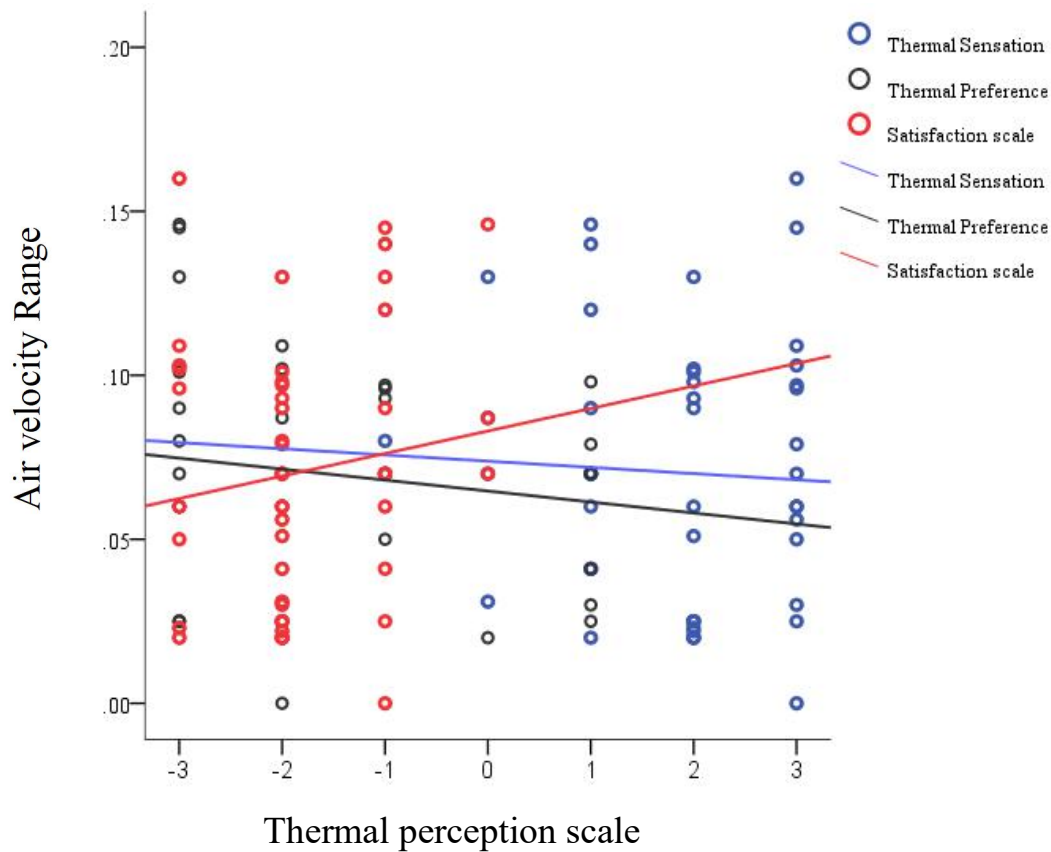
Figure 42. correlation between indoor and out door air velocity.

B. Indoor air velocity and thermal perception scale

The introduction of airflow with higher velocities into high-temperature indoor environments is desirable.

ASHRAE comfort zone lies between (-1=slight discomfort, 0=neutral, 1=slight comfort). As we see from the above figure, the thermal perception level lies on the comfort zone for the air velocity 0.07m/s to 0.14 m/s. 25 % of the vote is in the comfort range.

These numbers increase with the increment of air movement. As the range of the air movement is below the standard, it doesn't make a significant difference in improving thermal perception level.



Figure; 3 correlation percentages of thermal preferences with air movement.

4.7. Environmental variables affecting thermal efficiency

A building is designed and built to protect occupants from harsh weather conditions. The thermal comfort level of indoor space can be affected by factors that determine heat gain and loss. And can be divided into two categories namely personal and environmental factors. The environmental factors are based on the micro climatic conditions of the thermal environment (air temperature, air speed, mean radiant temperature, and relative humidity) (ASHARE 55, 2017).

Under these study the three environmental conditions that affect thermal comfort (TC) are discussed. The effect of each factors is identified according to thermal comfort limit of ASHARE 55. and correlation result with the thermal perception scale of occupants.

According to the analyzed data, the phenomenon of high indoor temperature and low indoor air velocity is questioning the performance of both sample buildings in terms of occupants thermal comfort. The recorded data of each variable is below the

standard limit. And the correlation level with thermal perception is high. Almost all experimental spaces use manually adjustable indoor sun protection like curtains, to solve the problem of overheating. Unfortunately, internal shadows cannot protect the heat gain, because heat is transferred to the internal environment through the facade of the glass and building structures before sun protection is achieved. At the same time the out door air is blocked, resulting low cross ventilation. These decreased the thermal comfort of the spaces.

And Thermal comfort is an important part of an occupants' physical and psychological experience in hospital building. Receiving excess heat from the air can cause physical and emotional distress and depression. Resulting increase instances of dissatisfaction, health issues, and decreased productivity. The out gassing of toxins from building materials also increase (Tanabe S, 1987).

Air speed can affect convective and evaporation heat losses from the human body. It is an important factor affecting the thermal comfort level of individuals with in a certain space. Air velocity also helps removing heat stored in the buildings thermal mass. This implies the building needs appropriate passive strategy to mitigate the indoor high temperature and low air velocity.

4.8. Conclusion and recommendation

4.8.1. Conclusion

Indoor thermal Satisfaction can be characterized as as a person's sense of physiological and psychological well-being in their environment. In a hospital, the general health of the patient and all medical personnel is extremely importance. This allows "stress and nerves" to calm down before the procedure or even when the patient is not fond with the hospital.

From the study, the thermal responsiveness of selected spaces in hospital buildings is analyzed. The analysis used a cross-sectional study between parameters of thermal comfort relative to occupants' comfort level. A series of physical measurements have been done on three environmental parameters to identify the indoor thermal performance of the building.

Thermal preferences of patients, clinical staff, and visitors have also been measured at three different hours. The data has been evaluated according to thermal comfort requirement of ASHRAE 55. And correlated with the thermal perception of occupants. According to the study, the indoor thermal condition of the sample space is out of the comfort range. High indoor temperature and low air movement has decreased the thermal satisfaction of occupants. Design and construction of the buildings didn't consider the bio climatic condition of the study area. mitigation measure that can decrease the indoor temperature and allow better natural ventilation is desired.

The objective of the study was to create insight in buildings design in thermal-sensitive regions of Ethiopia. And improve design considerations for the effectiveness of thermal performance of indoor space for the future.

✧ Over all Result and discussion of data analyzed have been summarized below.

Environmental factor

Environmental variables
✧ Temperature; The standard requirement of ASHER 55 suggest, comfortable temperature range from 20 ° C in winter to 25 ° C in summer. The average

mean T^0 of the sample spaces in ‘Dillchora referral hospital’ and ‘Sabian general hospital’ is 30.2°C and 29.4°C respectively. Indicating most of the spaces do not full fill the standard requirement.

Building design is exposed to solar radiation and the thermal insulation capacity of the building material is low. In addition to that the room accommodate more than its capacity creating indoor heat.

Receiving excess heat from the air can cause physical and emotional distress and depression. The out gassing of toxins from building materials also increase (Tanabe S, 1987).

✧ **Humidity;** 38% of the humidity data of the whole building was within the acceptable limit as on ASHARE 55, Relative humidity in Dillchora referral hospital is 36% and 32% for ‘Sabian general hospital’. The level of humidity has no critical influence according to the standard. There is no significant difference between sample rooms but the over all humidity level is not stable through out the recording period.

Air velocity; The airspeed range of sample space is 0.01m/s to 0.18 m/s, only 27% of the data is above 0.1 m/s. According to ASHRAE 55 most of the data is out of the comfortable range. Indoor air speed in hot climate exceed, from the normal comfort range 0.1 m/s - 0.3 m/s, to 0.2 - 1.50 m/s.

Air velocity can affect convective and evaporation heat losses from the human body. It is an important factor affecting the thermal comfort level of individuals with in a certain space. Air velocity also helps removing heat stored in the buildings thermal mass.

From the study it can be concluded that high indoor temperature in the building is caused by less ventilation due to enclosed space.

Table 17; summarized data of environmental variables.

Thermal perception scale

Thermal preference
Thermal sensation scale; According to survey result discussed in section 4.2.1 on average 61 % (64.5%-patients, 64 % -Clinical staff, and 56.2%- visitors). Are out of ASHREA comfort range (slightly cool to slightly warm). the standard states that more than 80% should be within comfort range, but only 38.7% did.
Thermal preference; The result reveals that around 66.7% and 33.3% of patients and clinical staffs respectively prefer much cooler indoor environment. 54.1%,(More than half) of the visitors are in the comfort range(-1 to 1). The thermal preference of the majority occupants were cooler and has a statistically significant effect on thermal sensation and thermal acceptability.
Satisfaction level; 93% and 89.6 % of patients and clinical staff are dissatisfied From the total sample population 59% of them are out of thermal comfort zone. Thermal dissatisfaction of indoor environment condition heavily reduce the effectiveness medical treatment (Protocol, 2018). and it does have negative implications on clinical staff who spent most of their time and also affect their performance (Seppanen et al., 2006). Thermal discomfort is not a temporal sense of stress which will be felt in a particular moment. It is a cumulative reaction, which either is interpreted into a physiological response or reimbursed in adaptive behavior. In extreme cases, thermal stress can also cause a real health problem. Buildings can modify the external environmental condition. A comfortable indoor environment reduces the effort needed by the human body to stay stable at normal body temperature

Table 18. summarized data of thermal perception scale.

Correlation

Correlation
Temperature According to survey, result shows the indoor and out door

temperature have weak correlation, there is 70% probability in which increase in outdoor temperature increase the indoor temperature, Even if the magnitude is dispersed not exact. The indoor temperature affect the thermal perception of occupants directly. With 62% probability the change in indoor temperature changes the mean thermal perception of occupants.
Humidity; The indoor and out door temperature have no correlation. According to the correlated data there is 88% and 67% probability that thermal sensation and thermal preference differ from the humidity data. The satisfaction level had zero or no relation with the humidity level.
Air velocity; The indoor and out door air velocity have weak positive correlation The chance of finding a relation is 51%. The thermal perception of occupants will improve 75% with the increasing air movement.

4.8.2. Recommendation

Based on the analysis result, suited alternative measure and topics for future study were recommended on the paragraph below.

The indoor environment is over heated in which passive cooling demand is desirable in almost all sections of the building. In which natural ventilation combined with solar protection are the most effective building design strategies to achieve thermal comfort without resorting to mechanical cooling. Almost all sample have relative equal discomfort, and same kind of thermal comfort requirement is desirable. This can be achieved by passive cooling strategies. The wind is potential for cooling the indoor temperature in DDAC. Despite these favourable conditions, The main cooling design strategy dominating modern buildings in DDAC is air-conditioning systems. Based on this scenario, the recent energy need has increased dramatically. Energy demand in DDAC (Dire Dawa Administration Council) is projected to grow at a rate of 4 percent per year and is expected to reach 7.5 PJ (three times 2002 values)(Gont & Kebede, 2018).

passive technique cooling is preferable sustainable method of the globalized world. prevention of heat gain, modification of heat gain, heat dissipation, and improving natural ventilation are basic strategy need to be implemented.

- ✧ Heat preventative mechanism; The heat can be avoided using two basic techniques micro climate and solar control.vegetation is one of the micro climate method minimizing the out door heat and reflected heat. Vegetation's might obstruct the wind, need to be orient relatively.
- ✧ The potential wind speed also had the ability to regulate the external and internal heat around the building, According to climatic data of Dire Dawa, from September 9 to June 4 is windier part of the year with average speed of 9.2 miles per hour.
- ✧ Orientation of a building is critical solar control decision for designer, in order to achieve solar energy in to the building simultaneously avoid over heating. Good orientation can help reduce or even eliminate the need for cooling, resulting in lower energy bills, reduced greenhouse gas emissions and improved comfort.
- ✧ Modification of heat gain; the excess heat from the external environment can be modified through effective thermal mass capacity of building material used.
- ✧ Mass effect cooling is one of the most important passive energy techniques that had been used in developing countries for a long time to provide thermal comfort. Most of vernacular/traditional buildings in dire dawa have also used stone for better thermal comfort and the space has greater efficiency. Stone is one of cheep building material available around DDAC. the price is 12 times lower than the average cost around the country. the “Dengego mountain” circling the city of DDAC is the major source of the stone. The stone is one of recommended building material. It is a highly durable, low maintenance building material with high thermal mass and low embodied energy /toxicity. Hence,
- ✧ phase change material (PCM) can also improve the thermal performance of interior space. It can reduce the the heat gain and improve the indoor thermal environment effectively.

- ✧ Heat dissipation is the third passive technique in which the building can naturally breath. Wind need to be given much attention in the modern building approach. Houses need to be oriented with respect to prevailing wind.
- ✧ The wind in Dire Dawa is most often from the south for 7.7 months of the year from February 23 to October 15, Natural ventilation of a buildings need to attain better orientation, window size, location and operable relative to the wind direction.

According to the study result more detail study need to be conducted on specific topics related to thermal comfort requirement in medical environment on thermal sensitive regions. The building regulation need to incorporates specifications on indoor thermal environment of a building. In particular for hospital buildings. Considering the thermal need of occupants and the bio-climatic conditions.

Building performance evaluation in both on design stage and post-occupancy study is helpful in generating guideline and to mitigate the thermal performance of buildings. passive design technologies need to prepare based on the potential environmental resource of specific area. And the Vernacular trends also need to be identified and incorporated to best fit the modern construction.

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APPENDIX

1. Informative description of the measuring device.

A. Thermo-hygrometer

General description	Features
■ Large character LCD display ■ Multi functional ■ Low power consumption ■ High stability and accuracy	Displaying temperature, humidity and time simultaneously. Memory of MAX/ MIN Measuring value. 12-houre/24hour displaying system selectable

Table 19. General description of thermohygrometer

Specification

- Temperature range 10⁰C-70⁰C (14⁰F-15⁰ F)
- Hmidity; 10%-99%

Resolution

Temperature; 1⁰C(1.8F)

Humidity;5% RH(940%-80%)

Power supply; 1.5V(AAA size)*1

Product dimension; 100*108*20mm

Weight; Approx =140g

B. Digital Anemometer

Model number; AS836, Anemometer ,, manufacture date 2016/12/12 EC

1. Features

- Wind speed & temperature measurement
- Wind speed & temperature measuring unit option
- Data hold
- Max/Min/Avg/Cu measurement , LCD back light, Auto power off

2. place and environment conditions of the calibration;

Place	Temperature		RH
Smart sensor FQC	23 ⁰ C- 27 ⁰ C		50RH-75RH
Function range mode	Normalized value (m/s)	Actual value (m/s)	Permissible (m/s)
Measured value	1.50	1.48	-0.02
	3.50	3.52	0.02
	4.50	4.47	-0.03
	6.00	6.02	0.02
	10.00	9.98	-0.02
	15.00	15.01	0.01
	23.00	23.01	0.01

Table 20. place and environment conditions of the calibration of anemometer.

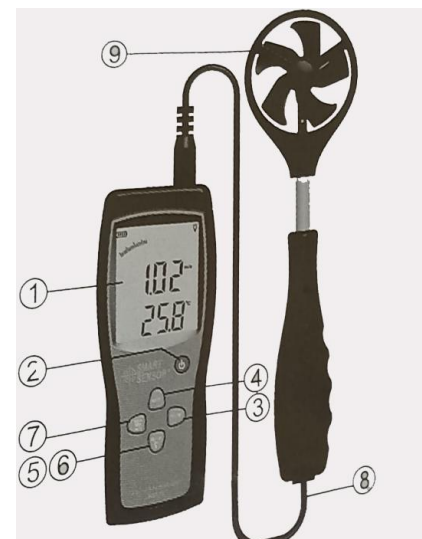
3. Specification

Unit	Range	Resolution	Accuracy
⁰ C	0.0 ⁰ C-45.0 ⁰ C	0.2	2 ⁰ C
⁰ F	32.0 ⁰ F-113.0 ⁰ F	0.36	0.36 ⁰ F

Table 21. Wind and temperature range

Diagram description

1. LCD
2. ON/OFF button
3. Wind speed unit switch button
4. Wind speed unit select button
5. Data hold button
6. Temperature switch and LCD black light button
7. Max/Min/Avg/Cu function button



8. Connection lead wire

9. Vane

2. Structured questioner format

General description;

Dear respondents the purpose of these questioner is to support Research on **thermal comfort evaluation of hospital building user's in DireDawa**; in case of 'Dillchora' and 'Sabian '. These questioner help the research with qualitative and quantitative data. Your answer play great role in this research, Please provide the required information on the following questions by making **(mark /x)**. you can ask the data collector for any help regarding to the questioner.

All responses will be treated in strict confidentiality and will be used for academic research only. Thank you for your priceless cooperation in advance.

Questioner N°: __ sample hospital: __ Date: _____ Sign: __

Researcher : Bethlehem seifu shigaze

General information (filled by surveyor)

Clothing type

Activity level

A. Demographic Information:

1. Gender ☐ F ☐ M
2. Age group: ☐ 15-20 ☐ 21-30 ☐ 31-40 ☐ 41-50 ☐ 51-60 ☐ 61-70 ☐ 71-80 ☐ 81-90 ☐ 91-100
3. Sample type ☐ IPD patient ☐ Outpatient ☐ Staff
- Family(visitor)
4. ward type: ☐ Pd ☐ atal ☐ ☐ ☐
- wound care General medical ward
5. Admission period /duration. Days Week
- Month year

B. ASHRAE thermal sensational scale

Note: fill each question on the time mentioned

Thermal sensation scale								
Level of Scale		Cold (-3)	Cool (-2)	Slightly cool(-1)	Neutral (0.0)	Slightly warm(1. 0)	Warm (2)	Hot (3)
Time	2:00 AM							
	6:00 AM							
	10:00 AM							
Thermal preference scale								
Level of Scale		Much cooler (-3)	Coole r (-2)	Slightly cool(-1)	No change(0.0)	Slightly warmer (1)	Warmer (2)	Much warmer(3)
Time	2:00 AM							
	6:00 AM							
	10:00 AM							
Satisfaction scale								
Scale		Very dissati sfied (-3)	Dissat isfied (-2)	Slightly dissatisf ied (-1)	Neutral (0.0)	Slightly satisfied (1)	Satisfie d (2)	Very satisfie d (3)
Time	2:00 AM							
	6:00 AM							
	10:00 AM							

Table 22. ASHRAE thermal sensational scale

C. Related information

6. Availability of AC or fan : ☐ ☐es
 No ☐ ☐ ☐
8. Level of natural ventilation: Weak Fair
 Good
9. Do the thermal condition influenced you? ☐ H☐ ☐Mood
 Not at all

3 . Raw Data for Environmental Variables

A. Air Temperature

P/Room= Patient room, E/Room= Examination room , W/Area = waiting Area

Temperature Data (°C) for the Month of April and May April								
Date	Time	Dillchora Referral Hospital ; (Sample one)			Sabian General Hospital; (Sample two)			External /outside
		P/Room	E/ Room	W/Area	P/Room	E/Room	W/Area	
April	2:00AM	31.8	30.9	29.8	29.2	30.5	28.9	31.8
10,20 21	6:00AM	33.5	32.1	31.2	31.2	29.8	30.5	30.2
	10:00AM	32.9	34.3	34	30.6	31.6	30.7	29.8
April	2:00AM	31.7	31	33.2	32.2	31.6	32.2	32.5
13,20 21	6:00AM	32.4	32.1	32.4	32.5	33.1	32.2	29.9
	10:00AM	32.3	33.4	32.8	32.7	34.3	34.1	31.5
April	2:00AM	32.4	31	32.1	33.3	33	32.9	32.2
15,20 21	6:00AM	32.2	30.9	31.4	33.4	31.1	33.5	30.3
	10:00AM	32.2	30.8	33.4	32.2	32.6	32.9	31.5
April	2:00AM	29.1	30.1	30.6	29.7	29.5	30.7	28.9
18,20	6:00AM	29.3	30.2	31.4	31.4	31.6	31.4	30.3

21	10:00AM	30.2	30.8	32.4	32.4	33.2	32.8	28.4
April	2:00AM	27.5	29	30	3.5	28.9	32.9	30.6
21,20 21	6:00AM	28.5	27.3	31.4	32.4	30.3	33.5	31.4
	10:00AM	29.6	30.1	32	32.2	32.6	32.9	33.2
April	2:00AM	29	28.7	29.3	28	27.8	38.9	29.5
24,20 21	6:00AM	28.9	29.7	30.1	31.4	31.6	31.4	30.5
	10:00AM	29.9	28.6	30.3	32.4	33.2	32.8	28.9
April	2:00AM	32.1	32.8	33	31.3	30.3	29.7	28.4
27,20 21	6:00AM	33.7	31.5	31.8	32.4	30.3	33.5	34
	10:00AM	32.9	31.6	32.9	34.2	32.6	32.9	34.2
April	2:00AM	32.7	32.3	32.6	31.4	31.6	31.4	33.2
30,20 21	6:00AM	32.4	30.3	31.5	32.4	33.2	32.8	31.8
	10:00AM	32.2	31.6	32.9	31.4	31.6	31.4	29.5
May	2:00AM	31.5	31.3	32.6	32.6	32.8	31.7	34.5
3,202 1	6:00AM	32.2	30.5	31.5	32.8	32.6	32.2	33.4
	10:00AM	31.4	31.6	31.9	31.9	33.2	33.2	32.4
May	2:00AM	32.1	32.8	32	31.5	31	30.2	31.8
6,202 1	6:00AM	30.9	31.1	30.7	32.4	32.2	32.6	29.5
	10:00AM	31.5	31.4	30.8	32.3	32.9	33.1	30.2
May	2:00AM	31	31.4	31.8	31.5	32.7	31.9	33.4
9,202 1	6:00AM	33.2	32.1	31.2	30.4	31.3	32.2	31.7
	10:00AM	32.9	34.3	34	34.3	33.6	32.6	32..5
May	2:00AM	29.7	30.9	29.4	29	28.7	29.3	29.5
12,20 21	6:00AM	32.2	30.5	31.5	28.9	29.7	30.1	30.5
	10:00AM	31.4	31.6	31.9	33.5	34	32.9	28.9

May 15,20 21	2:00AM	32.4	31	32.1	32.7	32.3	32.6	33.4
	6:00AM	32.2	30.9	31.4	32.4	30.3	31.5	32.1
	10:00AM	32.9	34.3	34	31.4	31.6	31.9	33.4
May 17,20 21	2:00AM	33.5	34	32.9	32.6	32.8	31.7	34.5
	6:00AM	32.4	30.3	33.5	32.8	32.6	32.2	33.4
	10:00AM	34.2	32.6	32.9	31.9	33.2	33.2	32.4
May 20,20 21	2:00AM	30.4	32.8	31.6	28.7	28.7	29.3	29.5
	6:00AM	30.7	30.2	30.8	28.9	27.7	30.1	30.5
	10:00AM	31.4	31.8	31.5	29.3	28.6	28.6	28..9

Table 23. Temperature raw data (Field survey, 2021)

B. Humidity (RH)

P/Room= patient room, E/Room= Examination room , W/Area = waiting area

Humidity Data (%) for the Month of April and May								
Date	Time	Dillchora Referral Hospital ; (Sample one)			Sabian Referral Hospital; (Sample two)			External /outside
		P/Room	E/ Room	W/Area	P/Room	E/Room	W/Area	
April 10,20 21	2:00AM	20	23	33	25	27	31	28
	6:00AM	43	41	40	29	32	34	45
	10:00AM	23	25	31	23	30	37	39
April 13,20 21	2:00AM	29	28	27	20	24	23	29
	6:00AM	25	22	24	43	41	40	25
	10:00AM	27	26	25	23	25	31	27
April 15,20 21	2:00AM	20	24	23	29	28	27	27
	6:00AM	37	38	44	43	41	40	44
	10:00AM	49	40	42	45	43	41	43
April	2:00AM	27	26	26	38	35	45	29

18,20 21	6:00AM	20	29	21	55	52	49	20
	10:00AM	37	42	45	39	58	45	45
April	2:00AM	26	25	26	45	39	42	20
21,20 21	6:00AM	29	34	32	43	41	40	35
	10:00AM	39	58	45	29	28	27	43
April	2:00AM	29	28	27	43	41	40	29
24,20 21	6:00AM	25	22	24	39	58	45	25
	10:00AM	27	26	25	27	26	25	27
April	2:00AM	55	52	49	38	35	45	26
27,20 21	6:00AM	37	38	44	39	58	45	29
	10:00AM	27	26	25	18	35	33	31
April	2:00AM	39	58	45	43	47	35	29
30,20 21	6:00AM	55	52	49	29	28	27	32
	10:00AM	37	42	45	39	58	45	33
May	2:00AM	29	28	27	39	58	45	28
3,202 1	6:00AM	25	22	24	27	26	25	34
	10:00AM	27	26	25	37	42	45	36
May	2:00AM	43	47	35	55	52	49	28
6,202 1	6:00AM	29	28	27	43	41	40	29
	10:00AM	27	26	25	42	37	34	25
May	2:00AM	25	22	24	29	28	27	27
9,202 1	6:00AM	29	28	27	25	22	24	24
	10:00AM	37	38	44	27	26	25	32
May	2:00AM	39	58	45	29	28	27	36
12,20	6:00AM	55	52	49	29	28	27	28

21	10:00AM	27	26	25	42	37	34	29
May	2:00AM	37	42	45	39	58	45	34
5,2021	6:00AM	25	22	24	37	46	52	32
	10:00AM	29	28	27	34	42	44	28
May	2:00AM	25	22	24	29	28	27	34
17,2021	6:00AM	37	42	45	25	22	24	36
	10:00AM	37	38	44	27	26	25	43
May	2:00AM	25	32	24	25	22	24	29
20,2021	6:00AM	27	26	25	27	22	27	30
	10:00AM	27	26	25	37	38	44	32

Table 24. Humidity raw data (Field survey, 2021)

C. Air velocity

Air velocity (M/s) for the Month of April and May April								
Date	Time	Dillchora Referral Hospital ; (Sample one)			Sabian Referral Hospital; (Sample two)			Out Door
		P/Room	E/ Room	W/Area	P/Room	E/Room	W/Area	-
April	2:00AM	0.12	0.15	0.23	0.103	0.23	0.09	0.84
10,2021	6:00AM	0.05	0.02	0.014	0.022	0.08	0.06	1.27
	10:00AM	0.01	0.024	0.012	0.07	0.014	0.012	0.16
April	2:00AM	0.14	0.07	0.21	0.071	0.109	0.11	2.03
13,2021	6:00AM	0.02	0.07	0.045	0.102	0.065	0.02	0.7
	10:00AM	0.078	0.108	0.076	0.08	0.02	0.02	0.82
April	2:00AM	0.13	0.19	0.102	0.16	0.109	0.24	1.02
15,2021	6:00AM	0.08	0.028	0.09	0.07	0.103	0.09	0.2
	10:00AM	0.045	0.10	0.02	0.12	0.015	0.09	0.9

April 18,20 21	2:00AM	0.12	0.102	0.08	0.031	0.057	0.04	1.2
	6:00AM	0.08	0.113	0.034	0.023	0.02	0.065	0.7
	10:00AM	0.098	0.066	0.089	0.02	0.102	0.62	0.4
April 21,20 21	2:00AM	0.1	0.05	0.08	0.03	0.043	0.12	1.5
	6:00AM	0.03	0.031	0.076	0.145	0.19	0.05	1.01
	10:00AM	0.01	0.12	0.04	0.05	0.032	0.102	0.7
April 24,20 21	2:00AM	0.16	0.12	0.09	0.101	0.89	0.013	2.12
	6:00AM	0.109	0.102	0.089	0.056	0.09	0.057	1.6
	10:00AM	0.024	0.022	0.087	0.06	0.012	0.065	1.2
April 27,20 21	2:00AM	0.034	0.076	0.15	0.14	0.013	0.16	1.03
	6:00AM	0.07	0.045	0.06	0.13	0.013	0.027	0.8
	10:00AM	0.091	0.012	0.31	0.025	0.026	0.023	0.9
April 30,20 21	2:00AM	0.002	0.51	0.061	0.109	0.087	0.012	0.89
	6:00AM	0.06	0.105	0.077	0.098	0.35	0.046	0.3
	10:00AM	0.08	0.031	0.031	0.06	0.12	0.054	0.74
May 3,202 1	2:00AM	0.17	0.15	0.14	0.09	0.12	0.21	0.6
	6:00AM	0.012	0.65	0.021	0.025	0.051	0.105	0.23
	10:00AM	0.042	0.022	0.102	0.06	0.0109	0.24	0.31
May 6,202 1	2:00AM	0.14	0.12	0.09	0.093	0.103	0.89	0.84
	6:00AM	0.09	0.067	0.02	0.087	0.102	0.09	0.22
	10:00AM	0.09	0.103	0.054	0.051	0.043	0.04	0.9
May April 9,202 1	2:00AM	0.12	0.174	0.087	0.079	0.102	0.15	1.03
	6:00AM	0.04	0.054	0.05	0.09	0.012	0.62	1.6
	10:00AM	0.01	0.05	0.08	0.06	0.06	0.12	0.7