THERMAL DISCOMFORT AND ADAPTATION STRATEGIES AMONG THE RESIDENTS OF KANO MUNICIPAL LOCAL GOVERNMENT AREA, KANO STATE, NIGERIA

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DECLARATION

I declare that the work in this Thesis entitled "THERMAL COMFORT AND ADAPTATION STRATEGIES AMONG THE RESIDENTS OF MUNICIPAL LOCAL GOVERNMENT, KANO, NIGERIA" is a record of my own research work under the supervision of Dr. I.A. Abdulhamid and Dr. B. Abdulkarim. The information derived from literature has been duly acknowledged in the text and a list of references provided. No part of this work has been submitted for the award of degree or diploma in any other University.

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CERTIFICATION

This Thesis entitled "THERMAL COMFORT AND ADAPTATION STRATEGIES AMONG THE RESIDENTS OF "KANO MUNICIPAL LOCAL GOVERNMENT, IN KANO, NIGERIA" by Aminu SHEHU, meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This research work is dedicated to my beloved parents; my late father Alhaji Usman (Shehu) Aliyu Jidama and our mother (Hajiya Halima Usman) and my entire late brothers and sisters who have passed away; may Almighty Allah reward them with Aljannatul-Firdaus, Ameen.

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ABSTRACT

The purpose of this study is to analyze the residents' perception and adaptation strategies to thermal discomfort in Kano Municipal LGA. The work was conducted in Kano Municipal Local Government Area, during the (hottest) month of April, 2015 between 1200 to 1600 hours on each study day. Digital Thermo-Anemometer, whirling wet- and dry-bulb Thermometer as well as semi-structured questionnaires were simultaneously used as research instruments. Three hundred and eighty four respondents were selected from the six sampled political wards of the area using purposive sampling out of which 363 responded positively. The data were analyzed using table of frequency and regression analysis. The result has shown that months of April, May, and June have the highest THI greater than $30^{o}C$; while January and December recorded the lowest THI of less than $25^{o}C$. The result also revealed that 51% of the people living in the area rated climate as the most key factor for their discomfort and preference while only 7.4% disagreed. The findings revealed that the R-squared value as 48.2% indicating that there was a fair relationship among the independent variables (thermal perception and thermal Adaptation) on the dependent variable (thermal humidity index). The F-value (index of reliability) is significant at $P< 0.000$. This implies that the effects of thermal humidity index is significant on the perception and adaptation. The study concludes that respondents in Kano Municipal L.G.A. have a high heat tolerance, since

they accept the thermal conditions which exceed the ASHRAE standard. The study recommended among other things for Kano Municipal Authority to make improvements, in the area of pursuant of 'climate sensitive' urban design, establishment of more green areas and to publicize enlightenment to residents on the issue of thermal discomfort problems.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Urban climates globally are distinguished from those of less built-up areas by differences in air temperature, humidity, wind speed and direction and amount of precipitation. These differences are attributable in large part to the altering of the natural terrain through the construction of artificial structures and surfaces. For example, tall buildings, paved streets, and parking lots affect wind flow, runoff, and the energy balance of a locality (Ariko, 2014).

Urban Heat Island (UCHI) is defined as a temperature differences between the air within the urban canopy layer and the air in a rural reference area outside the settlement. Microclimatic variations manifested as UHI, contribute in exacerbating heat-related health problems, increase in energy demand for indoor cooling and refrigeration and increase in air pollution as a result of poor dispersal of pollutants due to formation of pollution domes over urban areas. UCHI also affects the thermal comfort of urban dwellers as it robs them of the night-time relief from high temperatures which is experienced in the rural areas. These problems according to Stewart and Oke (2006) will become increasingly heightened under the future climate change scenarios and projections of urbanization, coupled with unplanned urban growth, characteristic of our cities.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers ASHRAE (2004) defined thermal comfort as a condition of mind which expresses satisfaction with the thermal environment. However, environmental thermal comfort is a significant component for measuring the quality of indoor micro-environments. ASHRAE (2004) stipulates that for a building or a space to be comfortable, 80% of the occupants are assumed to be satisfied with the thermal conditions.

Thermal comfort plays a significant role in human performance at both mental and physical levels. Failure of human beings to respond to the environment through thermoregulatory mechanism causes thermal discomfort. This discomfort experienced by occupants of a built environment during hot season can cause lower emotional health manifested as psychological distress, depression and anxiety, as well as lower physical health, manifested as heart disease, insomnia, headache, fatigue, boredom and poor arousal (Ibrahim, Ishaq, Muhammad, Yerima 2014).

The quality of lives of human beings to a large extent depends on the quality of their indoor environments because people spend most of their time indoors (Lawal and Ojo, 2011). Human beings partake in various activities within building enclosures and these activities can only be performed best when the environmental conditions are favorable. Inside a building, people are affected either positively or negatively as a result of the physiological reactions and psychological responses to the environment.

Many thermal indices have been widely used to express the human comfort level in areas or time periods by the combination of meteorological and physiological data based on environmental conditions. However, from records of previous studies and indices considered for Nigeria, it was suggested by Garba, (2015) that temperature - humidity or thermo-hygrometric index (THI) is important as an index of thermal comfort in the tropics because of its advantage in providing the combined effect of temperature and humidity on comfort within a narrow range of environmental conditions. The index also has the capability of giving direct rather predictive results of thermal comfort conditions relying only on temperature and humidity values.

Indeed, persons staying in very similar spaces subjected to the same climate and belonging to a common culture, issue very different opinions on thermal comfort due to the combination of a large number of factors that affect the perception of human comforts. Adefolalu (1981) believes that relative humidity (RH) is an important factor in

human comfort and discomfort indices, especially in hot climate. When there is low humidity the air is very dry and sweating is more effective in cooling down the body. On the other hand, when the RH is high the air is damp and sweating is no longer very effective in cooling down the body. Umoh (2000) stresses further that in the coastal region, the months of June to October have monthly means over 90% while in the North during January to April mean values are close to 20% or 25%.

The populations of the tropics are peculiarly subjected to thermal discomfort, due to the high temperature of their environments, associated overcrowding, urban decay and low health thresholds as a result, according to Anyam, (1989) additional effect of thermal discomfort is a course for concern to many scholars. Several types of research such as Meyer (2002) and Wong and Khoo (2003) have revealed that man's physical strength and mental activities are at their best within a given range of climatic conditions, and outside this range, efficiency lessens, while stresses and the possibility of disease increases. Based on the foregoing, the importance of studying the thermal comfort in residential buildings of Kano Municipal cannot be overemphasized. However, people vary, sometimes markedly, in their feeling of comfort according to their metabolic rate, type of clothing, workload, age, diet, emotions, cultural influences, past climatic experience, and climatic zone among others. People from tropical regions tend to accept as comfortable higher levels of air temperature and humidity than people from temperate zones (Stewart and Oke, 2010).

1.2 STATEMENT OF THE RESEARCH PROBLEM

Thermal comfort is one of the most immediate and direct impact exerted by the built environment on its occupants, and it is one of the strongest determinants of the overall post occupancy evaluation of a building. In the previous time, most thermal comfort investigations about buildings and building designs were addressed by applying instrumental observations or simulations of indoor climate parameters to predictive models of human thermal

comfort. But in the last few decades, field studies involving large samples of actual occupants in real buildings have highlighted the shortcomings of such models. The reinstatement of building occupants and experimental subjects as the final arbiters of thermal comfort leads to a clearer understanding of thermal interactions between occupants and buildings, and a complete understanding of how thermal comfort interacts with other elements of indoor environmental quality to influence overall occupants' satisfaction (de Dear, *et al*, 2013)

Humans have always striven to create a thermally comfortable environment. This is reflected in building traditions around the world - from ancient history to present day. Today, creating a thermally comfortable environment is gaining more concern as one of the most important parameters in designing an indoor space where the majority of people usually spend more than 20 hours of their days - at home, at the workplace or during transportation. Most people today spend most of their time in artificial thermal environments, working, resting, pursuing recreational activities or sleeping. Since everyone likes to be comfortable, the thermal environment has to be suitable to them. As our sense of well-being and productivity are dependent on the indoor climate, it is important to equip them with well-planned air conditioning systems and to ensure that the building provides comfort specific to the comfort level of the occupants (Leung, 2008)

In fact, human physiologic comfort is a prerequisite to appropriate planning, designing and weather sensitive enterprises, forecasting and consequent management. Unfortunately, little has been achieved because of obvious reasons as inadequate of relevant information. Human beings vary sometimes remarkably in their feelings of comfort depending on their physiological, psychological, socio-cultural differences, climatic zone and, importantly on their climatic experiences (or adaptation).Indoor thermal comfort is essential to occupants' wellbeing productivity, and efficiency. Hot-dry climates with its high temperatures and intense solar radiation are nowadays becoming hotter and drier especially in this era of climate change and global warming. Thus, providing for the

indoor thermal comfort and reducing energy use in the building is increasingly becoming difficult. This according to Akande and Adebomowo, (2010), has called for a new way of thinking and re-evaluation of the existing methods of tackling discomfort problems.

Kano Municipal comprise of old-part and New layout. The design of the area especially the part of the ancient city wall is such that buildings are so closely parked, and are only separated by narrow and crooked paths and often not motor able. This is clearly in agreement with the findings of Abdulhamid (2011) of a smaller proportion of sky view factor (SVF) in Kano Metropolis. The research of Usman (2012) observed that there is a significant relationship between S.V.F. and microclimate and therefore, suggested urban climate studies to include the influence of Urban Canopy Heat Island (UCHI) on human comfort and heat-related health problems. Considering this, climatic comfort limit and the high density of population of Kano Municipal, thermal discomfort is very much an issue that required urgent investigation.

The congestion and rapid increase of urban activities in Kano State have resulted in thermal comfort challenges. This problem has remained stagnant in the air for quite a long time, despite the control in the design of buildings that have emerged of recent, there still remains the problem of indoor air quality and humid hot interior spaces that affect building occupants.

Thermal comfort, especially indoor, have serious socioeconomic effects on the life of the residents of Kano Municipal. These effects range from bad mood (changing the behavior of the people to hotheaded), boredom, insomnia (making sleep difficult or impossible especially at night), headache and thirstiness (forcing people to take cold drinks at an unhealthy threshold)

Amongst the commonest environmental phenomena influencing the life and wellbeing of the residents of Kano

Municipal is the issue of thermal discomfort. In the area, it is not quite unusual to observe the majority of people clamoring about being thermally uncomfortable to the extent that they often make qualitative expression about the matter. Another typical experience is the way the larger majorities of the residents of the area stay away from their homes and form joints of various age groups outside the home, trying to mitigate indoor discomfort and/or receive outdoor comfort.

Human satisfaction is subject to the nature of his environment, it is however very important to acquire their opinion, as stated by Adedayo, (2010) that seeking users' view in creating a livable environment for potential owners assist in meeting up their needs and aspirations, thus their satisfaction is expected to have been captured too. There is a paucity of literature regarding indoor thermal discomfort in local urban settings such as Kano Municipal, giving emphasis to residents' viewpoint. This gap in knowledge motivated the researcher to conduct the study on indoor environmental conditions and occupants' thermal comfort as well as an adaptation in a residential building during the hot dry season particularly based on the occupants' responses.

1.3 RESEARCH QUESTIONS

To achieve the stated study's objectives below, the investigation focuses on several key questions:

1. What is the spatial pattern of thermal comfort in the study area?
2. How do the respondents perceive thermal comfort of in the study area?
3. What adaptive measures the respondents employ to cope with thermal discomfort in the area?
4. Is there any relationship between the residents' thermal perception, adaptation and thermal humidity index in the area?

1.4 AIM AND OBJECTIVES

The aim of the study is to analyze the residents' perception and adaptation strategies on thermal discomfort in Kano Municipal LGA.

This aim was realized using the following specific objectives; which are to:

i. determine the pattern of thermal humidity index in the study area.

ii. examine the residents' perception on thermal comfort in relation to spatial variation of physical characteristics of the study area.

iii. assess respondents' adaptive measures in coping with thermal discomfort.

iv. determine the effect of thermal humidity index have effect on the perception and adaptation of comfort on the residents of the area.

1.5 HYPOTHESIS

Ho: Thermal perception and Thermal adaptation of residents are not significantly related to thermal humidity index of the environment.

1.6 SCOPE OF THE STUDY

In terms of spatial extent, this study is limited to Kano Municipal LGA part of Kano metropolis; comprising 13 political wards and adult population of 284, 204(Independent National Electoral Commission, INEC, 2015). The respondents are usually adult males and females in the study area, who can be able to clearly express their comfort experiences; that is why registered voters of 2015 National election was adopted. The field data were collected in the month of April (dry and hottest month of the year in the climate of Kano) 2015; secondary meteorological information of 2009 to 2014 was also used in this work. This represents the temporal scope of this research. The content scope of this work restricted itself to the thermal perceptions of discomfort and its consequent adaptations experience of the residents using temperature and humidity indices only in the area.

1.7 SIGNIFICANCE OF THE STUDY

The outcome of this work may be useful to both residents as well as stakeholders in adding the growing knowledge of thermal comfort of buildings. In another perspective, it will help to enlighten building designers on the attention required for proper orientation and climatological check.

Findings of this study can be of value to decision makers, architects, scholars and the general public on the interaction that exists between sustainable urban climatology and urban design. The one aspect that may help in enhancing the urban design is to improve microclimate of residential areas in modern Kano. However, incorporating new perspectives needed in the urban design process can be done by considering microclimate as well as thermal comfort in urban planning regulations so as to develop urban spaces and enhance the quality of life.

CHAPTER TWO

CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

2.1 INTRODUCTION

This chapter focuses on the overview of the history of thermal comfort, the conceptual fact, including classification of thermal comfort, indices of thermal comfort, theories, and factors that influence thermal comfort, as well as their existing and potential coping strategies adopted. The review of the literature was aimed at establishing knowledge gap on which this research is linked. It also includes the use of an index of thermal comfort (THI), use of standard comfort limits for the tropics and the various impact of temperature, humidity on thermal comfort.

2.2 CONCEPTUAL FRAMEWORK

2.2.1 Urbanization and Air Temperature

Urban heat island (UHI) magnitude is the most widely recognized indicator of city climate modification in the environmental sciences. Understood broadly as a nocturnal "urban- rural" air temperature difference at screen height, UHI magnitude has been measured and reported in thousands of cities and towns worldwide since the early 1900s

Montavez, et al (2008) in Abdulhamid, Kibon, Usman and Nduka, (2016) asserted that of all the earth surfaces phenomena, an urban area is perhaps the most complex due to the multifacetious nature of its artificial character as promoted by the various activities taking place in such an area. Naturally, the temperature of these surfaces differs from those of the surrounding countryside because of the variation in their thermal and albedo characteristics. The highly varying temperature characteristics of the urban structures, the artificial injection of heat into the urban system and the presence of aerosols in the atmosphere have led to a considerable urban temperature field. These variations have been noted to be as a result of the extent of influences exerted by the various factors responsible for these changes. Some of the main factors related with urban heat island formation are the canyon radiative geometry (or reduced SVF which

results in trapping of heat by buildings), the thermal properties of the building materials with high heat capacities (such as metals, cement, and asphalt concretes etc.), anthropogenic heat release and the urban greenhouse effects (Oke *et al*, 1991 in Abdulhamid, Iguisi, Sawa and Nduka, 2012).

In the UHI literature a wide variety of different landscape types have been classified as urban and rural. This is partly a consequence of urban areas not being homogenous with clear borders but rather a continuum of morphologies of different densities with different degrees of imperviousness and various physical material properties. Stewart gave a review of the discrepancies in the classification into urban and rural sites and proposed to overcome the 'urban-rural' dichotomy as space classification paradigm and proposed to replace it by a more 'multidimensional, local-scale landscape classification scheme better suited to the complexity of surface climates characterizing UHI in cities and regions worldwide' (Stewart, 2007). Two years later Stewart and Oke proposed local (thermal) climate zones (LCZ) as a more purposeful local landscape classification system to better quantify UHI magnitude and put 'methodological rigor behind computations of UHI magnitude' (Stewart and Oke, 2009 in Usman, 2016) as shown in table 2.1 below.

In the research conducted by Abdulhamid (2011) it was concluded that UCHI in Kano metropolis is generally warm profile both during the day and night time and most study stations had high temperatures. This can be attributed to the season (hot/dry) and consequent warming of the surface and the over atmosphere as well as high intensity of UCHI (attributed to nature of the surface materials and characteristics, as well as moderate to high level of human activities taking place within the various stations.

Table 2.1: Adapted LCZ scheme and short description of the classes

LCZ	ID	DESCRIPTION
Natural Series		
Forest	*Forest*	Forest(coniferous and mixed)
Agricultural Series		
Cropped/Bare Fields	*field*	Agricultural areas
City Series		
Block layout	*Blocks*	Clustered high-rise buildings in uniform geometric
Modern core	*Mocore*	High-rise commercial buildings
Industrial/extensive low-rise	*Industry*	Commercial activities in low-rise buildings
Extensive low – rise	*Port*	Also contains container arrays and storage facilities
Regular typical Housing	*Reghous*	Single family houses, high% of green between for suburbs
Compact Housing	*Terrace*	Regular pattern aligned in rows
Compact Housing	*Urbdens*	Perimeter block buildings of uniform height with courtyards in the
Old core	*Urbcore*	Historic inner city with massive buildings of uniform height and single spires

Adopted from Bechtel and Daneke (2012)

2.2.2 Thermal comfort

Every facet of human life is under the influence of atmospheric environment. Weather and climate more than any other element of the environment exercise a considerable influence on man. More often, man blame climate on his failure especially in the tropical areas. Man's very existence virtually depends on the fundamental concept of comfort. Therefore, the potential dangers of thermal discomforts are imminent (Anyam, 1989).

Thermal comfort is defined by ASHRAE as “that condition of mind in which satisfaction is expressed with the thermal environment". The phrase ‘condition of mind’ implies that psychological as well as physiological factors are involved. One way of identifying the 'condition of mind' is to develop empirical equations that can relate comfort perceptions or feelings to physiological responses (ASHRAE, 1981). In this way, the subjectivity element of the respondent can be reduced to quantifiable factors. It is also possible that emotional factors can affect thermal comfort. Thus, thermal comfort is more of a non-objective expression when compared to thermal sensation. A simple way of expressing thermal comfort is to ask subjects to indicate their comfort feeling on a scale which contains terms referring to comfortable or uncomfortable conditions. Examples of the terms often used are ‘slightly comfortable, ‘warmly comfortable, ‘slightly uncomfortable, and 'very uncomfortable'. Comfort Temperature is the temperature at which respondents express comfort feelings by voting with the middle category of the comfort scale. The middle category is known as 'comfortable'.

Thermal comfort basically has to do with the temperature that the resident considers as comfortable to stay in. Indoor thermal comfort is achieved when occupants are able to pursue without any hindrance, activities for which the building is intended. Hence, it is essential for occupants’ well-being, productivity, and efficiency. International Standard for Organization (ISO) 7730, as well as ASHRAE, use the results of an extensive research carried by Fanger (1970) to define thermal comfort as that condition of mind which expresses satisfaction with the thermal environment.

However, there are physiological and psychological variations of comfort from person to person that make it difficult to satisfy everyone in a space, but by using statistical data based on the laboratory and field study research it is possible to specify the percentage of occupants that are thermally comfortable (ASHRAE standard 55R 2004).

Urban Canopy Heat Islands (UCHI), Sky View Factors (SVF) as well as urban geometry were listed by Abdulhamid

(2011) as issues of urban concern. The research analyzed UCHI in Kano and revealed the existence of spatial and temporal thermal differences. The study discovered that SVF is low in the city center particularly along the narrow road between high rise buildings; this has made the air temperature to be high at those points.

2.2.3 Historical Development of Thermal Comfort Investigations

Thermal comfort has been investigated since the early 19th century in America. During that era, heating ventilation systems proved problematic and created uncomfortable environments for occupants. The American Society of Heating and Ventilating Engineers (ASHVE) was established in Pittsburgh to study ways to create a better indoor thermal environment. These early researchers mainly focused on the working thermal conditions in industries or in hot environments.

The earliest published study (Yaglou and Miller, 1923) was carried out in the early twentieth of this century and was based on a man in a three-piece woolen business suit with cotton shirt and cotton underwear. In this study, which was carried out in the United States, the lower extreme of the 'comfort zone' was established as 20.6°C with 20% relative humidity. By the 1930s, perhaps partly due to the Great Depression, people seemed to have become satisfied with living at a slightly lower temperature (Kidder, and Parker, 1958). This is also evidenced by the British who, according to Kell and Martin (1971) were living comfortably at about 17.8°C. After the Depression and up to 1977, the comfort temperature began to rise. For example, during the 1950s, the lower extreme of the ASHRAE thermal comfort zone had risen to 22°C at 20% relative humidity. By 1975, this extreme had increased to 22.8°C also at 20% relative humidity (ASHRAE, 1977).

Throughout the last century, thermal comfort models were developed because they quantitatively (based on large surveys of people) describe the ranges of conditions where people will feel thermally comfortable in buildings. There are two prevailing thermal comfort models which are: the comfort model originally proposed by Fanger takes into account the

adaptation to the prevailing climate of occupants of buildings (Adaptive Comfort Model). Thermal comfort studies started in earnest in the 20th century and one of the early common references in thermal comfort literature is Bedford (1989). The research was based on field studies and the seven point scale for thermal sensation which is still in use. The study was a survey of factory workers, the workers' feeling of the environment compared with the measured specifications of their environment.

The diverse ways in which climate affect man and his activities, as well as the impact of man and his activities on climate, constitutes the subject matter of the growing field of applied climatology. Human comfort and health were the major reasons for the early interest in urban climatology. The early urban climatologists were concerned with the city-induced anomalies that have a concomitant effect on the comfort and health of city dwellers. Luke Howard was the first urban climatologist that scientifically studies urban climate modification, who did an urban-rural comparison of temperature record and discovered a variation, with urban area having higher temperature than the rural (Ariko, 2014)

2.3. THERMAL TERMINOLOGIES

In the literature of thermal comfort studies, several terminologies are frequently mentioned and commonly found. It is necessary to clarify the concepts behind these terminologies at the outset of the discussion.

2.3.1 Thermal Sensation

Thermal sensation is an expression of the sensation of warmth or its lack. This is related to a rational experience that is probably not influenced by any factors other than physiological and environmental, including the activity and clothing levels of the person. The ASHRAE (1981) Scale, also known as the Thermal Sensation Scale, is one way of expressing thermal sensation. The neutral temperature is the temperature at which people experience a sensation which is neither slightly warm nor slightly cool. The neutral sensation is indicated by voting for the central category, known as 'neutral' on the thermal sensation scale.

In thermal comfort studies, the subjective sensation experienced by an occupant can be measured by the vote cast on a Likert scale. The most common scale used is the ASHRAE scale, a seven-point thermal sensation scale, which has been used by Fanger (1970) and subsequently used in ISO standards regarding thermal comfort (ISO 7730). The scale assigns the value of zero to the neutral sensation, whilst hot being given a value of +3 and cold a value of -3. There are other scales used by other researchers.

2.3.2 Thermal Neutrality

In thermal comfort study, thermal neutrality can be described as the thermal condition in which a subject expresses neither warm nor cold sensation. In the seven- or five-point comfort scale, this is the temperature that corresponds to the zero vote. A scientific definition of thermal neutrality can be found in the Glossary of the American Meteorological Society: "The condition in which the thermal environment of a homoeothermic animal is such that its heat production (metabolism) is not increased either by cold stress or heat stress" (Glickman, 1999). It goes on to define the neutral temperature range for a naked human, which is between 29°-31°C.

2.3.3 Thermal Acceptability

Thermal acceptability describes the thermal conditions, which a significant number of people would describe as acceptable. As such, it is described in terms of a range of conditions rather than a specific value. Normally, this is expressed as a lower and a higher value of a thermal sensation scale (i.e. slightly cool (-1), ok (0) and slightly warm (1)) as acceptable. In ASHRAE RP-884, the adaptive model of thermal acceptability is specified, on the seven-point scale, as between -1.5 (slightly cool to cool) and +1.5 (slightly warm to warm) according to de Dear, Brager and Cooper, (1998).

2.3.4 Thermal Preference

Another concept in subjective assessment of comfort focuses on the issue of thermal preference, introduced by McIntyre (1978). This scale identifies the thermal conditions people prefer to be in rather than the exact sensation they

are experiencing. The neutral vote is categorized as ‘no change’ whilst the other two are ‘want cooler’ and ‘want warmer’.

2.4 THERMAL COMFORT STANDARDS/MODELS

Conventionally two major publications dealing with thermal comfort standards are ISO 7730 and ASHRAE standards 55. This section gives an overview of these standards.

2.4.1 ASHRAE Standards 55

American Society of Heating and Refrigerating Engineers (ASHRAE) Standard 55 (ASHRAE 2010) provides comprehensive general guidelines on thermal environmental conditions for human occupancy, specifying the combinations of thermal environmental factors and personal factors. *ASHRAE Handbook—Fundamentals* (ASHRAE 2009) lists the fundamentals of human comfort in terms of useful parameters for operating systems and for providing comfort to building occupants.

A thermal environmental condition for human occupancy standards specifies conditions in which a majority of occupants will find the environment thermally acceptable. In the standard, a majority is defined as 80% of the occupants exposed to the same conditions within a space. The standard is intended for use in the environmental design and commissioning of buildings and other occupied spaces and their HVAC systems. The standard also specifies the PMV-PPD method for the evaluation of thermal environments (ASHREA, 2004)

The standard allows a designer at the outset to decide the level of comfort class to be provided in a space. This will influence the HVAC-system design and possibly the building design. The establishment of a universal model of thermal comfort enables the assessment of thermal comfort to be mandated in these standards. The reliance of these standards on the PMV- PPD model, however, raises some criticisms. The following section explains the development of an alternative model of thermal comfort and its subsequent inclusion into ASHRAE standards 55. This study is largely

associated with this model as it relates to the employment of both physical parameters as well as personal factors.

2.4.2 International Standard - ISO 7730

Another well-known international standard, ISO 7730, provides methods for predicting the thermal sensation and thermal dissatisfaction of personnel. Calculation of the predicted mean vote (PMV) and predicted the percentage of dissatisfied (PPD) associated with other environmental conditions enables the analytical investigation and interpretation of thermal comfort.

The ISO standards regarding the provision of comfort for human occupations are divided into three main areas, i.e. hot, moderate and cold environment. The standards for the ergonomics in hot and cold environment deal with the requirements for extreme thermal conditions. For the purpose of this study, the area of concern is the moderate environment, which is dealt in ISO 7730 (1994) Moderate thermal environments - determination of the PMV and PPD indices and specification of the conditions for thermal comfort ISO 7730 specifies the use of PMV-PPD based on Fanger's work for the determination of comfort. It also establishes criteria for local thermal discomfort due to droughts, based on the works of Olesen (1977) and Fanger (1972). It is derived from a heat balance equation for the human body combined with empirically determined equations, which define sweat rates and mean skin temperatures that are within comfort limits.

2.5 FACTORS INFLUENCING THERMAL COMFORT

Human comfort is very much an individualistic perception of the environmental stimuli. Certainly, physiologic comfort varies with time and over space. Human beings also vary sometimes remarkably in their feelings of comfort depending on their physical physiological, psychological, socio-cultural differences, climatic zone and importantly on their past climatic experiences (Anyam, 1989).

Garba, (2015), like many researchers have shown that thermal indices have effect on human thermal comfort sensation

and they include the following six factors: four physical variables: air velocity, air temperature, relative humidity, radiation and two personal variables (clothing insulation and activity level, i.e. metabolic rate). From the works of Heisler and Wang (2002) environmental condition are important factors influencing human thermal comfort. They are summarized as follows:

2.5.1 Radiation

Radiation is the net exchange of radiant energy between two bodies across an open space. The human body gains or losses radiant heat, for example, when exposed to an open fire, the sun or a window on a cold winter day. The rate of radiant transfer depends on the temperature differential, the thermal absorptive of the surfaces, and the distance between the surfaces

2.5.2 Air Temperature

Air temperature becomes a great distraction if it is either too hot or too cold. If people are sweating a lot, their main focus would be both uncomfortable and their perception of worrying about sweating, getting water to drink and getting up and moving to help evaporate some heat. All of these can't be good for concentration towards one's daily activities.

Excessive sweating can lead to painful muscle spasm called heat cramp, or to, heat exhaustion, which has many symptoms including excessive thirst, dizziness, and nausea. Both can be treated by drinking cool water and resting in a cool place. But, heat stroke requires urgent medical attention a body's thermostat stops working, so sweating is significantly reduced and the body's temperature becomes very hot. Several investigations have shown that variation in the heat indices especially temperature; have significant relations with human mortality (Lin, and Matzaraskis, 2011). Among other environmental conditions, the temperature is the most obvious, thus affecting human comfort index. Lechner, (2009) described global temperature increase due to the effect of the urban 'built' environment as a major cause of Urban Heat Island (UHI). It absorbs heat during the day and radiates it out at

night, raising nighttime minimum temperatures, which have been epidemiologically linked to excess mortality.

2.5.3 Relative Humidity

Humidity affects thermal comfort indirectly by altering the rate of evaporation of sweat in warm environments. The fraction of the body surface wet with perspiration, necessary to maintain the evaporative cooling for temperature regulation is a measure of the stain indirectly caused by humidity.

2.5.4 Air Velocity

Air motion significantly affects body heat transfer by convection and evaporation. Air movement or velocity results from free (natural) and forced convection as well as from the occupant's bodily movements. The faster the motion of the air, the greater, the rate of heat flow by both convection and evaporation. The natural convection of air over the surface of the body allows for the continuous dissipation of body heat. When ambient temperatures rise, however, natural air flow velocity is no longer sufficient and must be artificially increased, such as by the use of fans. Stratification causes air temperatures to vary from floor to ceiling. When air motion is too rapid, unpleasant drafts are felt by the room occupants.

The exact limits to acceptable air motion in the occupied zone are a function of the overall room conditions of temperature, humidity, and Mean Radiant Temperature (MRT), along with the temperature and humidity conditions of the moving air stream. A noticeable air movement across the body when there is perspiration on the skin may be regarded as a pleasant cooling breeze. When the surrounding surface and room air temperatures are cool, however, it will probably be considered a chilly draft. The neck, upper back, and ankles are most sensitive to drafts, particularly when the entering cool air is (1.5^{o}C) or more below normal room temperature. Every 15 fpm increase in air movement above a velocity of 30 fpm is sensed by the body as a 1^{o}C temperature drop. Air systems are usually designed for a maximum of 50 fpm in the occupied zone, but that is typically exceeded at the outlet of air registers.

When the temperature of the air impinging on an occupant is below the ambient temperature, the individual becomes

more sensitive to air movement and may complain of drafts. Therefore, careful attention must be given to air distribution as well as velocity. The tendency of warm air to rise can greatly affect occupant comfort due to convective air motion, and thus influences the correct placement of the heat source in a room. Air outlet design is determined by the air distribution pattern it is intended to create.

2.5.5 Clothing Level

Adjusting clothing is one of the most important personal behavioral adaptations to restore thermal comfort at a different temperature. Another determinant of thermal comfort is clothing. In the majority of cases, building occupants are sedentary or slightly active and wear typical indoor clothing. Clothing, through its insulation properties, is an important modifier of body heat loss and comfort. The insulation properties of clothing are a result of the small air pockets separated from each other to prevent air from migrating through the material. Newspaper, for example, can serve as good insulation if several sheets are separated so that there are layers of air between the layers of paper; this can be used as a crude, but effective, an emergency blanket to cover the body. Similarly, the fine, soft down of ducks is a poor conductor and traps air in small, confined spaces. In general, all clothing makes use of this principle of trapped air within the layers of cloth fabric.

2.5.6 Other Factors

The age, sex, body shape, state of health, ethnic grouping, diet, sleep, the colour of clothing, acclimatization, availability of fresh air, transients, the colour of a spaced enclosure and noise factors may have some effect on thermal comfort. The way the minor factors listed above affect comfort is not well understood. Fanger, et al (1989), among others, however claims that the effect of ethnic grouping, colour of a space enclosure and noise are negligible. An indication of the relative importance of these other factors, is the fact that when all the six major factors are within the acceptable and optimal range, about 70% of the population would be comfortable

2.6 TEMPERATURE - HUMIDITY INDEX

Temperature Humidity Index (THI) is a measure developed by Earl (1959), which has been in use since then. The index accounts for the combined effects of environmental temperature and relative humidity, and is a useful and easy way to assess the risk of heat stress. It however, has some limitations. It does not indicate the effect of other environmental conditions on thermal comfort. However, Epstein and Moran (2006) conducted a study on thermal comfort and heat stress indices. They reported that the level of risks corresponding to given heat stress were classified according to the THI values as follows (safe) 27^{o}C (heat fatigue is possible with prolonged exposure to activity) 32^{o}C (sunshine and heat exhaustion are possible with prolonged activity.

Gawith, Doening and Karacostas, (1999) using the temperature humidity index (THI) and a THI threshold of 84, above which the majority of a mid-latitude population would feel discomfort, found for Thessaloniki that the frequency of hours of discomfort will increase markedly by 2050. Only a few years exceed 50 hours at present but over 100 years will exceed the THI 84 threshold by 2050.

2.7 THERMAL ADAPTATION APPROACH

This is based on field surveys of thermal comfort and can be used to demonstrate how tolerant of temperature changes people can be that the laboratory experiments. When people consciously or unconsciously act to attract heat balance of the body, the action may change metabolic heat production in individuals.

2.7.1 Some Adaptive Models

The wide range of adaptive actions available for achieving comfort makes it difficult to construct a model that will cater for the effects of various adaptive actions on the neutral temperature of a population. However, several studies had shown that the neutral temperatures for various populations can be simplified on several measurable parameters, such as the ambient internal conditions or outdoor conditions.

2.7.2 Categories of Adaptation

It is necessary to establish what constitutes an act of adaptation; de Dear (1998) identified three broad categories of adaptation that will help the understanding and analysis of thermal comfort studies. They are:

1. Behavioural adjustment: can be further classified into three subcategories- According to the adaptive principle, "If a change occurs, and produces discomfort, people react in ways that tend to restore their comfort" (Humphreys and Nicol, 1988).

. Personal adjustment - This includes modification to personal variables such as clothing, posture, activity level etc.

b. Technological/environmental adjustment - modifications of the environment, e.g. turning on cooling/heating appliances, increasing ventilation or air movement by fans or opening windows.

2. Cultural adjustments: for example shifting work/rest time, putting on the appropriate dress code for certain occasions etc.

3. Physiological: concerns with the changes in physiological responses resulting from exposure to environmental stressors. Over time, the strain induced by such exposure is reduced. This type of adaptation can further be broken down into two subcategories:

a. Genetic adaptation: Such adaptation is hereditary and takes place over several lifetimes of a group of people.

b. Acclimatization: Changes in the setting of one's thermoregulation system over a period of days or weeks, in response to exposure to environmental changes.

4. Psychological: This adaptation refers to the changes in perception and reaction to the thermal experience. It includes personal experiences and expectations of the internal conditions. As such this type of adaptation varies between different times and conditions, even within a single individual. For example, a person on a golf course in the tropics can tolerate a higher temperature than when he is inside an air-conditioned building.

Physiological adaptation relates to the acclimatization of subjects with the local climate, and as such its effect can only be practically tested by investigating the difference in the thermal sensation of subjects when they move from one climatic zone to another and studied over a period of days or weeks. Assuming the percentage of the population doing this on regular basis is small, the effect of this adaptation on the thermal sensation of a population is negligible. While psychological adaptations do affect the thermal perception, it is assumed that subjects sleeping in an air-conditioned room have a similar psychological expectation of their thermal conditions; hence the effect of this type of adaptation on the thermal perception of a population can be assumed insignificant. Behavioural adaptation has the most direct influence and can be ascertained by identifying differences in thermal neutralities between different behavior. Hence, this type of adaptation is the focus of the current study.

2.8 EFFECTS OF THERMAL DISCOMFORT

Thermal comfort is a state people strive for when they feel discomfort. It influences human behavior. When in thermal comfort there will be a minimum drive for change although it should be remembered that people are not passive and often seek stimulation, exhilaration, and pleasure. That thermal environment affect such feelings is easily demonstrated as are the consequences of not achieving thermal comfort, when humans might complain, health and productivity might be affected, morale might fall and workers might refuse to work in an environment. According to Markus and Morris (1980) in Lawal and Ojo, (2011), thermal conditions will affect levels of arousal, vigilance, fatigue, attention, and boredom.

2.9 REVIEW OF RELATED LITERATURE

2.9.1 Pattern of Thermal Comfort Conditions

In the past, many works have been conducted on finding practical methods for predicting the effects of a particular

thermal environment in terms of comfort or discomfort. However, some of these studies were based on either indoor, outdoor, steady-state or transient thermal comfort. This present study has adopted a conceptual framework that links thermal comfort and human range of comfort level with meteorological elements. Reviews and summaries of this were made by Fanger (1972), McIntyre (1978), Benzinger (1979) and ASHRAE (1985). From these references, there is much evidence from thermal sensation studies that environmental parameters have a strong relationship with thermal comfort. These relationships are the basis for methods like Fanger's (1972) Comfort Equation. For Western and South Pacific Islands, Gagge (1973), has shown that climate change-related increase in temperature and humidity will result in changes in frequency, duration and intensity of physio-climatically stressful periods.

Most thermal comfort studies carried out have been devoted to determining thermally comfortable temperatures in various settings, in climates ranging from temperate to tropical. Several studies on the thermal comfort in an equatorial (tropical) climate were carried out as early as in the 1950s. Webb (1959), conducted a study in Singapore and derived an equatorial comfort index which was based on the dry and wet bulb temperature and wind speed. Ellis (1952) also carried out a study in Singapore and concluded in his that the levels of thermal comfort were similar for acclimatized European and Asian men and women.

After that, McNail et al (1967) derived a linear relationship between activity levels and sweat rate. Later, Fanger (1970) described thermal comfort as the balance between heat flow from the body in a given thermal environment and heat flow required for optimum comfort (that is neutral). Again, Fanger (1972) described the general thermal comfort as a material and energy balance being the bases of the actual general thermal comfort research. While Fang and Fanger (1998) studied the impact of temperature and relative humidity on the perception of air quality; then carried out an experiment using chamber with clean air heated to 18^{o}C and 30% relative humidity.

One of the main paradigm shift was the fundamental conceptual reorientation that has taken place in thermal comfort thinking over the last 20 years; a shift away from the physically based determinism of Fanger's comfort model toward the mainstream and acceptance of the adaptive comfort model. Another noticeable shift has been from the undesirable toward the desirable qualities of air movement. Additionally, sophisticated models covering the physics and physiology of the human body were developed, driven by the continuous challenge to model thermal comfort at the same anatomical resolution and to combine these localized signals into a coherent, global thermal perception. Finally, the demand for ever-increasing building energy efficiency is pushing technological innovation in the way we deliver comfortable indoor environments. These trends, in turn, continue setting the directions for contemporary thermal comfort research for the next decades (de dear, et al, 2013).

2.9.1.2 Trend of Thermal Comfort studies in Nigeria

Researchers such as Eludoyin and Adelekan (2013) Conducted a research on air temperature, relative humidity, climate regionalization and thermal comfort of Nigeria using tropical wet and dry-climates, along with thermal indices such as temperature humidity index (THI), Relative Strain Index (RST) and Effective Temperature (ET). They concluded that variation in both temperature and relative humidity increased from South towards the North, and that variation in ET is greater in the Sahel (Nguru) and a station in the Sudan Savanna (Potiskum) But in terms of THI, this region was shown to be thermally comfortable, while the montane location was also classified as most comfortable

Abdulrahim, Richard, Olajide, and Emmanuel (2012) examined thermal stress and physiological comfort in Maiduguri, Nigeria using thermal heat stress index as a measure of human comfort. Dry-bulb temperature, Relative humidity, and Air velocity were measured in three observatory sites; classroom, under neem *(Azadirachta indica)* tree and under direct sunlight within the Faculty of Engineering University of Maiduguri, Nigeria between the hours of

7.00 am and 5.00 pm on some days from October to December 2010 in order to establish the physiological responses to thermal stress and disorder. The data were analyzed using Effective Temperature (ET) and Relative Stress Index (RSI). The mean ET obtained vary from 23.58^{o}C to 31.18^{o}C, while the RSI values vary from 0.12 to 0.49 for the period just after the raining season. And for the hamattan period, the mean ET vary from 19.31^{o}Cto 29.09^{o}C, while the RSI values vary from -0.01 to 0.38. The results showed that the three locations are generally comfortable during the morning hours and become uncomfortable as the day progresses. The classroom was found to be the most comfortable during the period of the investigation while the location under the sun recorded the highest level of discomfort in both seasons.

2.9.2 Perception of Thermal Comfort

Thermal perception refers to the expression of the conscious feeling of people about the level of cold or warmth of the environment which is normally assessed through subjective evaluation. It is closely related to thermal comfort/discomfort conditions and is determined in individuals by both physical and human factors. Physical factors include air temperature, humidity, mean radiant temperature, and wind speed. Human factors include psychological (individual expectations), metabolic rate (degree of work, food and drinks habit), cultural (clothing insulation) and physiological (gender and age) (de Dear and Brager, 1998).

In terms of physiological factors, research has established that a tall and skinny person has a larger surface-to-volume ratio, can dissipate heat more easily and can tolerate higher temperatures than a person with rounded body shape (Szokolay, 2010). It is also evident that thermal perception declines with age. While in terms of gender, Graudenz *et al* (2013) reveal that clothing is more important determinant of thermal perception than the sex of individuals.

2.9.3 Adaptive Approach to Thermal Comfort

Adaptation is the progressive reduction of an organism's response to repeated environmental stimulation such that an

organism acclimates to survive in a given environment (Lin, 2009). The concept of adaptation is generally defined as the gradual decrease of the organism's response to repeated exposure to a stimulus, involving all the actions that make them better suited to survive in such an environment (Dear, and Brager, 1998). Nikolopoulou and Steemers, (2003) defined three different categories of adaptive opportunities related to thermal comfort; those physical, physiological and psychological adaptation.

In parallel with climate chamber studies, field studies have been conducted throughout the world with the same objective of determining comfort conditions for various populations. While several field studies seem to agree with the results obtained by using the PMV-PPD method, some studies have found discrepancies with it. Among the explanations for the reasons of this discrepancies offered by researchers conducting field studies is that people in real life have the capability to adapt to achieve comfort that they eventually can be neutral in a wider range of thermal conditions. These adaptations are not accommodated in the development of climate chamber study model. An adaptive approach to thermal comfort was proposed from the results of these field studies. This section discusses the development of the model based on this approach.

2.9.3.1 Coping Strategies for Thermal Discomfort

Thermal adaptation can be divided into three different processes including behavioral adjustment, physiological acclimatization and psychological expectation (Brager and de Dear 1998). Humphreys (1994) stated that 'characteristically, people seek to be comfortable, and take actions to secure thermal comfort, the motivation to do so is powerful. There is also a behavioural adaptation that related to the actions that occupants might take to achieve thermal comfort conditions. These actions include opening windows, adjusting blinds or shading devices, operating fans, adjusting thermostats or blocking ventilation outlets, changing clothing, moving to different room, modifying activity levels and even consuming hot or cold food and drinks (Humphreys, 1994, Brager and de Dear 2000).

It also has been discussed that occupants might refine their expectations and behavior towards the thermal environment. These behavioural adjustments as psychological adaptation are argued to be affected by culture, social norms, and previous experiences (Cena 1990, Oseland 1995). Studies have shown that occupant's thermal perception with the same clothing and activity level in the same environment tended to differ from occupant to occupant (Cena, 1990).

Brager and de Dear (2000) argued that application of ASHRAE Standard 55 as a valid source for all buildings and climates across the world may lead to exaggerating in the necessity of air conditioning systems in some regions due to the discrepancy of cultural and social aspects of people that are ignored in this standard. Also people in HVAC centralize building have been adapted to current range of indoor temperature of HVAC practice. While occupants of naturally ventilated building expected to accept more extensive range of temperature (Brager and de Dear 2000).

The main function of built environments is to provide protection from the stresses imposed by the climate". The general definition of thermal comfort is the sensation of the well-being of an individual in a given environment. Thermal comfort is affected beyond just physiological, but psychological factors, too; therefore, "the limits for thermal comfort vary depending on the degree of adaptation to the climate and the psych-social environment" (Koch-Nielsen, 2007). Individual levels of adaptation to a particular environment are constituted by their experiences, which gives a strong predictive correlation to how they will respond to an environment (Krishan, 2015).

The factors that influence psychological adaptation to the thermal environment include experience, expectations, and perceived control (Lin, 2009). People who have control or choice of their thermal conditions have been shown to have better satisfaction in outdoor environments. For example, a study on naturally ventilated indoor environments

(no air-conditioning) involving personal control over conditions found that employees who have the choice of operable windows, stack ventilation, and ceiling fans were able to tolerate and thermally adapt to their environment (Brager, Paliaga, and Dear, 2004). “Adaptive theory states that the temperature at which people are most comfortable is related to the temperature they are used to experiencing” as a result of behavioral and psychological adaptations (Pacuik, 1990). Perceived control is similar to what people experience in outdoor environments—such as having the choice to sit in the sun or in shade (Lin 2009). Freedom to choose which space to occupy allows individuals to be in control of their own thermal comfort. Inefficiency in thermal comfort has led to the dissatisfaction of users and they have resulted in taking actions to mitigate discomforts and thermal stress. Nikolopoulou and Steemers (2003) defined Physical adaptation as the changes one makes in order to adjust to their environment, thus identified two types of physical adaptation namely reactive and interactive. The physical adaptation (as a change one make to adjust to their environment) was also categorized into two: Reactive and interactive. Reactive is the altering of one’s clothing levels posture and position; while interactive means making changes to the environment. Reactive means altering one's clothing levels posture and position while interactive means making changes to the environment.

According to de Dear, and Brager, (1998) the concept of adaptation is generally defined as the gradual decrease of the organism's response to repeated exposure to a stimulus, involving all the actions that make them better suited to survive in such an environment. Nikolopoulou and Steemers (2003) have identified three different categories of adaptive opportunities related to thermal comfort as that physical, physiological and psychological adaptation. Employers Guide

(2010) has divided the interactive physical adaptation to the environment due to thermal discomfort into two periods.

The primary function of all buildings is to adapt to the prevailing climate and provide an internal as well as external environment that is comfortable and conducive to the occupants (Akande and Adebamowo, 2010). However, in this

era of climate change and global warming, providing comfort for the occupants of a building is quite challenging and very fundamental. This is as a result of growing ranges of challenges now facing designers to provide buildings that will be fit and comfortable for the 21st century.

In another word, the characteristics of users of the building may actually take a role in the determination of their pattern of use of the room spaces. These characteristics include socioeconomic, educational level, enlightenment and intellectual exposure, cultural and traditional values and background. All these affect the personality of building users which ultimately has a notable input in their behavioral tendencies. The behavioral tendencies have an expression in the adaptive actions taken within thermal environments. The adaptive nature of human thermal comfort has been expressed as being a means of extending the comfort conditions within spaces as occupants utilize the adaptive opportunities available to them. The adaptive principle states that if a change occurs such as to produce discomfort, people react in ways which tend to restore their comfort (Nicol and Humphreys 2002). The behavioral tendencies of building users as regards relocation within a space or from space to space as well as adjustments in clothing, posture and activity level all contribute to the attainment of adaptive thermal comfort. Movements within the building as necessary adaptive actions as well as user preferences for more comfortable conditions will contribute to the space use pattern for the residents (Adunola and Kolawole, 2012).

The results from field studies suggest that behavioral, cultural, and climatic adaptation change the perception of comfort. Several researchers have attempted to resolve this problem. Humphreys (1976) introduced the concept of the adaptive approach to thermal comfort. The adaptive principle in thermal comfort can be defined as "if a change occurs such as to produce discomfort, people react in ways which tend to restore their comfort" (de Dear and Brager, 1998). In this approach, other factors that have an influence on comfort are taken into accounts, such as local climate, geographical location, building design, occupants' choice of control, clothing, and posture.

2.10 CONSEQUENCES OF THERMAL DISCOMFORT

Higher standards of living are being demanded today worldwide. A comfortable environment is where there is freedom from annoyance and distraction so that working or pleasure tasks can be carried out unhindered physically or mentally (Page, 2000). Air temperatures, humidity, air movement and air purity play a part while psycho-sociological factors also have important roles to play. The attitudes of space users, the organization of indoor spaces, color schemes, and many other factors can all have an influence on the occupants' mood and work output. Thus, there is an interaction between all these factors, which complicate the comfort problem further. Such factors can be grouped under three headings: physical factors (sound, light, area-volume, radiation, air movement, temperature, inspired air, force field, relative humidity and atmospheric pressure), organism factors (age, diet and sex) and reciprocities factors (activity, clothing exposure and social level) (Derek and Brain, 1978 in Lawal and Ojo,2011).

Differences in the feeling of comfort amongst individuals exposed to some climatic conditions that arise from variation in age, state of health, physical activity, type and amount of clothing, past climatic experience or degree of acclimatization. High temperature and humidity tend to decrease physical and mental vigor (alertness). Weather also appears to influence human emotion and behavior for instance crime, riots, insanity, and other individuals and group emotional outburst and seem to reach their peak at the onset or during hot unpleasant weather.

The populations of the tropics are peculiarly subject to thermal discomfort, due basically to the warmth of the climates in which they live but often, for secondary reasons connected with the lightness of their clothing and the meagerness of their diet, or a sensation of cold. This fact coupled with the prevalence of overcrowding in tropical cities has long been recognized as constituting in relation to human happiness and even to health, a problem of some magnitude (Webb, 1959 in Anyam, 1989). Alhaji and Ahmed (2013) in their study on the heat stress condition and its implications on academic activities of the Kano University of Science and Technology highlighted the height of

complaints on academic stress from both the staff and students. Their findings suggested hence the need to detect periods more vulnerable to heat stress and its disorders; to inform the stakeholders of the institution toward improving the academic learning environment and offer suggestions to adjust the subsequent academic calendars. Their result revealed that the study area is vulnerable to severe discomfort condition, especially during the hot and humid season particularly during the afternoon hours when the influence of temperature and humidity elements is at their peak.

This study recommends that (both passive and active mean of ventilation such as) air conditioners, surrounded with trees as well as the orientation of the building be taken into cognizance from the design stage for the effect of solar radiation on classes and rooms of the students/staff; Subjects that are mathematics based should be scheduled for morning period, while for the benefit of students the semester examinations should coincide with period around December or August when there is less risk of heat stress.

The high level of activity, congestion and industrial processes in the cities within the tropical climate contribute to the buildup of heat. All these add to the discomfort experienced within the residential building spaces. The effect of high levels of temperature on the residents' discomfort and use of spaces will affect the level of user satisfaction for the buildings. Though comfortable indoor environment is desirable for human activities, in Nigeria however, buildings are thermally uncomfortable for considerable periods. This may be due to poor design standards. Costa (1989) observed that studies of traditional buildings in Nigeria have laid too much emphasis on socio-cultural and economic factors to the neglect of environmental factors. There are constraints of extreme environmental conditions, limited financial resources and poor building technology manifesting in low standards of thermal comfort of buildings in many tropical developing countries. According to Givoni (1998), the urban climate and the building indoor climate are both parts of a climatological continuum. There is an operational regional natural climate which is modified at the urban scale by the structure of the town or city. This is further modified at the site scale by the individual building.

Similarly, in each building end climate, there occurs a definition of different levels of spatial discomfort. There is a variety of climatic effects on individual, buildings, and communities and thus architecture and climate have mutual influence.

2.11 THERMAL COMFORT COMPARISON

Table 2.2 demonstrated the various comfort zones within different climatic belts. Nigeria and India, Malaya and Indonesia have the widest comfort zones of 7^{o}C each. While Northern USA got the narrowest comfort zone of only 3^{o}C

Table 2.2 Comparison of some Worldwide Comfort Zones based on THI

THI (^{o}C)	Location
14-19	England
20-22	Northern US
21-25	Southern USA
20-26	India, Malaya & Indonesia
21-27	Nigeria

Source: Adopted from de Dear, et al (2013)

Table 2.3 Sensation Scale for THI in Some Parts of the World

THI value (^{o}C)	Remark	Source	Location
17.8	More than 70% of people consider this temperature comfortable in summer	Terjung, 1966	USA
18.9	Uncomfortable (cold stress)	Ayoade, 1978	Nigeria
21	Most people feel comfortable	Niewolt, 1977	UK
22	Comfortable temperature	Olaniran	Nigeria
22.2	About 90% of the people consider this comfortable in summer	Terjung, 1966	USA
24	About 50% of people experience thermal stress	Niewolt, 1977	UK
25.6	Less than 10% of people consider this comfortable in summer and the upper limit of comfort in the tropics	Terjung, 1966	USA
29	Distinct stress (some US Government Offices dismiss their employees)	Griffiths, 1976	USA
30	Upper limit of good health and Practically limit of efficient outdoor labor for extended periods.	Terjung, 1966	USA

Source: Ayoade, 2004

The Table 2.3 reveal the fact about the thermal humidity index of different parts of the globe as well as the interpretation of each zones' comfort temperatures.

2.10 COMFORT MITIGATION ROLE OF OCCUPANTS

Recent development in housing has indicated the importance of placing users in a position to make decisions and participate in the design process; as stated by de Dear, et al (2013), that owners' participation brings about a better end product, one which echoes the need and target of the users better than that of the designer working on his own.

The growing complain of inadequacy of good dwelling facility in terms of comfort in Kano state is getting to an alarming stage, most people develop thermal stresses as a result of these inadequacies, this fact motivated Adedayo,

Ayuba, Oyetola, and Audu (2013) to carry out a research in the field of thermal comfort in residential settings of Kano.

Many tropical cities suffer from increasingly higher temperatures due to both global and urban warming. This has adverse effects on health and well-being of urban dwellers. Several studies in warm-humid countries have shown that daytime temperature rise, often, the thermal conditions are worsened by poor urban design including lack of vegetation and shade (Johansson, 2010). Assessment of thermal comfort in Kano becomes one of the most urgent issues or tasks related to applied climatology. This is due to the fact that Kano being the most populated state in Nigeria and the study area contained the majority of ancient Kano city where buildings are densely placed, and effect of urban heat island is strong. That is why the researcher is investigated the perception of the thermally generated discomfort values among the residents of the urban Kano

CHAPTER THREE

THE STUDY AREA AND METHODOLOGY

3.0 INTRODUCTION

This chapter explained the location and general characteristics of the study area as well as present the procedures used in the study

3.1 THE STUDY AREA

3.1.1 Location and Extent

Kano Metropolis (within which Kano Municipal is located) like many urban centers accounts for about half (50%) of the developed areas of the state. Kano Municipal Local Government Area (KMC) is located relatively at the center of Kano on between Latitude 11^{o} 56' and 11^{o} 59' North of the Equator and Longitude 8^{o} 28' and 8^{o} 32' East of Greenwich Meridian with an approximate mean height of 472.4m above sea level (Mapcarta, 2016). Urban Kano is about 900km from the southern edge of the Sahara desert and 1,140km away from the Atlantic Ocean (Abdulhamid, 2012).

Land area covers about $17km^2$ and it is made up of 13 wards with political headquarters in Kofar Kudu (south of the city). The occupancy rate is approximately 16 persons per m^2; this alone is enough to envision its discomfort level. It is bordered to the North and Northwest by Gwale Local Govt., Area, to the south and southwest by Kumbotso Local Govt. Area and to the east and southeast by Tarauni Local Govt. Area.

3.1.2 The Weather and Climate

The climate of Kano is characterized by high temperature and low relative humidity in the dry season. The average maximum temperature is $37.9^{o}C$ in April and the coolest average minimum temperature is $29.02^{O}C$ in December. The relative humidity ranges from 12.9% in March to 63.5%

in August (Ibrahim, Baba and Ishaq, 2012)

The climate of Kano is typical dry and wet type classified as (Aw) by Koppen. Rainfall is the most critical element in the area because of its deficiency during the dry-season (Olofin and Tanko, 2002). Four main wet months (June to September) dominate and receive over 90% of the rain, with the month of August receiving almost 40% of the annual rainfall and regarded as the peak month for downpour. Mean annual rainfall ranges from over 1000mm in the extreme south to about 800mm in the extreme north. The duration of the rain is between two to five months. On the other hand, the temperature regime is warm to hot throughout the year, even though there is the slightly cool period between Novembers to February. The mean annual temperature is about 22^{o}C in the coolest months (December or January) and 31^{o}C in the hottest months of April or May (Tukur, 2010). The temperature is averagely warm to hot throughout the year at about 27 ± 7^{0}C with an annual monthly range of 10 - 15^{o}C and higher daily ranges (Olofin and Tanko, 2002).

The state is characterized by four seasons- a dry and cool season, *(Kaka)* spanned between mid-November to February. This is marked by cool and dry weather plus occasional dusty haze; the dry and hot season, *(Bazara)* spanned between March through April to mid-May when temperatures climb up to 40^{o}C which represents the period of great thermal discomfort of buildings and which is a transition period between Hamattan and wet season; the wet and warm season, *(Damina)* lasted from mid-May to September, is the proper wet season when the lowest diurnal temperatures are recorded; and lastly dry warm season *(Rani)* reigned from October to mid-November is marked by high humidity and high temperature.

The mean annual potential evaporation, transpiration, sunshine, and relative humidity are about 1,772mm, 8.5 hours per day, and 50% respectively (Tukur, 2010). The natural vegetation of the area and indeed most of the Kano region is Sudan savanna. The climate is characterized by high temperature and low relative humidity in the dry season. Humidity is determined by temperature factor, with more humidity in the wet season than the dry period (Alhaji and

Ahmed, 2013). The relative humidity ranges from 12.9% in March to 63.5% in August. (Abdulhamid, Iguisi, Nduka and Ati, 2011)

The climate of the area, like in most part of West Africa, is strongly influenced by the tropical maritime air mass and the tropical continental air mass. The tropical maritime air mass originates from the south belt is humid and attended with on-shore south-western winds off the Gulf of Guinea. The tropical continental air mass, on the other hand, is dry and accompanied by north-east trade winds. These two air masses control the climate of the Kano Region making it the wet and dry type which is more dry than wet in the Sudan and Sahel regions of Nigeria. (See Table 3.1)

Table 3.1: Summary of Climatic Conditions of Kano State

Climatic Conditions	Average Measurement
Rainfall	4.10^{v}day/rain peak month
Temperature	33-34^{o}C /Day
Humidity	80% (in wet season)
Wind Speed	18mph
Sunshine Duration	9hrs/day

Source: (Kano Meteorological Agency, 2011)

3.1.3 Population

The 1991 population census figure for Kano state was 5.63 million, out of this figure, 35.5% were residents of Kano metropolis. The 2006 population head count put the population of Kano at 9.34 million depicted an increase of about 3.71 million (65.8%) over 1991 population census. The 2006 Nigerian national population commission (NPC) also revealed that about 4.6 million (49%) people reside within the metropolis (NPC, 2009). From the same census it was deduced that Kano metropolis has an occupancy rate of 16 persons/m^2 this is enough to envisage its congestion level. Kano Municipal is one of the six major LGA in Metropolitan Kano, and according INEC (2015), the area contained about 284,204 people of 18 years and above. The high increase of population could be attributed to the high

rural-urban migration (characteristic of all developing countries) as well as the factor of natural increase. The Population of Kano Municipal LGA was put to 365,525 (NPC, 2009).

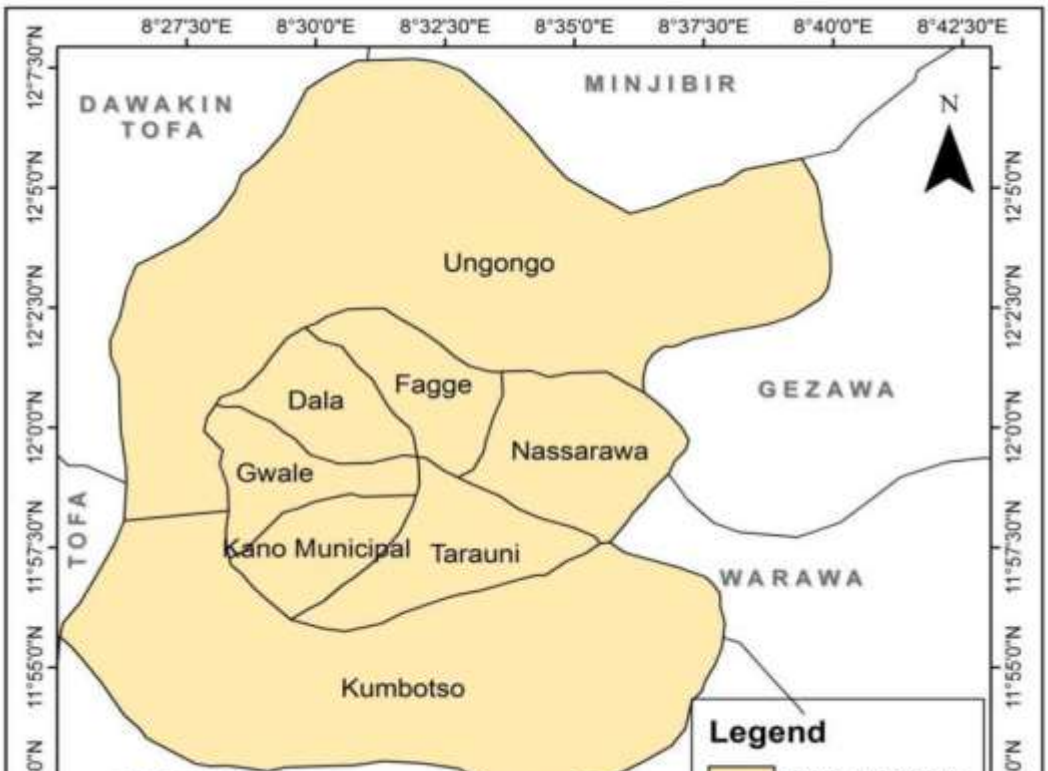
3.1.4 Land Use

Land use in the study area is dominated by the urban structures including both residential, industrial (that includes small and large scale industries), commercial and recreational purposes; and few agricultural engagements which include rain-fed and irrigated cultivation and fishing around the ponds (Mustapha 2008).

Kano Metropolis, like many urban centers, accounts for about 50% of the developed areas of the state. Quite unlike the contemporary metropolitan Kano, this old city which comprising of a larger proportion of Kano municipal LGA, has no standard land use plan particularly prior to the colonial era, even though, it is a fact that large proportion of the country's landscape is used for residential housing (Tukur, 2010).

The area has a large population density while the settlement pattern falls into the first category classified as high to medium density settlements. It is located in the old city of Kano and is the most densely populated area in the metropolis. The pattern of the settlement is nucleated in nature; and it is common to find a market next to hospitals and houses, motor park stations next to hospitals and schools.

THE STUDY AREA



Source: KANGIS, Ministry of Land and Physical Planning, Kano State.

Fig. 3.1 Kano State showing Kano Metropolis and Municipal LGA.

3.1.4 Physical Settings

Kano Municipal is a Local Government Area within the urban area of Kano State, Nigeria as shown in figure 3.1. Kano Municipal is located relatively at the center of Kano State. The area has two main parts- Old Part and new Layout located within and outside the city wall respectively.

Old part: (one of the ancient portions of Kano located within the city wall) and New layout, located outside the famous city wall (it comprises of ten wards as shown in figure 3.2). Like many old towns and cities, generally old Kano municipal characteristically has irregular planning, no definite street orientation and the majority of streets and alleyways are narrow and winding.

New layouts: these include parts of the study area that emerged after independence. Some of the buildings in this segment are planned in a grid pattern while others have little evidence of physical planning. They consist of the three wards: Sharada and Gandun Alba

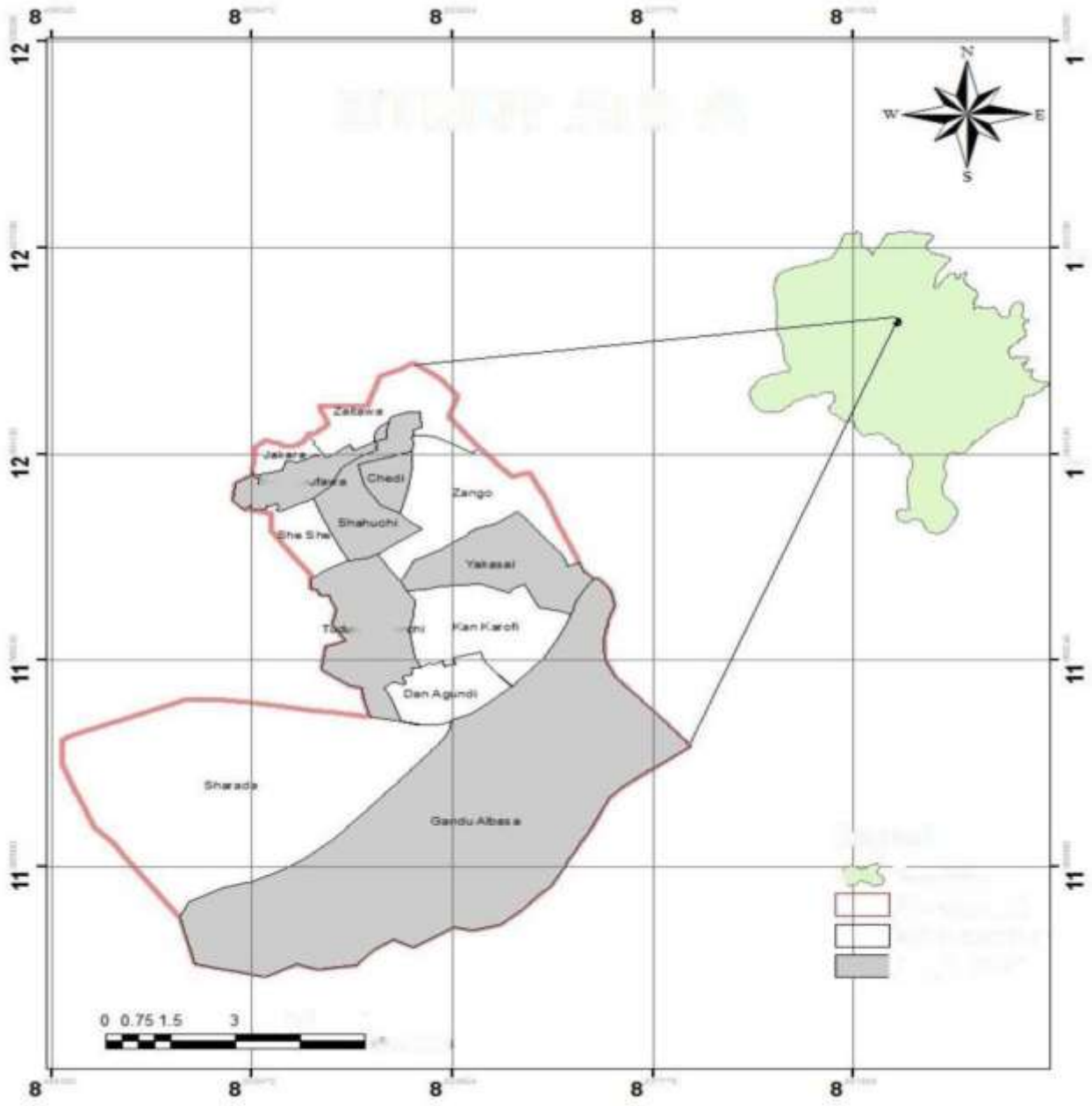

N
W
E
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Jakara
Jiawa
Chedi
Zango
Shahuchi
She She
Yakasai
Kan Karofi
Dan Agundi
Sharada
Gandu Albasa
0 0.75 1.5 3

Figure 3.2 Kano Municipal and Six Sampled wards

3.2 METHODOLOGY

The Research Methodology includes procedures and techniques used in this work such as Reconnaissance survey, Research Design, Types of Data, Instrumentation, Sample size and Sampling techniques; Techniques for Data Collection as well as Procedures for Data Analysis.

3.2.1 Reconnaissance Survey

This exercise was carried out prior to the survey proper and therefore a visit to INEC and NIMET offices as well strategic sites within 13 wards was made by the researcher with the aim of getting acquainted with the study area and to have insight on how to go about on data collection processes. The site selection and identification of suitable instruments to use in the study were also carried out during the survey.

3.2.2 Types of Data Used

Types of data used in this study include:

3.3.3.1 *Thermal comfort data*

3.3.3.2 *Air temperature data*

3.3.3.3 *Relative humidity data*

3.3.3.4 *Data on human population of the studyarea* 3.2.3 Sources of Data

The data for this study was obtained from both primary and secondary sources.

3.2.3.1 *Primary Source*

Primary sources of data used in this study include the followings:

3.2.3.1a Thermal comfort data: structured questionnaires were used to collect this type of data. The researcher and three research assistants conducted the questionnaire interview on every study day. The questionnaire interviews were translated and conducted in Hausa languages and required about 8-10 minutes to complete. Five (5) points Likert scale was employed to assess the respondents' thermal perception; it ranges from -2 (strongly disagree) to +2 (strongly agreed). Close ended questions were used to assess the respondents' perception and adaptation strategies.

3.2.3.1b Air temperature data: air temperature data in degree Celsius was collected using a handheld digital thermo-

anemometer which has a sensory accuracy of ±0.3^{O}C (Equipment-professional, 2012). It is shown in plate 3.1 below.

3.3.4.1c Relative humidity data: Relative humidity data in percentages was recorded using a whirling hygrometer; the instrument is shown in plate 3.2 below.

3.2.3.2 *Secondary source*

This data sources were obtained from the followings:

3.3.4.2a Data on average annual temperature and humidity: records of air temperature and humidity of Kano were accessed and obtained from NIMET (Northwest office) at Malam Aminu Kano International Airport (MAKIA) see Appendix 2, 3 and 4.



Plate 3.2: Whirling Hygrometer and its Psychrometer



Table 3.2 Population of the Study Area

Wards	Population
1. Chedi	11,107
2. Dan Agundi	13,670
3. Gandun Albasa	18,317
4. Jakara	11,191
5. Kankarofi	32,460
6. Shahuchi	25,739
7. Sharada	35,960
8. Sheshe	24,648
9. Tudun Wazirchi	11,819
10. Tudun Nufawa	23,635
11. Yakasai	25,500
12. Zaitawa	21,501
13. Zango	28,657
TOTAL	284,204

Source: INEC Office, Kano Municipal (2015)

Table 3.2 showed a population of Kano Municipal from 13 individual wards. Sharada is the ward with the highest figure of population and Chedi is the least populous ward in the area.

3.2.4 Sampling Techniques

According to INEC (Kano Municipal), there are 284,204 registered voters as at May 2015 National election figures, spread across 13 wards and constituted the population of the study (see Table 3.2). Table 3.3 clearly indicated the six wards that were purposively selected and surveyed based on their comfort related peculiarities; so also the selection of respondents was done using purposive sampling.

According to Krejcie and Morgan (1970) Table of sampling size determination, any population between 70,000 to 1, 000, 000 required a total of 384 sample size. Therefore, the target population of 116,117 has 384 sample sizes. The

numbers of copies of the questionnaire were administered with the help of three research assistants. The researcher makes a follow up during the data collection periods; whereas other research assistants were equally used to retrieve some copies of the questionnaire.

Table 3.3 Sampled Areas, Population and Size

Wards (Selected)	Target Population	Sample Size	Percentage (%) of sampled population
Chedi	11,107	37	10
Gandun Albasa	18,317	61	16
Tudun Wazirchi	11,819	39	10
Shahuchi	25,739	85	22
Yakasai	25,500	84	22
Tudun Nufawa	23,635	78	20
TOTAL	**116, 117**	**384**	**100**

Source: Field Survey, 2015

The formulae used in determining the sample size per each ward is n/N x 384 Where n= ward population, N= total population of sampled wards, 384= administered questionnaire.

3.2.5 Techniques of Data Collection

The field study process was carried out during the peak of the hot-dry season (Month of April) between 12:00 and 16:00-hour local time. This coincides with the time of the day when the air temperature and solar radiation reach their daily peaks. Three days Wednesday, Saturday and Sunday were taken as the study days for the period of four (4) weeks of April 2015. First April is considered study day one, 4th as study day 2 and so on until 29th April which was labeled study day 13th. This follows the fact that some respondents can only be traced on weekend (Sunday). A structured question was administered concurrently with the recording of physical climatic element of temperature and humidity.

Average temperature and humidity records were subjected to THI computation to derive the actual thermo-hydrometric index. See Table 3.4

Table 3.4: Survey day Chart for the month of April 2015

Mon	Tues	Wed	Thurs	Fri	Sat	Sun
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20S	21	22	23	24	25
26	27	28	29	30		

Survey days

Source: Field survey, (2015)

Due to the nature of this research, the researcher was assisted by three (3) research assistants on every survey day. These assistants were 'A' level geography students of Kano State College of Arts and Science Kano (see plate 3.3). Two of the research assistants were females which enabled them to interview female respondents inside their houses, while the remaining one assistant was a male.



Plate 3.3 Research Assistants holding Research Instruments



Plate 3.4: Researcher and one of the Respondents

3.3 METHOD OF DATA ANALYSIS

Objective i: determining the pattern of thermal humidity index in the study area from the air temperature and humidity data recorded, THI was determined as:

THI=T-(0.55-0.0055rh) (T-14.5)..... (i)

Where:

THI= Themohygrometric index; rh= Relative Humidity (%,)

T= Temperature (^{o}C) While 0.55, 0.0055 and 14.5 are constants.

The result is interpreted as follows, if:

THI < 21 it means no discomfort is felt

21> THI< 24 indicate that some people (about 10%) are uncomfortable

24>THI<27 at least half (50%) of people are uncomfortable due to heat

THI >27 means most people (more than 90%) will likely show sign of discomfort.

Objective ii: examining the residents' perception on thermal comfort in relation to spatial variation of physical characteristics of the study area.

Here the research subjects' responses on thermal perception of comfort are determined against physical characteristics of indoor spaces in the study area.

Objective iii: assessing respondents' adaptive measures in coping with thermal discomfort.

To achieve this was derived from questionnaire responses of the residents concerning adaptation measures. The result was descriptively analyze and presented in form of charts.

Objective iv: determining the effect of thermal humidity index have effect on the perception and adaptation of comfort on the residents of the area.

3.3.1 Hypothesis Test

Multiple regressions provide an avenue of neutrality assessing the degree and character of the relationship between independent and dependent variables (Page, 2007). The regression coefficient shows the relative importance of each of the independent variable in the prediction of the dependent variable. When independent variables are jointly regressed against the dependent variable an attempt to explain the variance in it, the size of each (individual) regression coefficient will show how much an increase in one unit in the independent variable and dependent variable cave in to multiple correlation coefficient (Sekaran and Bougie, 2010; Zikmund, Barbin, Carr and Griffin, 2010 in Aliyu, 2014).

Regression analysis was employed to test the research hypothesis of the study, it is intended to investigate the relationship between the predicting as well as the criterion variable respectively. For the conduct of regression analysis large sample is required and considered appropriate and also the underlying assumptions of multiple regression were fulfilled (Hair, et al., 2010). This assumption includes normality, linearity, multicolinearity, homoscedasticity, which are normally examine through the scatter residual plots and the normality probability plot in the regression standard.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter presents the results and discussion of findings for the investigation conducted on thermal comfort and adaptation strategies among the residents of Kano Municipal Local Govt. Area of Kano State. A total of 363 questionnaires were recovered in the analysis out of 384 questionnaires distributed in the field to respondents, 21 questionnaires were not used because they are not retrieved or inappropriately filled.

4.2 DEMOGRAPHIC CHARACTERISTICS OF THE RESPONDENTS

The demographic characteristics of the respondents such as sex, age, origin of the respondents, and level of education in the study area were shown in Table 4.1.

4.2.1 Sex of the Respondents

Table 4.1 indicated that a total of 73% of the respondents surveyed were females that dominated the male counterpart 27% of the respondents. This is due to the fact that females are more readily available or accessible than males who can only comfortably respond when contacted at home (indoor).

4.2.2 Age of the Respondents

The result in the Table 4.1 revealed that Respondents of the age 28-37 formed the majority (27%) those surveyed. These groups are mainly those left in the artisan occupations near the residents and happen to be available during the survey hours. Occupants with age group 5865 are very few (14%) in this research largely because the majority of them are not in a mood or willing to participate or honor the questionnaire.

Table 4.1 Demographic Characteristics of the Respondents

Demographic Variables	Categories	Frequency	Percentage
Sex of the Respondents	Male	99	27
	Female	264	73
	Total	363	100
Age of the Respondents (years)	18-27	63	17
	28-37	98	27
	38-47	93	26
	48-57	58	16
	58-65	51	14
	Total	363	100
Origin of Respondents	Kano	221	61
	Northwest and Northeast	89	24
	North Central	28	8
	South	1	0
	International	25	7
	Total	363	100
Level of Education	Adult Literacy	36	10
	Primary	84	22
	Secondary	104	29
	Tertiary	97	27
	Non-Formal	42	12
	Total	363	100

Source: Fieldwork, (2015)

4.2.3 Origin of the Respondents

Table 4.1 shows Respondents from various parts of Kano constituted the highest percentage of 61% followed by those from Northwest and Northeast of Nigeria (24%). Respondents from the southern Nigeria are the least with less than 1%. The respondents tagged as international origin mostly comes from Niger Republic, Ghana, and Sierra Leone and they constituted about 7% of the population.

4.2.4 Highest Qualification of the Respondents

Table 4.1 above respondents with secondary school has highest qualification are the majority (29%) followed by those with tertiary, that is either Diploma, NCE, degree, Masters, and Ph.D. constituting about 27%. Adult literacy is the minority qualification of the respondents with 10% value while none formal education carries 12% of the respondents.

4.2.5 Respondents' Period of stay in the Study Area

From the same table 4.2, respondents that stayed in the area for more than 20 years form the highest vote of 34%. Most of them come from the old part of Kano Municipal. Whereas respondents staying in the area for 1-5 years and 6-10 years are the minority (13%); they are mostly tenants or those staying at new layouts such as Gandu and Sharada wards.

Table 4.2: Respondents' Period of Stay in the Study Area

Period of Stay (years)	Frequency	Percentage
1-5	48	13
6-10	58	14
11-15	55	16
16-20	78	22
Above 20	124	34
Total	363	100

Source: field work, 2015

4.2.6 Type of Building

The result on Table 4.3 showed that the majority (about 42%) of the buildings in the study area consists of semi-

Type of building	Frequency	Percentage(%)
Traditional	116	32
Modern	95	26
Semi-modern	152	42
Total	**363**	**100**

modern where the initial building was rehabilitated with cement and concrete.

Source: Field work, 2015

Modern buildings formed the minority in the area (26%) and are often found in the new layout of

Gandun Albasa and some part of Sharada (NNDC quarters). Respondents residing in traditional houses have stayed for more than 16 years while those living in modern buildings have either not stayed longer or have transferred from elsewhere.

The traditional houses are mostly located within the ancient city wall and constitute about 32% of the total buildings contacted. Costa (1989) observed that studies of traditional buildings in Nigeria have laid too much emphasis on socio-cultural and economic factors to the neglect of environmental factors. Majority of the houses in the area characteristically are naturally ventilated as the electricity of whatever source during the afternoon (time of the survey) was uncommonly used. Houses, especially in the old city, are commonly constructed with mud, having smaller an fewer windows. The houses are also narrowly aligned, often separated by narrow alleys (locally called Lungu) as shown in the plate 4.1





Plate 4.1: Narrow Alley in T/Wazirchi ward **Plate 4.2: Relatively wider street at Gandu ward**

4.3 PATTERN OF THERMAL HUMIDITY INDEX IN KANO MUNICIPAL

The pattern of thermal humidity index in the study area is presented in the figure 4.1

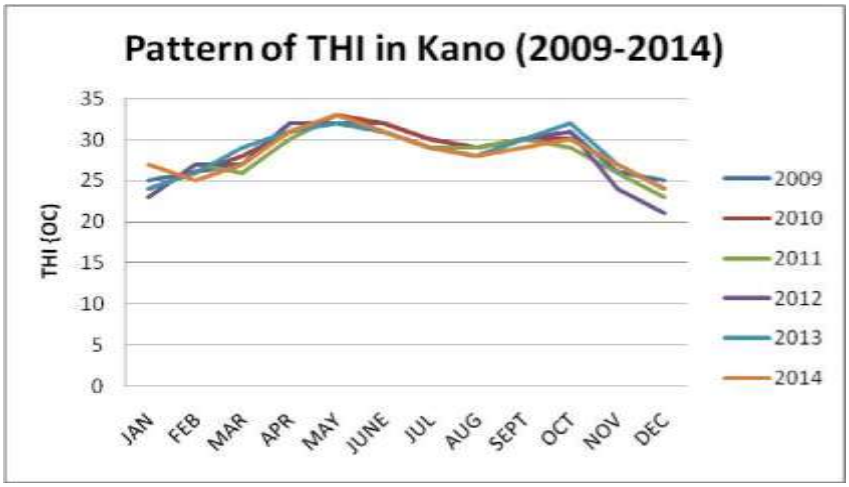


Figure 4.1: Pattern of THI in Kano Municipal from 2009-2014
Source: Field Study, 2015

Figure 4.1 shows the trend of thermal humidity index in Kano over a period of six years (2009-14).

The result has shown that months of April, May, and June have the highest THI greater than 30^{o}C; while months of January and December of these periods recorded the lowest THI of less than 25^{o}C. This result justifies the researcher's decision to conduct the research in the month of April to properly investigate the problem at its peak (See appendix 4).

4.9 THERMAL CLIMATE ZONES AND THERMAL HUMIDITY INDEX OF THE AREA

Landuse landcover (LULC) changes associated with urban growth alter the surface and air temperature significantly related (Weng, 2006). Table 4.13 revealed the nature of THI of six selected wards based on the physical air temperature and humidity measurements. The wards were categorized and fell under two major thermal climate zones (Compact housing and old core). The compact housing have a physical description of regular pattern aligned in rows old core is characterized by historic inner city with massive buildings of uniform height and single spires. Result

showed that urbcore classes (Gandu and Sharada) due to increased SVF relatively lower UCHI consequently have lowest THI in the area. While those of compact housing especially Tudun Nufawa and Chedi wards indicated relatively higher THI.

Table 4.13 TCZ and THI of the Sampled Wards

Wards	TCZ Class	Temp/Humidity	THI
Chedi	Compact housing(terrace)	38/34.1	29.5
Gandu	Old core (urbcore)	31.4/37.1	25.6
Shahuchi	Compact housing (terrace)	35.3/39.3	27.3
Sharada	Old core (urbcore)	32.7/35	26.2
Tundun Nufawa	Compact housing(terrace)	38.3/43.1	31.0
Tudun Wazirchi	Compact Housing (terrace)	36/43.7	29.4

Source: Field survey, 2015

4.3 Thermal Perception of Residents in Kano Municipal

Human comfort is very much an individualistic perception of the environmental stimuli. Certainly, physiologic comfort varies with time, space, as well as human physiological, psychological, socio-cultural differences, climatic zone and importantly on their past climatic experience (Anyam, 1989). Although there exist distinct variation among individuals due to numerous reasons, the possession of senses thus the ability to feel is a common feature to all human beings. The perception is categorized according to the question they have answered into TPC1, TPC2, TPC3…..to TPC13.

Table 4.4 : TPC 1: Respondents that Care being in discomfort : TPC2: Climate and Respondents' Comfort Level TPC3 : Temperature as a key to residents' Discomfort

	Frequency	Percent	Frequency	Percent	Frequency	Percent
Strongly disagree	9	2.5	32	8.8	32	8.8
Disagree	19	5.2	27	7.4	26	7.2
Neutral	36	9.9	44	12.1	52	14.3
Agree	78	21.5	75	20.7	62	17.1
Strongly agree	221	60.9	185	51.0	191	52.6
Total	363	100	363	100	363	100

Source: Field work, 2015

TPC 1: Number of Respondents who Care about being Discomfort

Table 4.4 indicated that 60.9% of the respondents strongly agree that they care much about their heat comfort. The Table further revealed that 2.5% of the respondents strongly disagreed to the claimed not to care about their thermal comfort.

TPC 2: Role of Climate in Controlling Respondents' Comfort Level

Table 4.4 show that 51% of the people living in the area rated climate as the most key factor for their discomfort and preference. While on the other hand, only 7.4% disconnect their discomfort with climate. This is in line with Garba, (2015), like many researchers have shown that thermal indices have effect on human thermal comfort sensation and they include the following six factors: four physical variables (air velocity, air temperature, relative humidity, radiation) and two personal variables (clothing insulation and activity level, i.e. metabolic rate).

TPC 3: Temperature played major role to residents' Discomfort

Table 4.4 make it is clear that 52.6% believed that temperature is the major element affecting the comfort level. While only

7.2% disagree that temperature played major role to residents' discomfort. Most of those that refused to connect temperature and their comfort are those with non-formal education.

Table 4.5: TPC 4: Relative Humidity and Thermal Discomfort **TPC 5: Air Movement as the Basis for Occupants' Body discomfort** **TPC 6: Feeding Habits Affecting Occupants' discomfort**

	Frequency	Percent	Frequency	Percent	Frequency	Percent
Strongly Disagree	44	12.1	65	17.9	51	14.0
Disagree	24	6.6	53	14.6	19	5.2
Neutral	54	14.9	27	7.4	24	6.6
Agree	75	20.7	74	20.4	101	27.8
Strongly Agree	166	45.7	144	39.7	168	46.3
Total	363	100	363	100	363	100.0

Source: Field work, 2015

TPC 4: Relative Humidity (R/H) and Thermal Comfort

The R/H of the area is relatively low compared to most (especially southern) parts of the country but yet it plays a significant role in the comfort condition of the occupants. Table 4.5 revealed that 12.1% of the respondents strongly disagree that R/H is connected to their thermal discomfort, but around 45.7% of them strongly agree the fact that R/H is a key determinant of their comfort level. Among those of the believed that R/H is significant factor are respondents from tertiary education level, of younger age and those from other parts of the country (especially those residents who came from the southern Nigeria)

TPC 5: Air Movement as the Basis for Occupants' Body Discomfort

The result on Table 4.5 shows a little disagreement to this fact where a significant of 39.7% of the respondents are in agreement to the fact that air movement is responsible to their comfort condition. Only 7% of the respondents remain neutral.

TPC 6: Feeding Habits Significantly Affects Occupants' Discomfort

From the Table 4.5, 46.3% strongly accepted that their feeding habit (that is the food and time they eat can induce comfort or otherwise to them), and few (5.2 %) are neutral on this. Subjects belonging to higher age group, those with non-formal education and females are amongst respondents that disagree with the role of feeding to discomfort.

TPC 7: Whether Subjects are Particular about What and When to Eat

From Table 4.6 results indicated that residents of Municipal Kano are very much aware of the food to eat and time to eat in connection to discomfort (for instance, frequent drink of cold water and other drinks like Fura during hot/dry season and vice versa at hamattan) with only 11.3% disagreeing and 44.1% strongly agree with fact. The only issue the researcher and his assistances observed was that, due to economic hardship facing the residents, they often ignore the ideal food and time and give priority to eating whatever and whenever is readily available.

TPC 8: Residents' Perception on Factors Other than Climatic

Table 4.6 shows that exactly 64.7% of the respondents agreed that other factors such as physical activities, clothing ensembles, building configuration, psychology and physiology can have an influence on their thermal comfort ability; whereas only 9.4% disagreed.

TPC 9: Thermal Sensation Vote is cold at this Moment

From Table 4.6 majority 43.8% disagree with assertion that Thermal Sensation Vote (TSV) is cold meaning most of their vote is pointing to warm condition as per TSV is concern; while conversely only 9.1% of the residents regard TSV as cold and most of them are people with age greater than 57 years or living in modern buildings.

TPC 10: Acceptable Thermal Sensation

From Table 4.7, it was shown that despite that 50.4% of the respondents voted contrary the sensation as warm, while 13.5% regard situation acceptable. This finding is in line with a lot of previous studies that showed the role of acclimatization or adaptation to the body system of residents who got used or accustomed to the prevailing environmental conditions though it might not supposed to be favorable.

TPC 11: Residents' Room Temperature is perfectly tolerable

Table 4.7 inferred that about 70.2% of the subjects referred the room temperature as intolerable; whereas the remaining 8.5% were neutral. Those that claimed the room temperature to be tolerable come from the female group (due to their psychological and attitudinal factors) as well as aged group respondents.

TPC 12: Relative Humidity (at this Moment) is better

Even though the time of this research was a period of low relative humidity, yet from the result, Table 4.7 shows that about 48.8% of the respondents confessed that the relative humidity is better, whereas 12.9% of the residents disagree that relative humidity is better at the moment. Interestingly, level of education played an important role in the response of the residents; with most people that attained tertiary education responded fairly on relative humidity and those from adult and non-formal

education have little or no knowledge on relative humidity.

TPC 13: Wind Velocity is quite acceptable at the moment

Table 4.8 shows that wind velocity according to the majority 50.4% is never acceptable, that is, they disagree with the statement above; while 13.5% are agree to this assertion. From the survey, the researcher observed that there is a direct relationship between age of the respondents and acceptability of air flow.

Table 4.7: TPC 10: Acceptable Thermal Sensation : TPC 11: Tolerable Room Temperature TPC 12: R/H is better (at the moment)

	Frequency	Percent	Frequency	percent	Frequency	percent
Strongly disagree	131	36.1	187	51.5	73	20.1
Disagree	52	14.3	68	18.7	47	12.9
Neutral	50	13.8	31	8.5	66	18.2
Agree	49	13.5	41	11.3	62	17.1
Strongly agree	80	22.0	36	9.9	115	31.7
Total	**363**	**100**	**363**	**100**	**363**	**100**

Source: Field Study, 2015

4.6 THERMAL PREFERENCE (TPR) OF THE OCCUPANTS IN KANO MUNICIPAL

Thermal Preference identifies the thermal conditions people prefer to be in rather than the exact sensation they are feeling. Thermal preferences of the occupants of Municipal Local Government of Kano in form of table were explained in the table 4.9 to 4.12 below:

TPr 1: Thermal Sensation is not Okay

Table 4.9 reveals that majority 55.9% of the residents contacted in the survey strongly agreed that thermal sensation is not normal or okay; and 9.6% of the respondents stand neutral.

TPR 2: Thermal environment should change to much warmer

In the Table 4.9 indicated that residents that advocated for changing the environment to warmer or strongly agreeing with

Table 4.8: Wind Velocity is quite acceptable Right now

Wind Velocity	Frequency	Percent
Strongly disagree	131	36.1
Disagree	52	14.3
Neutral	50	13.8
Agree	49	13.5
Strongly agree	80	22.0
Total	363	100

Source: Field Study, 2015

the statement are 52.3%. Only 5% remain neutral about changing the environment.

TPr 3: Relative Humidity should have increased

Table 4.9 demonstrated that 46.8% of the residents strongly agree on the fact that relative humidity should increase (meaning that they are not satisfied with it) while 6.9% neutral. This result is one kind as it reveals a higher level of poor understanding of the concept of R/H by the majority of the resident. This result contradicted the subjective analysis made by Appah-Dankyi and Koranteng (2012) where 81% of the respondents in Accra were satisfied with the humidity levels in their classrooms. This confirmed a study conducted by Arens, Bauman, and Huizenga (2002) on thermal comfort, saying that a high relative humidity has no significant psychological or physiological influence in human response.

TPr 4: Air flow should be increased

On the issue of air flow requirement on Table 4.10, only 1.9% of the residents disagreed that the air flow should have been higher; while on the other hand, 62.3% chooses a more regular flow of air. This finding confirmed the result of Modeste, Tchinda, and Ricciardi (2014), as preference 80.8% of the voters wanted more air velocity when they found their environment when they found their environment not acceptable.

Table 4.9: TPR 1: Thermal Sensation is not Okay		TPR 2: Much warmer Thermal Environment		TPR 3: Relative Humidity : should have increased	
	Frequency	**Percent**	**Frequency**	**Percent**	**Frequency**	**Percent**
Strongly disagree	21	5.8	64	17.6	54	14.9
Disagree	8	2.2	19	5.2	39	10.7
Neutral	35	9.6	18	5.0	25	6.9
Agree	96	26.4	72	19.8	75	20.7
Strongly agree	203	55.9	190	52.3	170	46.8
Total	363	100	363	100	363	100

Source: Fieldwork 2015

Table 4.10: TPR 4: Air flow should be Increase		TPR 5: Residents more comfortable in the morning		TPR 6: Residents more comfortable in the afternoon	
	Frequency	**Percent**	**Frequency**	**percent**	**Frequency**	**percent**
Strongly disgree	11	3.0	113	31.1	104	28.7
Disagree	7	1.9	49	13.5	80	22.0
Neutral	30	8.3	25	6.9	30	8.3
Agree	89	24.5	57	15.7	67	18.5
Strongly agree	226	62.3	119	32.8	82	22.6
Total	363	100	363	100	363	100

Sources: Fieldwork, 2015

TPR 5: Residents more comfortable in the morning

Table 4.10 shows that almost 32.8% of the residents strongly agree to have preferred morning period as far as thermal comfort is concerned while 6.9% were neutral with morning as the comfortable period of the day.

TPR 6: Residents more comfortable in the afternoon

Table 4.10 shows that there are more people 28.7% strongly disagree that afternoon as the comfortable period whereas only 22.6% strongly agree selected afternoon as the comfort of their daytime. 8.3%of residents is neutral to this statement.

TPR 7: Residents more comfortable in the evening

From Table 4.11 About 34.7% of the respondents are comfortable in the evening (from 5:00 pm - 12 am local time), and about 16.3% of them disagree with the evening as the comfortable hour.

TPR 8: Residents more comfortable from Midnight to Sunrise

Table 4.11 show that 7.4 % of the respondents disagreed with the assertion that midnight to sunrise formed the best time of their comfort day period. But 51.2% of the residents choose this period as their best time. 9% remained not sure.

Table 4.11: TPR 7: Most comfortable in the Evening TPR 8: Most comfortable between Midnight and Sunrise TPR 9: Residents preferring hot/dry season

	Frequency	Percent	Frequency	Percent	Frequency	Percent
Strongly disagree	85	23.4	33	9.1	138	38.0
Disagree	59	16.3	27	7.4	74	20.4
Neutral	32	8.8	30	8.3	36	9.9
Agree	61	16.8	87	24.0	48	13.2
Strongly agree	126	34.7	186	51.2	67	18.5
Total	363	100	363	100	363	100

Source: Fieldwork, 2015

TPR 9: Residents preferring hot/dry season *(Bazaar)*

On the issue of seasonality preference, Table 4.11 showed that those strongly disagree with "Bazara" or hot/dry season (period of this survey) were 38%. While the remaining 9.9% remained neutral.

TPr 10: Residents most comfortable during rainy season *(Damina)*

Table 4.12 show that 11.8% of the populations of the area were found to be neutral about preferring wet season for comfort; While 32.5% of the respondents strongly agreed that rainy season or Damina happens to be their thermal comfort best season. Those that prefer rainy season are young and those with modern or rehabilitated buildings. Old and those in traditional building setup seem to be disturbed during rainy hour on health ground or fear of building collapse respectively.

Table 4.12: TPR 10: Residents comfortable during wet season | **TPR 11: Residents that goes for cool/dry (Hunturu) season midnight to sunrise** | **TPR 12: Respondents preferring warm/dry season (kaka)**

	Frequency	Percent	Frequency	Percent	Frequency	Percent
Strongly disagree	72	20	72	20	111	30
Disagree	50	14	55	15	68	19
Neutral	43	12	10	3	17	5
Agree	80	22	98	27	71	20
Strongly agree	118	32	128	35	95	26
Total	363	100	363	100	363	100

Source: Fieldwork 2015

TPR 11: Residents that picked cool/dry season as the best *(Hamattan)*

Hamattan or cool and dry season is another extreme weather condition characteristically associated with cool, dusty and gusty wind affecting the comfort of the human body. Table 4.12 show 62% of the residents agree or chooses cool/dry

season as better for their comfort; while 3% of the population were neutral with this season. Many of the respondents that prefer hamattan season come from youth age group or those that have stayed for the relatively long period and hence acclimatized fully with the severity of the cool, dry air.

TPR 12: Residents more Comfortable during Warm and Dry Season *(Kaka)*

The warm and dry season is a fair season and according to the result gathered indicated that residents in favor and against the season are fairly distributed. Table 4.12 show about 30% strongly disagree the season while 5% preferred being neutral.

4.6 THERMAL ADAPTATION (TA) OF THE RESPONDENTS

The adaptive principle in thermal comfort can be defined as "if a change occurs such as to produce discomfort, people react in ways which tend to restore their comfort" (de Dear and Brager, 1998).

The factors that influence psychological adaptation to the thermal environment include experience, expectations, and perceived control (Lin, 2009). People who have control or choice of their thermal conditions have been shown to have expressed more satisfaction with the outdoor environments. Kano municipal residents thermal adaptation were presented in Figure 4.2

4.2.

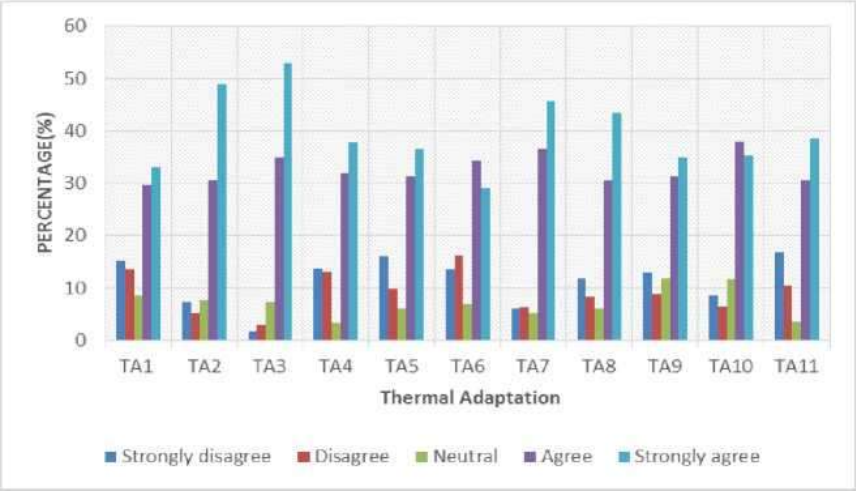


Figure 4.2 Kano Municipal Residents' Thermal Adaptation
Source: Fieldwork, 2015

TA 1: Change of Clothing (Wearing Light Cloth or Half Cloth)

From the figure 4.2 majority (63%) of the respondents agreed that changing clothes ensembles one of the strategies they employed in tackling the problems of thermal discomfort. Mostly they use light clothes or at the time even removing top clothes when they are indoors. On the other hand, few (29%) disagreed with the method of changing clothing pattern; and the majority of these respondents came from aged and female groups.

TA 2: Moving to Cooler positions (e.g. shade, upstairs or outdoor)

Figure 4.2 show that on average, 49% of the residents strongly agreed that moving to cooler position (such as upstairs, outdoors, shades, etc) indeed improves their comfort level; while another 31% agreed with moving to cooler places (totaling to 80%). Only 12% of the residents claimed not to have been using this strategy as the therapy for mitigating thermal discomfort issues.

TA 3: Taking Cold Drinks and Foods

In Figure 4.2 majority (88%) of the residents adopted the use of cold drinks and/or food in dealing with thermal comfort problem. While very few (5%) claimed not to have been employing such experience. Most common drink used in mitigating discomfort problems according to observation gathered by the researcher is the use of cold sachet (pure) water during the afternoon hot weather and cold yogurt *(Fura)* at night. It is quite common experience to see pure, sachet water vendors almost everywhere (e.g. on the traffic, street, in the market, door-to- door, at schools, mosques etc)

TA 4: Opening of Curtains, Windows or Doors

Only 27% of the respondents on Figure 4.2 disagreed on not opening their curtains, windows, and doors when they want to improve their thermal comfort indoors. Seventy percent of the residents acclaimed to have been using this method for quite a long period of time. This is quite in agreement with the findings of Adedayo, Ayuba, Oyetola, and Audu, (2013) who equally reported that in order to reduce 73% of the residents of urban Kano replaced their windows from sliding to casement (which have 100%).

TA 5 Taking frequent bath and toweling

Figure 4.2 shows that 68% of the respondents agreed that they use additional bathing or toweling or washing some parts of their body in the process of reducing the menace of thermal discomfort. Twenty six percent of the residents disagree with this method as their adaption strategy. Many of those that adopt this method come from young age, educated group and affluence home as additional bath means addition spending on water.

TA 6: Use of Hand Fan or Handkerchief

Use of local hand fan and handkerchief has been a common experience in Kano municipal, especially with the aim of increasing the air movement to evaporate as well as to wipe-out the body moisture/sweat. In figure 4.2, 63% of the people contacted claimed to have been using hand fan or handkerchief to improve their thermal comfort especially when in the naturally ventilated environment; whereas only 30% disagree or not in support of this method.

Akande and Adebamowo (2010) suggested in their work that it is convenient for naturally ventilated buildings in northern Nigeria to use a fan and increase the size of their windows instead of using Air-conditioning to improve the indoor thermal conditions with the interest of reducing energy consumptions in buildings.

TA 7: Use of Electric Fan or Air Conditioning

In figure 4.2, Majority of the respondent testified that nothing extinguishes their thermal discomfort like the use of an electric fan and or air conditioning devices. Around 83% of the respondents agree with this adaptation method whereas only 12% disagree with this strategy. Those that disagree with this option are either old or have certain cold-related diseases thereby running away from such devices. Those that embrace electric fan or alternative current have one or two limitations to the use of such devices: energy and money consumption.

TA 8: Switching off electric appliances

The idea of switching off electric appliances that often generate heat to the environment (or use of halogen instead of an incandescent bulb) is not common to many. Yet from the result shown in figure 4.2 only about 27% of the respondents disagree in applying this method to do away with thermal discomfort. On the other hand, 74% of the resident believed in this way as a measure to tackle thermal comfort problems. This has gone contrary to what is found in the work of Adedayo, Ayuba, Oyetola, and Audu, (2013) where about 73.5% of the occupants change their incandescent bulbs that generate heat to halogen bulb which does the opposite function.

TA 9: Covering the Floor and Walls

From figure 2.2, 35% of the residents strongly agree that covering walls and floor of their houses has a positive impact

on addressing the trouble of thermal discomfort issue. But only 13% disagree with the latter statement. Usually, the materials used in the cover of the walls and floor includes mostly of rugs, leather mats, and carpets. But interestingly within location away from traditional buildings of the ancient city (where modern buildings prevail and floor tiles are put in place) mostly the question of covering the floor does not arise as the floor is a bit cooler than where the floor is not tiled.

TA 10: Cooling the walls and floor of (with water)

The cooling mechanism is one of the measures resident embraced whenever there is a need to check the problems of thermal discomfort. From figure 2.2, Many (73%) of the residents (strongly) agreed that cooling their floors and walls have an impact on the comfort level of their environment. But the only hindrance to this method according to respondents is the lack of adequate or affordability of the water in the area. Many people in the area are struggling to purchase water only to meet up with their basic necessities (like drinking, cooking, and washing or bathing).

TA 11: Other Ways in Coping with Thermal Discomfort

From the figure 2.2, there are a great number of respondents (69%) who testified that they have other ways in which they tackle the danger of discomfort problems. Among their strategies includes moving to departmental stores and specific mosques (which many at times are colder), barbing their heads, avoiding any unnecessary physical activity among others. On the contrary, only 27% disagree with any additional strategy in addressing thermal discomfort issues, and 4% remain indifferent.

4.10 Hypothesis Test

Multiple regression analysis was conducted to determine the relationship between thermal Perception, and thermal Adaptation and that of thermal Humidity Index. The result is presented in table 4.14

Table 4.14 Multiple Regression Result

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics		
					R Square Change	F Change	df1
1	.694[a]	.482	.145	2.42557	.482	3.569	2

Source: Field Survey, 2015

The result indicated in Table 4.14 that predictors were significant, R= .694, R^2=.482, Adj. R^2=.145, F-change= 3.509. The multiple correlation coefficients between the predictors and the criterion variable were .694, the predictor accounted for 48.0% of the variance in the adaptation of thermal comfort.

Cohen (1988) classified R^2 into 3 as: a) 0.02 as weak b) 0.13 as moderate, c) 0.26 as substantial. Based on this, the value of R^2 (0. 482) is substantial. The significant F-test show that the relationship (3.509, P< 0.001) signifies the overall significant prediction of independent variable to the dependent variable but, did not explain the relative contribution of each independent variable to the dependent variable (Green and Salkind, 2008)

Among the two variables, thermal adaptation is the best variable that best predicts the criterion with the following values (P= .243, t= 4.608, p<.000) compared to thermal perception (P= .223, t= 3.390 p<.001). This was clearly indicated in Table 4.15:

Table 4.15 Regression Result

Model	Unstandardized Coefficients		Standardized Coefficients	t. Sig.	Correlations
	B	Stand. Error	Beta		Zero-order
(Constant)	14.942	.873		17.121 .000	
TerPerc	.223	.066	.198	3.390 .001	.067
TeAdapt	.243	.053	.269	4.608 .000	.173

Source: Field Survey, 2015

The level significance in colounm6 on table 4.15 show that thermal perception and thermal Adaptation are found to be positively significant with p-value of 0.001 and 0.000 at 5% significant level respectively because their P-values are less than 0.005.. This implies that the effects of perception and adaptation are significant on the thermal humidity index.

The regression model of Thermal humidity index is described thus:

Thermal humidity index = 14.942 + 0.223(thermal perception) + 0.243(thermal Adaptation).

CHAPTER FIVE

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

5.0 INTRODUCTION

This chapter presents a discussion of summary, conclusion, and recommendations based on the research findings.

5.1 SUMMARY

Thermal comfort is an important prerequisite in determining the appropriate day-to-day choice of action as well as performance in all facets of human life. Indeed the craving adaptation requirements 3of man to diverse environmental stimuli and their impacts on man's capacity to work, economic productivity and socio-cultural advancement require the need for research like this.

In this work, two data of meteorological and questionnaire sources were employed in an attempt to present existing characteristics of Thermal comfort according to an individual- centered framework of analysis. THI was chosen as a test index and its application in calculating the yearly cumulative stress in excess likely to be experienced by more than 10% of the population in Kano Municipal.

Out of the 13 survey days, only two (day one and nine) had THI that at least 50% of the people to feel uncomfortable; another two days (two and three) computed THI put 60-70% of residents to be uncomfortable. Remaining nine days all had THI tendency of making 90% of the residents not to be comfortable with their environment.

Perception of the comfort of the residents revealed that as many as 83% claimed to have cared very much about their comfort situation; 72% of them rated climate as the key determinant of their comfort. Even though 81% of the people labeled their Thermal Sensation Vote as hot, yet only 50% of them considered it as unacceptable; therefore they considered their room temperature as tolerable. This indicated (as in many similar types of research) that there is a clear contradiction between physical parameters and sensation scale of the individuals.

In terms of preference of comfort, about 72% of the respondents opted for changing their environment too much cooler area; while 87% required airflow to be more. Majority of the residents preferred midnight as the best comfort hour of a day as against the sensation scale of morning and afternoon (especially in hot/dry season). On the basis of seasonal preference, the majority of the occupants (62%) go for cool/dry or Hamattan season, followed by wet season; with the few voting for hot/dry season.

The most common adaptive strategies employed by the occupants to mitigate the menace of thermal discomfort includes, taking much of cold drinks and foods (88%), use of fans and AC (83%), opening of doors, windows and curtain (70%), taking bath and toweling (68%) and other strategic measures (69%).

Multiple regression analysis conducted indicated the positive or significant relationship between the independent variables (TPC and TA) and the dependent variable (THI). Thermal Adaptation represents the best predictor of Thermal humidity index with the following values (P= .243, t= 4.608, P< .000), while the Thermal Perception has a weaker affinity to adaptation looking the result of the analysis as (P= .223, t= 3.390, P< .001)

5.2 CONCLUSIONS

Temperature - Humidity Index (THI) is one of the thermal indices that affect human thermal comfort index. The effect is apparent in the continuous thermal discomfort in the study area. Indoor thermal comfort has been viewed as being highly dependent on occupants and the way they see their environment. The research showed that even though a large majority of the respondents accepted their overall thermal conditions, a number of them still voted far below the standard set by ASHRAE of 80% for thermal sensation. The study showed that respondents in a tropical environment, such as Kano, may have a higher heat tolerance since they accept the thermal conditions which exceed the standard.

5.3 RECOMMENDATIONS

The effect of THI on human comfort cannot be avoided completely but it can be mitigated. The following are therefore recommended:

i. Climate sensitive urban planning and design schemes should be pursued vigorously by authorities like Kano State Ministry for Land and Physical Planning, Urban Planning Development Authority (KNUPDA) and Kano State Ministry of Environment with special consideration given to thermal comfort in urban centers.

ii. More green areas should be established (through reforestation) by Kano Municipal council and urban authority (like KNUPDA) to improve air quality; mitigate urban Heat island and consequent thermal discomfort menace.

iii. There should be more enlightenment by government to residents on wise use of electric appliances for instance, by using electric appliances (like heating elements) in kitchens and not living or bedroom. For instance, the Replacement of incandescent bulbs and kerosene lamps with halogen bulbs (which are cheaper, last 10 times longer and use 75% less energy than the former).

iv. More awareness by government on Clothing Culture that is Constant use of clean and light colored flowing clothes with an air trapping structure, especially in hot/dry periods for people of Municipal Kano.

5.4 SUGGESTIONS FOR FUTURE RESEARCH

i. There is a need for further researches on thermal comfort in the area to be conducted on other variables such as outdoor environments, offices/workplaces, mosques, classrooms, hospitals and so on.

ii. More studies can still be carried out such as assessing the energy consumption and money expenditure in an attempt of achieving thermal comfort in the area of study.

iii. Influence of Thermal Comfort on human health should also be an interesting area of study in the area. Likewise, the implications of taking too much of cold drinks (such as cold water, which the inhabitants embrace badly) during hot/dry periods on the health of the occupants should also be investigated.

iv. There is a need for seasonal and regional analysis of comfort in urban cities of Nigeria like Kano; this will supply individuals with a much needed awareness of where, when and how often discomfort is likely to occur. Knowledge of anticipated values of stress will assist in the choice of site, food, clothing and activity, especially in hot dry weather.

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APPENDIX 1

ACADEMIC RESEARCH QUESTIONNAIRE

ABU ZARIA

Dear Respondent,

I am MSc Geography student in the above named university, currently conducting a survey title: THERMAL DISCOMFORT AND ACCLIMATIZATION STRATEGIES AMONGST THE RESIDENTS OF KANO MUNICIPAL LGA, KANO NIGERIA. I would appreciate your co-operation by providing objective and sincere answers to all the questions, as in academics there is no right or wrong answer. The researcher assures you that your identity and information will be handled confidentially and be used only for research purposes. Thank you.

Please carefully read and answer all the questions that follow:

Date: ____/_____/2015

Local time: _____pm

Occupant's location: _____

PART A: PERSOANL DATA

Kindly tick (√) as appropriate

PD 01: Gender

1. Male [ ]
2. Female [ ]

PD 02: Level of Education

1. Adult literacy [ ]
2. Primary [ ]
3. Secondary [ ]
4. Tertiary [ ]
5. None formal [ ]

PD 03: State /Town of Origin

1. Kano [ ]
2. North western [ ]
3. North eastern [ ]
4. North central [ ]
5. Southern [ ]

6. International [ ]

PD 04: Age of the Respondents

1. 18-27 [ ]
2. 28-37 [ ]
3. 38-47 [ ]
4. 48-57 [ ]
5. 58-65 [ ]

PD 05: Length of Stay in this Location

1. 1-5 years [ ]
2. 6-10 [ ]
3. 11-15 [ ]
4. 15-20 [ ]
5. Above 20 [ ]

PD 06: Type of Material Used In House Construction

1. Traditional [ ]
2. Modern [ ]
3. Combination [ ]

PART B: THERMAL PERCEPTION (TPC)

The following describe statements on thermal condition as perceived or sensed by the residents with regard to thermal discomfort level. Please tick (√) the number that most accurately reflects your opinion on each statement.

Strongly disagree Disagree Neither Agree or Disagree Agree Strongly agree **1 2 3 4 5**						
		1	**2**	**3**	**4**	**5**
TPc 01	Concerned about being thermally uncomfortable					
TPc 02	Climate is fundamental in being uncomfortable					
TPc 03	Temperature is central to my discomfort					
TPc 04	Relative humidity is key to being uncomfortable					

TPc 05	Air movement is basis to body discomfort					
TPc 06	Feeding habit affects my discomfort					
TPc 07	I am particular about what and when to eat					
TPc 08	Other factors other than climate (such as physical activity, clothing ensembles, building configuration, psychology and physiology are what me feels thermally uncomfortable					
TPc 09	Thermal sensation is cold at this moment					
TPc 10	Thermal sensation is quite acceptable					
TPc 11	Room temperature is perfectly tolerable now					
TPc 12	Relative humidity at this moment is better					
TPc 13	Wind velocity is quite acceptable right now					

PART C: THERMAL PREFERENCE (TPR)

The following describes the statements on thermal condition on the basis of personal preference by the subjects toward achieving optimum thermal comfort. Please read and tick (√) the number that most reflects your opinion on each statement.

Strongly disagree Disagree Neither Agree or Disagree Agree Strongly agree **1 2 3 4 5**						
		1	**2**	**3**	**4**	**5**
TPr 01	Thermal sensation is annoying					
TPr 02	Thermal environment should change to warmer					
TPr 03	Relative humidity should have been higher					
TPr 04	Air flow should have been higher					
TPr 05	comfortable during the morning					
TPr 06	comfortable in the afternoon temperatures					
TPr 07	comfortable in the evening (sunset to midnight)					
TPr 08	comfortable from midnight to sun rise					
TPr 09	Prefer hot and dry season (*Rani*)					

TPr 10	rainy season *(Damina)* the best					
TPr 11	Cool and dry season (*hunturu)* my preference					
TPr 12	Warm & dry season *(Kaka)* is the best season.					

PART D: ADAPTIVE BEHAVIOUR

The following describes the statements on adaptive strategies taken by the occupants whenever they wish to overcome thermal discomfort. Please read and tick (√) the number that most reflects your opinion on each statement.

Strongly Disagree Disagree Neither Agree nor Disagree Agree Strongly Agree **1 2 3 4 5**						
		1	**2**	**3**	**4**	**5**
TA 01	Wearing light or Half cloth					
TA 02	Moving to cooler positions (e.g. shade)					
TA 03	Taking cold drinks and foods.					
TA 04	Open curtains, windows or doors					
TA 05	Taking frequent bath & body toweling					
TA 06	Use of hand fan or handkerchief					
TA 07	Switching off electric appliances (such as bulb)					
TA 08	Covering the floor and walls (e.g. with carpet)					
TA 09	Cooling the walls and floor with water					
TA 10	Other ways					

Thank you.

APPENDIX 2

AVERAGE MONTHLY MAXIMUM TEMPERATURES (^{O}C) BY MONTHS 2009-2014, KANO

YEAR	MONTH												
	JAN	FEB	MAR	APR	MAY	JUNE	JUL	AUG	SEPT	OCT	NOV	DEC	MEAN
2009	31.8	34.8	37.0	39.7	38.0	36.8	32.3	31.0	32.2	35.1	33.2	31.6	**34.5**
2010	31.8	36.0	37.2	39.9	38.6	35.2	31.5	30.9	31.7	34.5	34.9	30.5	**34.4**
2011	29.0	35.4	36.4	39.4	39.2	35.0	31.8	30.2	32.3	34.2	33.3	29.0	**33.8**
2012	29.5	34.8	35.5	40.4	38.4	33.7	30.9	29.7	32.3	36.3	35.0	30.6	**33.9**
2013	30.7	34.2	39.5	38.9	38.7	35.3	31.8	29.6	32.3	34.6	35.4	31.8	**34.4**
2014	31.0	33.0	37.3	38.8	38.7	35.7	32.1	30.0	32.1	34.6	34.1	30.4	**31.1**
MEAN	**30.6**	**37.2**	**39.5**	**38.8**	**38.6**	**35.3**	**31.8**	**30.2**	**32.2**	**34.9**	**34.3**	**30.7**	

Source: *Nigerian Meteorological Agency, (MAKIA), 2015*

APPENDIX 3

AVERAGE MONTHLY MINIMUM TEMPERATURES (^{O}C) BY MONTHS 2009-2014, KANO

YEAR	MONTH												
	JAN	FEB	MAR	APR	MAY	JUNE	JUL	AUG	SEPT	OCT	NOV	DEC	MEAN
2009	15.6	16.4	20.6	26.1	25.2	24.4	21.3	22.5	22.8	23.2	18.3	14.1	**20.9**
2010	13.9	18.2	21.8	24.8	26.5	24.4	22.6	22.2	22.3	22.7	18.1	13.3	**20.9**
2011	11.9	18.9	22.0	23.2	25.5	24.0	22.3	21.4	21.7	21.1	14.6	12.0	**19.9**
2012	11.9	17.2	18.9	25.4	25.3	23.0	22.1	21.1	23.2	22.6	17.0	12.7	**20.0**
2013	14.5	16.6	21.7	24.3	25.9	23.7	22.0	21.8	22.2	18.6	11.9	10.6	**19.5**
2014	09.4	11.9	18.7	25.5	25.9	24.4	23.1	21.7	23.1	18.6	12.6	08.3	**18.6**
MEAN	**12.9**	**16.5**	**20.6**	**24.9**	**25.7**	**24.0**	**22.2**	**21.8**	**22.6**	**21.1**	**15.4**	**11.8**	

SOURCE: ***Nigerian Meteorological Agency, (NiMet), 2015***

APPENDIX 4

AVERAGE MONTHLY RELATIVE HUMIDITY (%) AT 09:00Z BY MONTHS 2009-2014, KANO

YEAR	MONTH												
	JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUNE**	**JUL**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**	**MEAN**
2009	25	17	18	44	52	59	73	79	76	64	34	29	**48**
2010	21	18	24	38	59	68	79	82	77	66	26	27	**49**
2011	25	24	28	32	52	65	74	80	74	54	24	27	**47**
2012	24	27	21	42	53	70	79	82	73	57	28	26	**49**
2013	28	21	24	42	53	61	72	79	72	72	47	24	**50**
2014	22	17	19	41	56	59	70	78	73	55	29	26	**46**
MEAN	23.3	**20.7**	**22.3**	**39.8**	**54.3**	**63.7**	**74.5**	**80.0**	**74.2**	**61.3**	**31.3**	**26.5**	

SOURCE: ***Nigerian Meteorological agency, (MAKIA), 2015***

APPENDIX 5

Daily (Afternoon) Temperature-Humidity-Index (THI) and Human Comfort

Study days	Afternoon Temp (^{O}C)	R/H (%)	THI	Discomfort felt by residents
1	32.0	30.8	25	At least half (50%) of people are uncomfortable
2	39.4	38.0	30	More than half (60-70%)
3	39.9	37.1	31	More than half (60-70%)
4	43.3	41.9	33	More than 90% of people show sign of heat stress
5	40.5	33.3	30	More than 90% of people show sign of heat stress
6	36.2	32.0	28	More than 90% of people show sign of heat stress
7	36.3	37.2	28	More than 90% of people show sign of heat stress
8	37.2	35.5	29	More than 90% of people show sign of heat stress
9	37.5	37.3	24	At least half (50%) of people are uncomfortable

10	39.3	45.0	31	More than 90% of people show sign of heat stress
11	41.5	40.9	32	More than 90% of people show sign of heat stress
12	39.6	41.1	31	More than 90% of people show sign of heat stress
13	40.5	37.1	31	More than 90% of people show sign of heat stress

Source: Field Study, 2015

APPENDIX 6: RESULT OF FACTOR ANALYSIS

INDEPENDENT VARIABLE – THERMAL PERCEPTION

Correlation Matrix[a]

		TPC09	TPC10	TPC11	TPC12
Correlation	TPC09	1.000	.562	.500	.380
	TPC10	.562	1.000	.469	.490
	TPC11	.500	.469	1.000	.531
	TPC12	.380	.490	.531	1.000
Sig. (1-tailed)	TPC09		.000	.000	.000
	TPC10	.000		.000	.000
	TPC11	.000	.000		.000
	TPC12	.000	.000	.000	

a. Determinant = .307

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.750
Bartlett's Test of Sphericity	Approx. Chi-Square	424.510
	Df	6
	Sig.	.000

Anti-image Matrices

		TPC09	TPC10	TPC11	TPC12
Anti-image Covariance	TPC09	.612	-.242	-.178	-.013
	TPC10	-.242	.585	-.077	-.175
	TPC11	-.178	-.077	.604	-.229
	TPC12	-.013	-.175	-.229	.643
Anti-image Correlation	TPC09	.740[a]	-.404	-.293	-.021
	TPC10	-.404	.748[a]	-.129	-.286
	TPC11	-.293	-.129	.760[a]	-.368
	TPC12	-.021	-.286	-.368	.754[a]

a. Measures of Sampling Adequacy(MSA)

Communalities

	Initial	Extraction
TPC09	1.000	.604
TPC10	1.000	.650
TPC11	1.000	.636
TPC12	1.000	.577

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.467	61.678	61.678	2.467	61.678	61.678
2	.644	16.095	77.772			
3	.509	12.717	90.489			

4	.380	9.511	100.000			

Extraction Method: Principal Component Analysis.

Component Matrix[a]

	Component
	1
TPC10	.806
TPC11	.798
TPC09	.777
TPC12	.759

Extraction Method: Principal Component Analysis.[a]

a. 1 components extracted.

INDEPENDENT VARIABLE - THERMAL PREFERENCE

Correlation Matrix[a]

		TPR02	TPR08	TPR09
Correlation	TPR02	1.000	.466	.592
	TPR08	.466	1.000	.574
	TPR09	.592	.574	1.000
Sig. (1-tailed)	TPR02		.000	.000
	TPR08	.000		.000
	TPR09	.000	.000	

a. Determinant = .420

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.685
Bartlett's Test of Sphericity	Approx. Chi-Square	312.434
	Df	3
	Sig.	.000

Anti-image Matrices

		TPR02	TPR08	TPR09
Anti-image Covariance	TPR02	.626	-.122	-.259
	TPR08	-.122	.646	-.246
	TPR09	-.259	-.246	.537
Anti-image Correlation	TPR02	.705[a]	-.192	-.447
	TPR08	-.192	.721[a]	-.417
	TPR09	-.447	-.417	.645[a]

a. Measures of Sampling Adequacy (MSA)

Communalities

	Initial	Extraction
TPR02	1.000	.673
TPR08	1.000	.656
TPR09	1.000	.760

Extraction Method: Principal Component Analysis.

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings	
Component	Total	% of Variance	Cumulative %	Total	% of Variance

1	2.089	69.649	69.649	2.089	69.649
2	.534	17.811	87.460		
3	.376	12.540	100.000		

Extraction Method: Principal Component Analysis.

Component Matrix[a]

	Component
	1
TPR09	.872
TPR02	.820
TPR08	.810

Extraction Method: Principal Component Analysis.[a]

a. 1 components extracted.

DEPENDENT VARIABLE – THERMAL ADAPTATION

Correlation Matrix[a]

		TA07	TA08	TA09	TA10
Correlation	TA07	1.000	.541	.509	.358
	TA08	.541	1.000	.644	.446
	TA09	.509	.644	1.000	.547
	TA10	.358	.446	.547	1.000
Sig. (1-tailed)	TA07		.000	.000	.000
	TA08	.000		.000	.000
	TA09	.000	.000		.000
	TA10	.000	.000	.000	

a. Determinant = .265

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.771
Bartlett's Test of Sphericity	Approx. Chi-Square	477.793
	Df	6
	Sig.	.000

Anti-image Matrices

		TA07	TA08	TA09	TA10
Anti-image Covariance	TA07	.660	-.183	-.117	-.045
	TA08	-.183	.517	-.214	-.070
	TA09	-.117	-.214	.480	-.204
	TA10	-.045	-.070	-.204	.683
Anti-image Correlation	TA07	.823[a]	-.313	-.208	-.068
	TA08	-.313	.753[a]	-.431	-.118
	TA09	-.208	-.431	.732[a]	-.356
	TA10	-.068	-.118	-.356	.812[a]

a. Measures of Sampling Adequacy(MSA)

Communalities

	Initial	Extraction
TA07	1.000	.564
TA08	1.000	.702
TA09	1.000	.740
TA10	1.000	.527

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.533	63.324	63.324	2.533	63.324	63.324
2	.659	16.483	79.808			
3	.470	11.752	91.559			
4	.338	8.441	100.000			

Extraction Method: Principal Component Analysis.

Component Matrix[a]

	Component
	1
TA09	.860
TA08	.838
TA07	.751
TA10	.726

Extraction Method: Principal Component Analysis.[a]

a. 1 components extracted.

APPENDIX 8: RELIABILITY TEST

RELIABILITY SCALE – THERMAL PERCEPTION

Reliability Statistics

Cronbach's Alpha	N of Items
.792	4

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
TPC09	11.20	5.281	.589	.747
TPC10	11.13	5.306	.632	.725
TPC11	11.10	5.421	.620	.732
TPC12	11.11	5.468	.566	.758

RELIABILITY SCALE - THERMAL PREFERENCE

Reliability Statistics

Cronbach's Alpha	N of Items
.781	3

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
TPR02	6.31	7.520	.598	.729
TPR08	5.93	6.959	.586	.739
TPR09	6.10	6.147	.680	.634

RELIABILITY SCALE - THERMAL ADAPTATION

Reliability Statistics

Cronbach's Alpha	N of Items
.800	4

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted

TA07	11.91	7.315	.556	.776
TA08	11.96	6.742	.669	.723
TA09	11.98	6.563	.713	.702
TA10	12.23	6.633	.535	.796

APPENDIX 9: CORRELATION AND MULTIPLE REGRESSION ANALYSIS

Correlations

		TerAdopt	TerPerc	TerPref
Pearson Correlation	Teradapt	1.000	.067	-.173
	Terperc	.067	1.000	.485
	Terpref	-.173	.485	1.000
Sig. (1-tailed)	Teradapt	.	.100	.000
	Terperc	.100	.	.000
	Terpref	.000	.000	.
N	Teradapt	363	363	363
	Terperc	363	363	363
	Terpref	363	363	363

Variables Entered/Removed[a]

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics		
					R Square Change	F Change	df1
1	.245[a]	.060	.055	3.27620	.060	11.488	2

Model Summary[b]

Model	Change Statistics		
	df2	Sig. F Change	
1	360	.000	1.377

a. Predictors: (Constant), Terpref, Terperc

b. Dependent Variable: Teradapt

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	246.613	2	123.307	11.488	.000[b]
	Residual	3864.053	360	10.733		
	Total	4110.667	362			

a. Dependent Variable: Teradapt

b. Predictors: (Constant), Terpref, Terperc

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations
	B	Std. Error	Beta			Zero-order

1	(Constant)	14.942	.873		17.121	.000	
	Terperc	.223	.066	.198	3.390	.001	.067
	Terpref	.243	.053	.269	4.608	.000	.173

Coefficients[a]

Model		Correlations			
		Partial	Part	Tolerance	VIF
1	(Constant)				
	Terperc	.176	.173	.765	1.308
	Terpref	-.236	-.235	.765	1.308

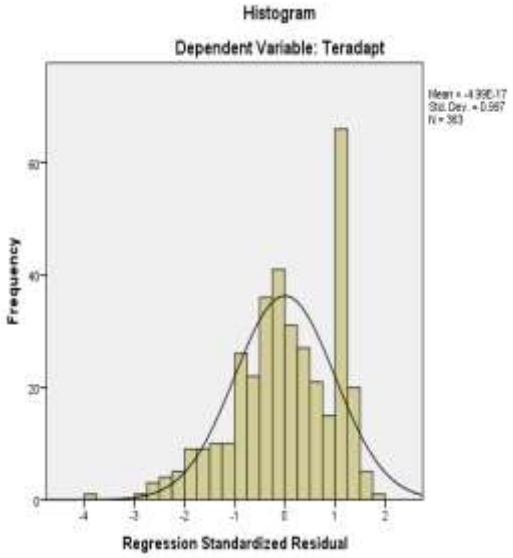
a. Dependent Variable: Teradapt

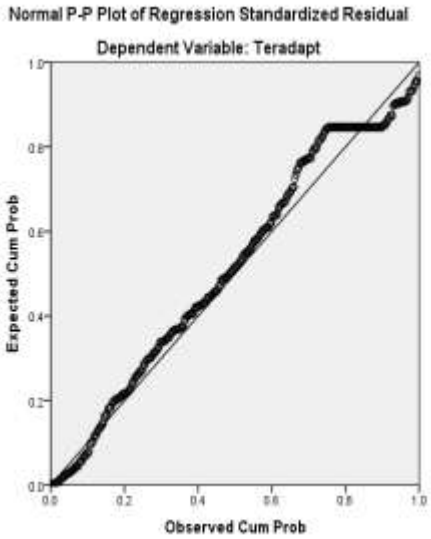
CollinearityDiagnostics[a]

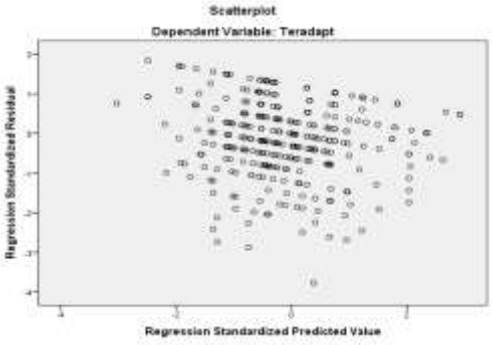
Model	Dimension	Eigenvalue	Condition Index	Variance Proportions		
				(Constant)	Terperc	Terpref
1	1	2.901	1.000	.00	.00	.01
	2	.081	5.972	.13	.03	.87
	3	.018	12.749	.87	.97	.11

a. Dependent Variable: Teradapt

Charts


Histogram
Dependent Variable: Teradapt
Mean = -4.99E-17
Std. Dev. = 0.997
N = 363
Frequency
Regression Standardized Residual


Normal P-P Plot of Regression Standardized Residual
Dependent Variable: Teradapt
Expected Cum Prob
Observed Cum Prob


Scatterplot
Dependent Variable: Teradapt
Regression Standardized Residual
Regression Standardized Predicted Value