EXPLORING SHADING DEVICE STRATEGIES FOR COOLING EFFICIENCY IN THE DESIGN OF FIVE STAR HOTEL, BAUCHI, NIGERIA

BY

ABRAHAM OTHNIEL
P14EVAT8018

THE DEPARTMENT OF ARCHITECTURE
AHMADU BELLO UNIVERSITY
FACULTY OF ENVIROMENTAL DESIGN
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A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES AHMADU BELLO UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTERS DEGREE IN ARCHITECTURE

DEPARTMENT OF ARCHITECTURE,
FACULTY OF ENVIRONMENTAL DESIGN,
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November, 2019

DECLARATION

I declare that the work in the dissertation entitled "EXPLORING SHADING DEVICE STRATEGIES FOR COOLING EFFICIENCY IN THE DESIGN OF FIVE STAR HOTEL, BAUCHI, NIGERIA" has been performed by me in the Department of Architecture under the supervision of Dr Hamza Babangida and Prof. M L Sagada.

The information derived from literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at any university.

Abraham OTHNIEL		
Name of student	Signature	Date

CERTIFICATION

This dissertation entitled "EXPLORING SHADING DEVICE STRATEGIES FOR COOLING EFFICIENCY IN DESIGN OF FIVE STAR HOTEL, BAUCHI, NIGERIA" by Abraham OTHNIEL meets the regulations governing the award of the degree Master of Science in Architecture of Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

Dr. Hamza Babangida

______________________________ ______________ ______________

Chairman, Supervisory Committee Signature Date

Prof. M. L. Sagada

______________________________ ______________ ______________

Member, Supervisory Committee Signature Date

Dr. A. S. Salisu

______________________________ ______________ ______________

Head of Department Signature Date

Prof. Sani Abdullahi Rabah

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Dean, School of Postgraduate Studies Signature Date

DEDICATION

This thesis is dedicated to almighty God who in his infinite mercy has seen me through from the beginning of this journey up to the end

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Thanks are to almighty God, for his unending love, mercies and compassion. I return all the glory to his name.

I would like to express my sincere gratitude and appreciation to my parents Mr. Othniel Bulus and Mrs. Deborah Othniel Bulus for the supports financially, emotionally and spiritually. For if not for your guiding love and support, I would not have the opportunity to reach this level.

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ABSTRACT

Over the years, the need for energy efficient building is on the increase as the current practice of building trends consumes a lot of energy. Buildings such as hotels consume a lot of electricity in providing comfort to the occupants through mechanical cooling. The most effective way of reducing cooling load is by reducing the solar heat gained by the building. External shading device are efficient in reducing cooling load when properly designed. The study aims to improve cooling efficiency by assessing shading device strategies with different variables. The variables that are considered in this are the horizontal shading device on the north and south orientation, the distance of shading device from wall and angle of shading device in the area of study in the hot-dry climate.The based case was modeled in Autodesk Revit and simulated using the Autodesk simulation Computational Fluid Dynamics (CFD). Autodesk simulation CFD assess for natural ventilation using indicators such as Predicted Mean Vote (PMV), Percentage Persons Dissatisfaction (PPD) and temperature. The result for the based cased model was +2.4(warm) of the PMV, 78% of PPD and the temperature of 32.01°C. While the concrete shading device at an angle of 70° with no distance from the wall on the north and south proved more comfortable over the other shading device strategies with a PMV of +0.2 (slightly neutral) and a PPD of 15% which is satisfactory, with a temperature of 27.01°C. In conclusion, the study discourages the use of 90° angle shading device with 200mm from wall with a PMV of +2.4 and a PPD of 80%, which has high discomfort level in the space. The 70° with no distance from the wall has shown significant improvement of natural ventilation and a 5°C reduction in temperature.

CHAPTER ONE

INTRODUCTION

1.1 Background to Study

Buildings in general are one of the most essential elements of human civilization. They are further sub-divide into residential, institutional, industrial and so on (Harferkamp and Smelser, 1992). Statistics according to American Physical Society (2008) has shown that people spend about 90% their time in buildings and energy is used to sustain the occupancy. The use of energy has become a significant issue and the conservation of energy has gained a high importance(Sahel, 2014). In another study by the American Physical Society (2008), buildings consume 72 percent of energy generated. A considerable energy protection opportunity exists within the building. The energy is needed in a building for cooling, lighting, ventilation, heating, etc. However, the most energy used in buildings is air conditioning of space(Sahel, 2014).Cooling is the transfer of energy from the space or the air supplied to the space, in order to achieve a lower temperature and/or humidity level than those of the natural surroundings(Santamouris and Asimakopoulos, 2001).

According to World climatic regions (2016), Nigeria is in the tropical region where the temperature is high, which makes it a basic necessity for our buildings to be cool, furthermore, buildings such hotel and offices are mainly cooled mechanically through the use of air conditioning (Kamal, 2012) and these buildings consumes a lot of energy to cool them. Hence, the need to design buildings that would consume less energy is important.

Hotel facilities rank among top five in terms of energy consumption (Bohdanowicz, 2006). In addition, the hotel industries constitute one of the most energy and intensive branches of tourist industry (David, 2001). Its estimated annual carbon release is between 160 and 120kg of co_2 per m^2 of room area, depending on the fuel mix used to provide energy (Hotel Energy Solution, 2011).

Bohdanowicz (2006), Indicated that, hotel buildings consume substantial amount of energy in providing comfort and wide range of services to guests, which poses a serious environmental threat and this is due to poor environmentally friendly nature of architectural concept used. Hence, stating that the high-energy consumption in hotel buildings is a great fault on its architectural approach.Hotel Energy Solution(2011), goes on to outline the main energy consuming activities in a hotel which are; heating room, cooling room, hot water use and other energy consuming activities by guest, preparing meals (especially warm ones) and swimming pool.

Bohdanowicz, Churie-Kallhauge, Martinac and Rezachek (2001), indicates that, heating, air conditioning, ventilation and cooling systems typically account for a major and frequently the largest portion of energy consumed in a hotel.

Studies according to Maleki (2011) and Stack, Goulding and Lewis (2002) have shown that one of the most effective way of reducing cooling load and achieving energy efficiency is by ensuring that solar heat is not build up in the building. They also go on to indicate that shading devices are very efficient in addressing the issue. Maleki (2011) agrees with (Dubois, 1997) that there is no general application of shading device as it is dependent on climate, building typology and location. However,Maleki (2011) goes on in his study to indicate that caution must be put into the design of shading devices, as improper design would lead to unwanted conditions. The study made emphasis on the need for proper and careful design of shading devices.

1.2 Problem Statement.

Hotel designs in Nigeria have evolved over decades. In trying to keep with the global trend of hotel designs and the need for aesthetically pleasing facades, the increase use in glazing in the building façade to achieve aesthetics has led to overheating, glare and discomfort hence leading to increase in mechanical cooling(Morakabian, 2015), which does not only increase the cost of power generation but also maintenance cost.

The use of shading devices in hot climate is inevitable as they can be used to regulate heat gained by building into space through openings on the façade(Napier, 2015). There is need to take measures in reducing the heat transfer into building spaces from early stage, hence reducing the cost of cooling the space and improve natural indoor condition. Shading devices are not used to their full potential in the area. The conditions that can likely arise may lead to overcooling, impeding natural ventilation, impeding day lighting leading to increase in artificial lighting. They are often used neglecting some factors such as climatic conditions, location, building typology. However, these variables are within the control of the researcher.Variables such as the length of shading, width of shading, angle of shading, distance between the shading device, distance from the wall, and the materials are controlled by the researcher.

Some studies have been carried out towards addressing the effectiveness of shading devices used in the area of study but however, inefficient as there are no studies indicating the angle and distance at which the shading device are to be placed with respect to the prevailing climate and solar incident angle in the area of study. This research would attempt to optimize the use of shading device through the means of climate-based modeling to be able to find preferred shading strategy for the area of study.

1.3 Justification.

Electricity demand in Nigeria far outstrips the supply that is epileptic in nature. The country is faced with acute electricity supply problem (Chukwu, Ibrahim, Ojosu and Iortyer, 2014). According to Fabiyi, Abdulmalik and Taimiu, (2016), power generation reportedly dropped from 5000 megawatts to below 1600 megawatts in early 2016 and this worsened state of electrical power supply in the country. Hence, the present impediment of power supply in the country has given rise to the need of finding means to reduce the energy consumption used in cooling our buildings especially hotel facilities as it cannot continue depending on mechanical means of cooling (air-conditioning) as its major means of cooling. According to European Union (2013), limiting the growth of electricity consumption will not only have economic and environmental benefits. The study also provides guide for the proper design of shading device from early design stage in the area of study for future design of hotel facilities.

1.4 Aim.

The aim of this study is toimprove coolingefficiency in the design of hotels through the proper use ofshading device.

1.5 Objectives.

To achieve the aim of the research, the following steps have to be carried out;

i. To identify the various types of shading devices and strategies of use.
ii. To identify the ways in which shading device affects cooling efficiency.
iii. To identify specific shading device strategies that improves cooling efficiency in hotels in the area of study.
iv. To apply the identified strategyto the proposed design of five star hotel in Bauchi state.

1.6 Research Question.

The research questions of this research are;

i. What are the various types of shading device?
ii. To what extent does shading device affect cooling?
iii. Whatis the suitable optimum shading device strategy for cooling load reduction in hotel design in the area of study?

1.7 Scope.

The research focuses on achieving cooling efficiency through thermal comfort and natural ventilation in hotel rooms in hot dry climate by the means of proper shading device design. It would highlight a framework necessary for the application of shading device strategy to hotel designs in Bauchi. The research should be able to provide preferred solution tocooling efficiency in the design of hotels in the area of study.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction.

In a constant changing world, sustainability has become more eminent. According to Uyigue, Agho, Edevbaro, Godfrey, Uyigue and Okungbowa, (2009), energy efficiency has become the key driver of sustainable development. They further go on to state that energy efficiency does not mean that we should not use energy, but we should use energy in a manner that will minimize the amount of energy needed to provide services.

The literature review would give an insight to the vast body of knowledge as it discusses on the concept of passive cooling, strategies of passive cooling, shading devices, hotels, types of hotels, classification of hotels and energy consumption in hotels.

2.2 The Concept of Passive Cooling Design.

The primary function of passive cooling is to cool a building's structure and its indoor spaces to provide thermal comfort to the occupants (Teo and Hooi, 2013). Ever since humans have moved into shelters, in search of a more stable environment, they have looked for ways to improve indoor conditions. However, the indoor environment is influenced by prevailing outdoor conditions, daily and seasonal changes in climate and varying occupant requirements due to the type and operation of the building. Depending on the location and season, emphasis is given to either cooling or heating of indoor spaces, in an attempt to counterbalance the unfavorable outdoor conditions and achieve indoor comfort by controlling the indoor temperature, humidity, light availability and air quality (Santamouris and Asimakopoulos, 2001).

2.2.1 Historical development of passive cooling.

The development of cooling processes has passed through several stages, starting from simple intuitive applications of natural cooling techniques, such as shading, evaporative cooling and air circulation enhancing the comfort sensation, to mechanical cooling systems, known as air conditioners, based on mechanical refrigeration. It appears that there has been a return to the utilization of several well-known techniques and processes that were used successfully even in the early periods of civilization. The principles of passive cooling are the same, but they are now enhanced with the available technological knowledge and they are optimized so that they can be successfully incorporated into the building design and operation, in a suitable form for providing the best result (Santamouris and Asimakopoulos, 2001).

Natural or forced ventilation is one of the primary means of reducing the cooling load in buildings (removing heat from indoor spaces) and of extending indoor thermal comfort conditions for humans when the outdoor conditions (temperature and humidity) are not favorable. Ventilation is also necessary in all indoor spaces, in order to introduce the required levels of fresh air and to control odors and indoor pollutants. Quantified ventilation research has been conducted continuously since the 1930s (Chandra, 1990).

2.2.2 General principles of passive cooling design.

A passive solar design involves the use of natural process for heating or cooling to achieve balanced interior conditions without using any electrical device.Maintaining a comfortable environment in a hot climate relies on reducing the rate of heat gain into the building and encouraging the removal of excess heat from the building (Kamal, 2012). Furthermore, Kamal, (2012) mentioned some means of natural cooling through radiation, water (evaporation) and ground (conduction through building envelope).

2.2.2.1 Ventilative cooling.

Ventilative cooling refers to the use of natural or mechanical ventilation strategies to cool indoor spaces. This effective use of outside air reduces the energy consumption of air cooling system while maintaining thermal comfort. According to its definition, ventilative cooling depends on the availability of suitable external conditions to provide cooling. It also depends on the building type and thermal characteristics which determine its cooling demand and acceptability of internal environment by its users (Kolokotroni and Heiselberg, 2015).

2.2.2.2 Radiative cooling.

Radiative cooling refers to the physical process by which a body loses heat to another body of lower temperature via long wave. In the case of buildings, radiative cooling results from the thermal radiation exchange between building surfaces on the earth and the colder atmospheric layer in the sky (Fernadez, Wang, Alvine and Katipamula, 2015).The cooled body is the building and the heat sink is the sky, since the sky temperature is lower than the temperatures of most of the objects on earth (Geetha and Velraj, 2012). Night sky radiant cooling is a natural process that helps the earth maintain thermal equilibrium. The effect of this radiant heat leaving the surface of the earth can easily be seen on some mornings after a clear night. A layer of frost will form on rooftops and on automobiles even though the outdoor air temperature is well above freezing. This frozen condensation is proof that the rooftops were losing heat by radiation to the night sky faster than the surrounding warmer air could replace that heat by natural convection(sol-ice , 2012).

Thevarious concepts of radiative cooling of buildings as described in Table 2.1 below shows:

Table 2-1: Various concepts of radiative cooling of buildings.

	Concepts of radiative cooling of buildings	
1	Paint	The simplest passive radiative cooling technique is to paint the roof white. White paint does not significantly affect the radiation rate at night, since both white and black paints have almost the same emissivity in the long wave range
2	Movable insulation	Movable insulation systems are applied on the roof of buildings. They consist of an insulating material that can be moved over the roof of the building.
3	Movable thermal mass	The movable thermal mass technique is a variation of the previous one, but with an even higher cost. It requires the construction of a thermally insulated pond on the roof of the building with a movable insulation device above it
4	Flat plate air cooler	A flat plate air cooler can be used for cooling water in a loop, similar to the solar collector linked to a storage tank

Source: Geetha and Velraj (2012).

2.2.2.3 Evaporative cooling.

Evaporative cooling is the process by which the temperature of a substance is reduced due to the cooling effect from the evaporation of water (Liberty, Ugwuishiwu, Pukuma, and Odo, 2013). Ahmed, Khan, Maung and Rasul, (2014)is in agreement with Liberty et. al, (2013) as they define evaporative cooling a method of converting hot air into a cool breeze. By evaporating water, energy is taken from the air and the temperature is reduced. Outdoor air can be cooled by evaporating water before it is introduced into the building. The airflow can be induced mechanically or passively. In desert regions with too low humidity (from the comfort viewpoint), direct evaporative cooling can be an inexpensive system that is desirable physiologically as well (Givoni, 1994). Evaporative cooling is a process that uses the effect of evaporation as a natural heat sink. Sensible heat from the air is absorbed to be used as latent heat necessary to evaporate water. The amount of sensible heat ahsorbed depends on the amount of water that can be evaporated (Geetha and Velraj, 2012).

2.3 Strategies of Passive Cooling Design.

Passive cooling involves designing buildings for cooling load avoidance (RIBA Architects, 2015). Design strategies that minimize the need for mechanical cooling systems include proper window selection and orientation and day lighting design, selection of appropriate varnishing for windows and skylights, proper shading of glass when heat gains are not desired, use of light-colored materials for the building envelope and roof, careful sitting and orientation decisions and good landscaping design. Buildings should be designed in relation to specific climatic conditions, the changed function or the time of use or occupancy levels of internal and external spaces, and in relation to how these results will impact the parts that remain unchanged (Ahmed et al, 2014). They further went on to state that, passive cooling strategies eliminate mechanical air conditioning requirements such as fan, compressor, etc. in the modern buildings where cooling is a dominant requirement. Thus, the passive cooling is considered an alternative to mechanical cooling that requires complicated refrigeration systems.

There are many passive cooling strategies and these strategies are applicable to different climatic regions. As the cooling demand is always a result of climatic conditions on the building site, cooling strategies have to be adapted to regional climate characteristics (Staller and Tisch, 2011). Akande (2010), indicated some passive cooling strategies that are applicable to the area of study as;

2.3.1 Site selection, analysis and planning.

There are many sources of energy available locally within a building site. These include direct and diffuse radiation from the sun, air movement from winds and temperature differences, biomass from vegetation, as well as geothermal and hydro-kinetic sources. The most appropriate ecological, economic and physical fit between site, building development and the resulting cultural landscape is a product of sound site analysis and assessment.

Hence, a careful site assessment can enable developers to capture the land's potential views, solar access, natural drainage opportunities, natural shading through vegetation, cooling from prevailing wind while minimizing or avoiding damage or disturbance to the site and surrounding areas. Therefore, a proper understanding and analysis of the site resources, relationships, and constraints will enable the designers to maximize energy efficiency while conserving and restoring ecological and cultural resources (Akande, 2010).

2.3.2 Building orientation.

Orientation and form of the build, as well as the structure, character and color of surrounding surfaces influence on the values of absorbed solar radiation (Tang, 2012). The building orientation towards natural elements such as wind and sun influences energy consumption. Solar heat gain of a building depends on the sun orientation. Reduction of solar heat gain is the key strategy for warm and hot climates. Solar heat that does not enter the building does not need to be cooled, thus a reduction of the cooling load. (European Union, 2013).

Building orientation refers to way a building is situated on a site and the positioning of windows, rooflines, and other features(Energy centre Sofia, 2013). Properly oriented buildings take advantage of solar prevailing wind (Akande, 2010). According to Gut and Ackerknecht, (1993), the longer axis of the building should lie along east-west direction for minimum solar heat gain by the building envelope. Wong and Li (2007), performed field measurements and computational energy simulations to examine the effectiveness of passive climate control methods such as building orienteation in residential of singapore. Their results state the best orientation for buildings in singapore with its tropical climate is for longer axis of the building to lie along east-west direction.

The reflective characteristics of one or another façade material or covering are directly connected with the color and texture of the surfaces i.e depending on their optical characteristics. The orientation towards the four cardinal points has high influence on the surfaces of a given volume. At a given volume of the building its geometry also has an influence. The right choice of orientation and geometry can protect the building from excessive heating (Energy centre Sofia, 2013).

2.3.3 Surface to volume ratio of building envelope.

The form of the building mass influences the energy consumption. A compact building has a lower surface-volume ratio(S/V), and thus a smaller surface area to absorb solar heatcompared to a building with a higher surface-volume ratio (European Union, 2013). The volume of space inside a building that needs to be heated or cooled and its relationship with the area of the envelope enclosing the volume affects the thermal performance of the building. This parameter, known as the S/V (surface-to- volume) ratio, is determined by the building form. For any given building volume, the more compacts the shape, the less wasteful it is in gaining losing heat. Hence, in hot, dry, regions and cold climates, buildings are compact in form with a low S/V ratio to reduce heat gain and losses respectively. In addition, the building form determines the airflow pattern around the building, directly affecting its ventilation. The depth of a building also determines the requirements for artificial lighting - greater more the depth, higher the need for artificial lighting and greater the energy demand of such building(Akande, 2010). Figure 2.1 below illustrates the different building shapes with their respective surface area to volume ratio.

Figure 2-1: Surface Area to Volume Ratio of Building envelope shapes.
Source:European Union, (2013).

Envelope = 63m^2 Envelope = 71m^2 Envelope = 81m^2

S/V =1.2 S/V =1.35 S/V =1.55

2.3.4 Room orientation and floor plan zoning.

Orientation of the floor plan is important to not only orient a building toward the sun, but a designer should also consider directing the entire floor plan in accordance to the sunlight. Rooms that are most frequently used should be placed on the southern side of the structure (AutoDesk Education Community, 2015). Watson and Labs (1983), have claimed that a house can be made more energy efficient if it is planned according to solar orientation and prevailing wind direction. However, they did specify how much energy saving is possible through such planning. (Akande, 2010). According to Gut and Ackerknecht (1993), bedrooms can be located on the east side where it is coolest in the evening. Stores and other auxiliary spaces should be located on the disadvantaged side, mainly on the western sides. Rooms with high internal heat load, such as kitchens, should be detached from the main rooms. Givoni (1998), highlighted that cross ventilation can be used to enable faster cooling and better ventilation. Furthermore, stresses that building layout which provides good potential for cross-ventilation is more appropriate for developing countries in hot-humid regions where the vast majority of people cannot afford to buy air conditioners. Furthermore, recommends a spread out building with open able windows to facilitate cross-ventilation.

2.3.5 Building envelope.

A building envelope is the separation between the interior and the exterior environment of the building. The building envelope determines the energy exchange between outdoor environment and indoor spaces and hence governs the overall energy performance of the building(Hatice, 2010). It serves as the outer shell to protect the indoor environment as well as to facilitate its climatic control. Building envelope design is a specialized area of architectural and engineering practice that draws from all areas of building science and indoor climate control (Building and Construction Authority, 2010). An optimal design of the building envelope may provide significant reductions in cooling loads-which in turn can allow downsizing of mechanical equipment (Okba, 2005). The larger the openings the more likely it is to have a higher cooling load (European Union, 2013). It can lower operating cost, improve comfort and lifestyle and minimize environmental impact. As the main goal in building design of tropical climates is reduction of direct heat gain by radiation through openings and reduction of internal surface temperature, the building should be designed with protected openings and walls (Gut and Ackerknecht, 1993).

Solar heated buildings require particular attention in order to optimize both the solar and ventilation requirements. Ideally, solar orientation and breeze paths coincide (Richard, 2007). One of the most important factors affecting envelope design is climate. Hot/dry, hot/moist, temperate, or cold climates will suggest different design strategies. Specific designs and materials can take advantage of or provide solutions for the given climate. A second important factor in envelope design is what occurs inside the building. If the activity and equipment inside the building generate a significant amount of heat, the thermal loads may be primarily internal (from people and equipment) rather than external (from the sun). This affects the rate at which a building gains or loses heat.

Physical access to a building creates views to the outside, admit daylight and supply natural ventilation. The form, size, and location of the openings vary depending upon the role they play in the building envelope. Window glazing can be used to affect heating and cooling requirements and occupant comfort by controlling the type and amount of light that passes through windows. (Okba, 2005).

Building and Construction Authority (2010), Identify some strategies associated with building envelope as: heat gain and energy performance, shading devices, glass properties and window to wall ratio.

2.3.5.1 Heat gain and energy performance.

As an environmental filter, the building facade or envelope is often the first line of defense against undesirable external elements. Like all climates where cooling is the primary concern, the major issue is avoidance of solar radiation which leads to heat gain. This is quantified through the Envelope Thermal Transfer Value (ETTV) for non-residential buildings & Residential Envelope Thermal Transmittance Value (RETV) for residential buildings (Building and Construction Authority, 2010). The thermal mass of a building (typically contained in walls, floors and partitions, constructed of material with high heat capacity) absorbs heat during the day and regulates the magnitude of indoor temperature swings, reduces peak cooling load (Santamouris and Asimakopoulos, 2001).

2.4 ShadingDevices.

Traditional systems for solar radiation reflection are internal and external shading devices: curtains, blinds, sun canopies, etc. they reduce the brightness of the received sunlight, limit the ability of solar radiation penetration in the living space and improve its thermal and visual comfort (Gregg and Faia, 2016). The most efficient way to protect a building from the solar radiation is by window shading (European Union, 2013). Shading denotes the partial or complete obstruction of the sunbeam directed toward a surface by an intervening object or surface. The shadow varies in position and size depending upon the geometric relationship between the sun and the surface concerned (Geetha and Velraj, 2012).

After considering the best options for glass, the next step in reducing heat gain would be to install sunshades. An external sunshade can often be used as a design feature but its primary purpose is to reduce solar heat gains. Its secondary functions would be to control views into and out of a building, reduce solar glare, and provide rain protection for opening windows and to serve as part of maintenance strategy (Building and Construction Authority, 2010).

Well-designed sun control and shading devices, either as parts of a building or separately placed from a building facade, can dramatically reduce building peak heat gain and cooling requirements and improve the natural lighting quality of building interiors The design of effective shading devices will depend on the solar orientation of a particular building facade (Maleki, 2011). Furthermore, he classified shading device into interior and exterior shading devices.

2.4.1 Interior shading devices.

Interior devices are often less expensive than external shading devices, since they do not have to resist the elements. They are also very adjustable and movable, which enables them to easily respond to changing requirements. These devices provide numerous other benefits, such as privacy, glare control, insulation, and interior aesthetics. At night, they also prevent the "black hole" effect created by exposed windows(Galloway, 2004). From an energy-rejection point of view, the external shading devices are by far the most effective. Nevertheless, for a number of practical reasons, the interior devices, such as curtains, roller shades, Venetian blinds, and shutters, are also very important (Sahel, 2014) as shown in the figure 2.2 below:

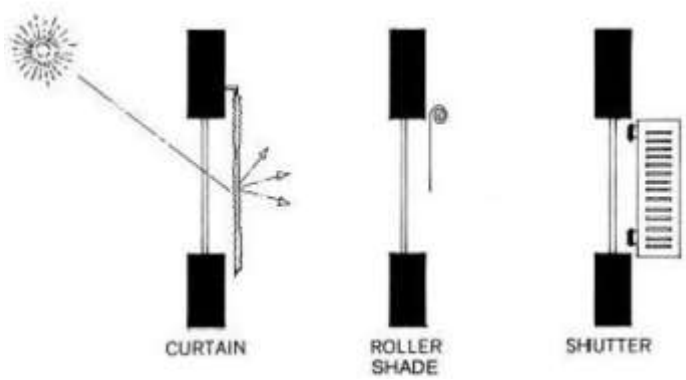


Figure 2-2: Interior shading devices for solar control.

Source: Lechner, (2009).

2.4.2 Exterior shading devices.

Exterior shading devices such as overhangs and vertical fins incorporated in the building facade to limit the internal heat gain resulting from solar radiation (Sahel, 2014). They have a number of advantages that contribute to a more sustainable building. First, exterior shading devices result in energy savings by reducing direct solar gain through windows. By using exterior shading devices with less expensive glazing, it is sometimes possible to obtain performance equivalent to un-shaded higher performance glazing. A second benefit is that peak electricity demand is also reduced by exterior shading devices resulting in lower peak demand charges from utilities and reduced mechanical equipment costs. Finally, exterior shading devices have the ability to reduce glare in an interior space without the need to lower shades or close blinds. This means that daylight and view are not diminished by dark tinted glazing or blocked by interior shades. With exterior shading devices, glare control does not depend on user operation(Carmody and Haglund, 2007). The figure 2.3 below illustrates the different types of exterior shading devices;

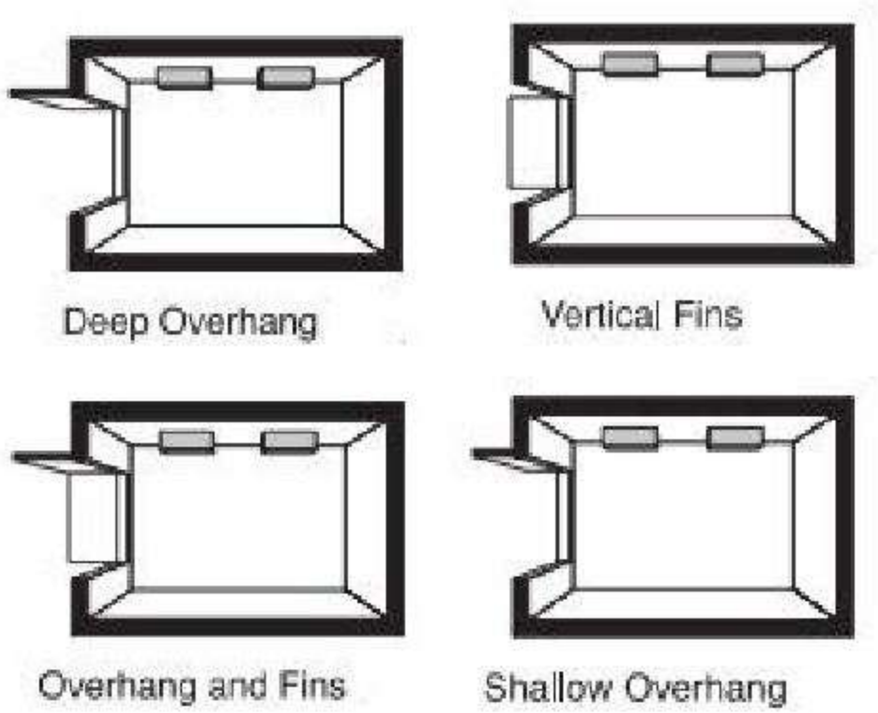


Figure 2-3: Examples of exterior shading devices.

Source: Grondzik, Kwok, Stein, and Reynolds, (2011).

European Union (2013), agrees with Maleki, (2011), as they stated that, exterior window shading reduces or can even prevent the direct solar radiation from entering the interior space. Building shading devices come in different forms. In the tropics, horizontal overhangs are generally used to combat high-angle midday sunshine. Vertical fins are used to indirectly block low-angle sunshine in the early morning and late afternoons. An egg-crate louver, which is a hybrid of the two previous shading devices, can be used in most façade orientations and be the most effective solution. Unconventional solutions are louvers, screens, or adjustable external shading. Adjustable shading is considered more energy efficient than fixed shading (Building and Construction Authority, 2010).

Laura, Concetta, Francesco and Alessia, (2014), illustrated using chart the breakdown of the classification of solar shading device as shown in the figure 2.4 below:

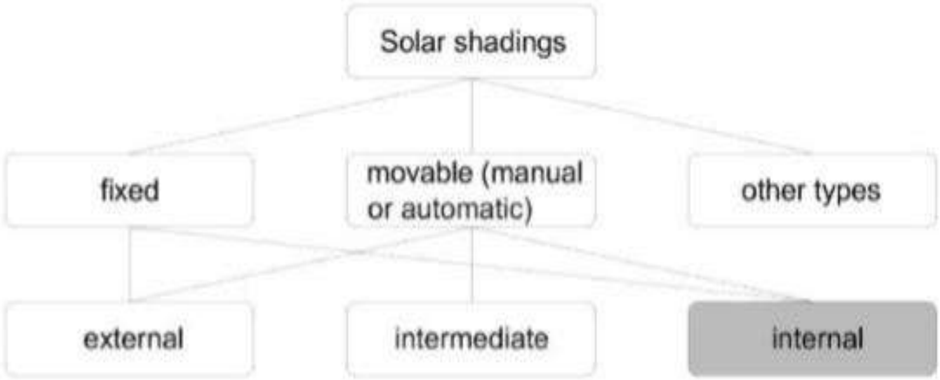


Figure 2-4: Diagram showing the breakdown of solar shading.

Source:Laura et al,(2014).

2.4.3 Shading device system types.

Works done by Olgyay and Olgyay,(1957), offers detailed classification of different systems and applications. Among the shading device types for sun control that designs have available for use are:

2.4.3.1 Overhangs

One of the simplest devices, an overhang is a continuation of the roof and provides shade to the envelope. Since the matter of shading is one of obstructing the sun at certain angles, several small devices will have constant impact as some massive ones (Sahel, 2014) as shown in the figure 2.5

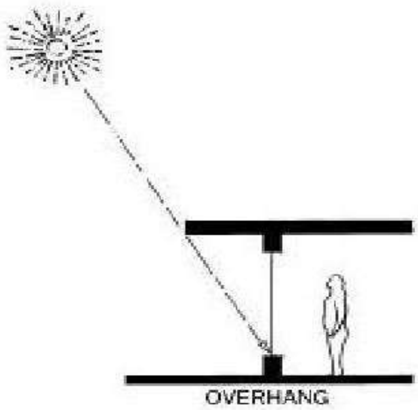


Figure 2-5: Shading effect of the overhang-shading device.

Source:Sun, Lu and Yang, (2012).

2.4.3.2 Sun screen

A waved material, either fabric or metal, will serve to block a percentage of solar radiation while letting another percentage pass through and another to be reflected

2.4.3.3 Fins or vertical shading device.

This system helps to reduce direct solar gain when low angles are present. The vertical shading devices, are primarily helpful for west and east exposures. These devices additionally improve the insulation value of enclose winter months by acting as a shelterbelt. Furthermore, vertical components can be designed to vary angle according to the sun's position (Brown and Dekay, 2001).

2.4.3.4 Horizontal shading device

Recommended for east, south and west elevation under the climate of Arizona. The horizontal overhang types are the best alternative for the south facade. As a result they are directionally selective, they will let the low sun into the interior spaces whereas absolutely shade the high heat season sun with minimum obstruction of the view (Sahel, 2014). When designing an overhang for the south facade, one should keep in mind that the sun comes from the southeast before noon and from the southwest afternoon. Thus, the sun can outflank an overhang a similar breadth as a window (Maurya, 2011). Figure 2.6 below shows the solar shading of the horizontal louvers:

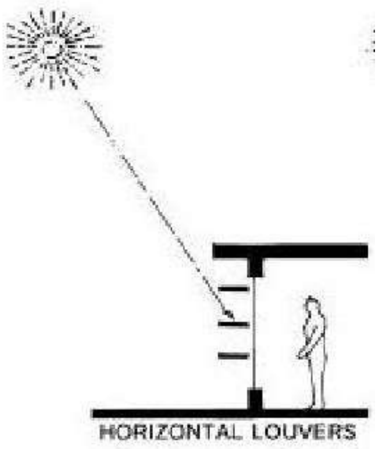


Figure 2-6: Shading effect of the horizontal louvers -shading device

Source: sun et al, (2012).

2.4.3.5 Egg crates

This system combines horizontal and vertical louvers. The shading devices are principally for west and east windows in hot climates and for the extra southwest and southeast orientations in very hot climates. An egg crate is a combination of vertical fins and horizontal overhangs (louvers). By dominant sun penetration by both the azimuth and altitude angle of the sun, extremely impressive shading of windows can be attained (Sahel, 2014).

2.4.4 Shading design.

Solar radiation incident on a window consists of three components: beam-(direct-) radiation, diffuses-(sky-) and reflected radiation. External shading devices can eliminate the beam component (which is normally the largest) and reduce the diffuse component. The design of such shading devices employs two shadow angles: HAS (horizontal shadow angel) and VSA (vertical shadow angel)(Sahel, 2014).

2.4.5 Shading system, natural ventilation and thermal comfort.

Shading devices could contribute to thermal comfort by attenuating the amount of the direct solar irradiance transmission and to an improvement of building energy performance (Lee, Alshayeb and Chang, 2015)External shading devices have been utilized very extensively in buildings in the tropics to reduce the amount of solar radiation entering into the buildings. However, this will affect the availability of natural ventilation for passive cooling and thermal comfort(Hien and Istiadji, 2003)

2.4.5.1 Glass properties.

The thermal properties of the glazed surfaces of a building affect the penetration of solar radiation to the interior. The influences of channel width and the dimensions of the inlet and outlet openings affect the convection process, and hence, affect the overall heating performance. Using double glazing could increase the flow rate by 11-17%. On the other hand, insulating the interior surface of the storage wall for heat season cooling can avoid excessive overheating due to south facing glazing(Geetha and Velraj, 2012). When selecting glass for any project, the most important considerations besides cost are performance properties, both thermal and visual. Glass performance can be indicated through a number of properties, such as Visible Light Transmittance (VLT), shading coefficient (SC) and U-value. Glass properties have significant impact towards reducing the cooling load. Any number of measures can be undertaken to improve glazing performance, each with their own advantages and disadvantages (Building and Construction Authority, 2010). A window can lose heat around five times faster than a wall of the same area. Therefore, it important to improve the thermal transmittance of the window glazing. In other words, glazing with a low U-value has to be considered (European Union, 2013).

Table2.2 below showing the various measures to improve glazing performance with their advantages and disadvantages as identified by Building and Construction Authority:

Table 2-2:Advantages and disadvantages of various measures to improve glazing performance.

	Advantages	Disadvantages
Use double-glazed units.	Lower U-value compared to single glazing less heat transmission through conduction	Increased cost greater structural load.
Use glass with lower sc.	Less solar heat gain.	Usually darker appearance Less opportunity for day lighting
Specify different glass according to function and orientation.	Balanced budget-spend on high-performance glass where it is most beneficial.	More difficult to keep track of various glass types for a single façade or window unit.

Source: Building and Construction Authority (2010).

2.4.5.2 Window to wall ratio.

The design of window openings in the building envelope needs to be done properly, as these transparent parts of the elevation also allow for solar heat gain, which can increase the cooling demand (European Union, 2013).

2.4.6 Natural ventilation.

Natural ventilation is the most important passive cooling technique. In general, the ventilation of indoor environments is also necessary to maintain the required levels of oxygen and air quality in a space. Traditionally, ventilation requirements were achieved by natural means. In the majority of older buildings, infiltration levels were such as to provide considerable amount of outdoor air, while additional requirements were satisfied by simply opening the window (Geetha and Velraj, 2012).

Living in hot climate can quickly become uncomfortable for its inhabitants with the extreme heat that is built up by midday. That is why it is important building for the building structure to have effective ventilation and an internal temperature below the outdoor level. Natural ventilation keeps the air moving within the indoor environment and, therefore, keeps the inhabitants cooler even without the use of energy (Akande, 2010).

The real test for naturally ventilated buildings is the provision of adequate cooling in hot condition Under this condition it is necessary to have sufficient external wind pressure to create air movement within the building and particularly, through the occupied zones. Under hot, dry conditions, when the outside air temperature is well above the tolerable internal level, it may be necessary to shut off the external air altogether until the temperature drops to more acceptable levels (Richard, 2007). Modern architecture and the energy-conscious design of buildings have reduced air infiltration to a minimum, in an attempt to reduce its impact on the cooling and heating load. Better construction has resulted in buildings being sealed from the outdoor environment. In particular, the construction of large glass buildings, which do not allow the opening of windows, has further eliminated the possibility of using natural ventilation for supplying fresh air to indoor spaces. The successful design of a naturally ventilated building requires a good understanding of the airflow patterns around it and the effect of the neighboring buildings (Geetha and Velraj, 2012).

Wong and Huang, (2004) made a comparative study on indoor air quality of naturally ventilated and air-conditioned bedrooms of residential buildings in Singapore. They observed that CO_2 levels of bedrooms using air conditioners are consistently higher than those utilizing natural ventilation. It further goes on to compare thermal comfort of air-conditioned bedrooms and naturally ventilated bedrooms, result indicates that the air-conditioned bedrooms are usually substantially overcooled, resulting in extremely high PPD (Percentage People Dissatisfied). Whereas, in natural ventilated bedrooms, the utilization of fans was sufficient to achieve the required thermal comfort. They also found that occupants utilizing air conditioners exhibited more SBS (Sick Building Syndrome) symptoms than those utilizing natural ventilation.

Liping, Hien and Shuo, (2007), stated that natural ventilation is an alternative to reduce the associated problems with air-conditioned buildings because natural ventilation has potential benefits such as reduced operation cost, improved indoor air quality and satisfactory thermal comfort. Ahmed et. al.(2014), stated that there are two major techniques in natural ventilation systems: Cross ventilation and Single-sided ventilation.

2.4.6.1 Cross ventilation

Cross ventilation is attained when rooms with a double orientation with at least two walls face externally in opposite directions (Ahmed et al, 2014). According to European Union (2013), natural ventilation is enhanced when the inlet and outlet are placed at the diagonal of the indoor space, for both plan and section. Key considerations include:

i. Buildingorientationtoward the prevailing wind direction.
ii. Sizeoftheinletandoutletopenings.
iii. Depthofthespace**:** limit to 12 to 14 meter for a space with a height of 3 meter.

Figure 2.7 below illustrating with a diagram cross ventilation of a building with double sides opening in which the airflow moves through the spaces of the building.

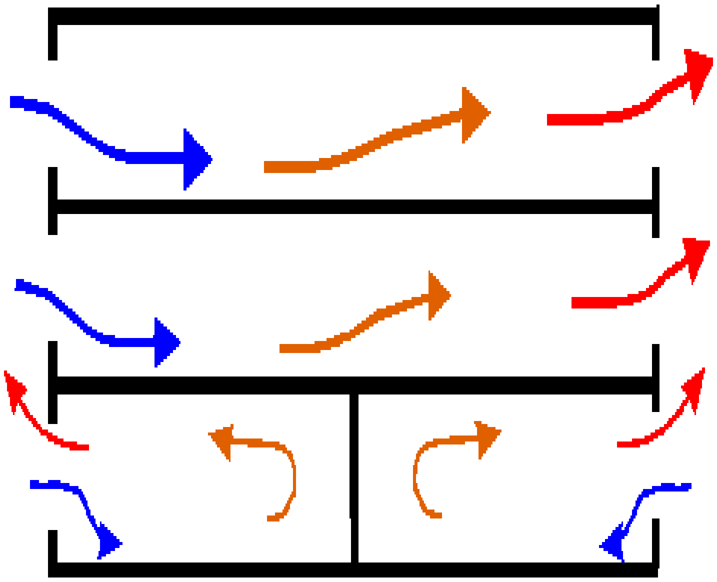


Figure 2-7: Cross ventilation of building with double sides opening.

Source:European Union, (2013).

2.4.6.2 Single sided ventilation

Single ventilation is achieved when there is only one external façade (Ahmed et al., 2014). According to European Union (2013), the strategy is applicable when a space has only one side along the elevation. Key considerations include:

i. Buildingorientationtoward the prevailing wind direction.

ii. Locationofopenings, windows, towards the prevailing wind direction.

iii. Elevationfeatures(“brise vent”) to create the required negative pressure zone.

Figure 2.8 below illustrating with a diagram ventilation of a building with single sided opening in which the airflow moves through the spaces of the building.

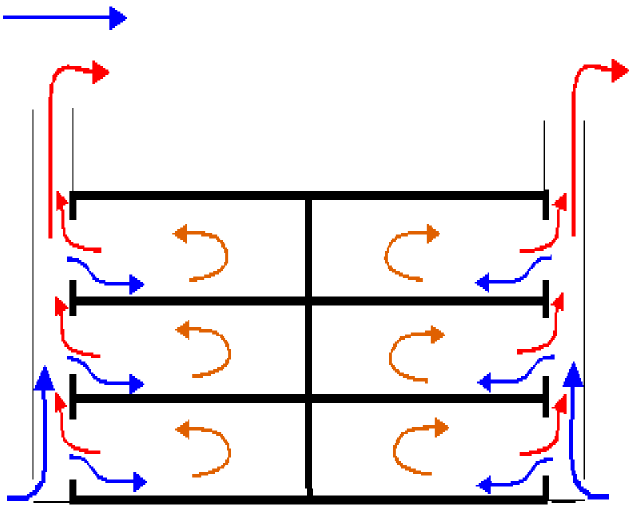


Figure 2-8:Single-sided ventilation of building with one side opening.

Source:European Union, (2013).

Ahmed et al, (2014), concluded by stating thatbenefits of using natural ventilation are 40% lower energy cost than the air-conditioned equivalents, capital costs savings in the region of 10% to 15%, increased fresh air supply to a space which may result in higher thermal comfort levels and increased productivity and so on. Furthermore, all the typical cost indicators such as installation cost, capital and maintenance are low.

In addition,air-conditioning spaces does only consume energy; it is also associated with some dissatisfaction and some health problems.

2.5 General Benefits of Passive Cooling in indoor spaces.

The energy required for heating and cooling of building is approximately 6.7% of the total world energy consumption. By proper environmental design, at least 2.35% of the world energy output can be saved (Agrawal, 1988). In hot climate countries, energy needs for cooling can amount to two or three times for heating, on an annual basis (Goulding, Lewis and Steemers, 1993). Utilization of basic principles of heat transfer, coupled to the local climate and exploitation of physical properties of the construction materials, could make possible the control of the comfort conditions in the interior of buildings (Santamouris and Asimakopoulos, 2001). Even in areas with average maximum ambient temperature around 31.7^{0}C, comfortable conditions inside buildings can be achieved by means of proper building design(Shaviv, 1988)that frequently makes the use of air conditioning units in dwellings unjustified.

According to Santamouris and Asimakopoulos (2001), passive cooling strategies in the design of buildings should be considered, since the extensive use of air co-conditioning units is associated with the following problem as shown in the table 2.3below:

Table 2-3: The problems associated with extensive use of air- conditioning.

	Environmental	Indoor Quality	Economical
1	Increased electrical peak loads resulting in increase of the average cost of electricity to cover the construction of new power stations.	Increased indices of illness symptoms (lethargy, headache, blocked or runny nose, dry or sore eyes, dry throat and sometimes-dry skin and asthma), known as 'sick building syndrome'.	Installation of air-conditioning units presents an extra cost in cost in the construction of a building, followed by an additional operation and maintenance cost.
2	Increased electrical energy production contributes to exploitation of the finite fossil fuels, to the atmospheric pollution and to climatological changes. This leads to a great deal of CO_2 released into the atmosphere.	Occupants' dissatisfaction with indoor comfort conditions	Expenses for importation of air-conditioning units. Countries with hot climates exhibit an increased rate of sales of air-conditioning units.
3	Heat generation during production process (for electrical energy and air-conditioning units) and from the operation of air-conditioning units themselves increase the phenomenon of the 'urban heat island'.		
4	Ozone- layer depletion can be caused by CFCs and HFCs (the most common refrigerants of currently used air-conditioning units) from possible leakage during manufacture, system maintenance or unit failure.		

Source: Santamouris and Asimakopoulos, (2001).

2.6 Building Computer Simulations.

Building energy simulation (BES) is used to predict the building energy performance (Harish and Kumar, 2016). Energy simulation tools are used for analysis of energy performance of buildings and the thermal comfort of their occupants(Rallapalli, 2010). To model the indoor airflow in buildings, many popular BES programs, such as Energy Plus, TRNSYS, ESP-r, IDA-ICE, BSIM, use a multi-zone modelling approach for its reasonable computation time and easy implementation(Foucquier, Robert, Suard, Stephan, and Jay, 2013).

Autodesk Simulation computational fluid dynamics (CFD) provides computational fluid dynamics and thermal simulation tools. The CFD design study environments with a solver to predict product performance, optimize designs, and validate product behavior before manufacturing, (Autodesk Incorporated, 2016). Tian, Han, Zuo, and Sohn, (2018),indicated state of data obtained in the CFD as Predicted Mean Vote (PMV), Percentage Persons Dissatisfaction (PPD), temperature, humidity and speed.Autodesk CFD Help (2016) states the predicted mean vote (PMV) is a way to characterize specific conditions in which an occupant will find the environment thermally acceptable. PMV is an index that predicts the mean value of votes of a large group of people on the seven-point thermal sensation as shown in Table 2.4 below:

Table 2-4: Predicted Mean Vote (PMV) seven-point of thermal sensation.

Value	sensation
+3	Hot
+2	Warm
+1	Slightly warm
0	Neutral
-1	Slightly cool
-2	Cool
-3	Cold

Source; Autodesk CFD Help (2016).

Autodesk CFD Help, (2016) states the percentage persons dissatisfied (PPD) is an index that establish a quantitative predication of the percentage of people that dissatisfied with the thermal conditions as determined from PMV.

2.7 Concept of HotelDesign.

A hotel is an establishment that provides accommodation and usually meals, entertainment and various personal services for public (Merriam-Webster, 2016). Furthermore, a hotel means an establishment held out by the proprietor as offering sleeping accommodation to any person presenting himself who appears able and willing to pay reasonable sum for the services and facilities provided and who is in a fit state to be received (Chan and Mackenzie, 2013). They further classified hotel as a commercial establishment providing accommodations, meals and other guest services.

2.7.1 Types of hotel.

Types of hotel can differ by location and wether the hotel is independent, part of a chain or affiliated with a brand such as associated luxury hotels international depending on wether you are travelling for business or leisure, or a combination of both (Johanna , 2019).Chan and Mackenzie, (2013) discussed hotels types as:

2.7.1.1 Airport hotels.

These hotels are designed specially to accommodate air travelers. They offer a mix of facilities and amenities

2.7.1.2 Highway hotels or motels.

They are designed for overnight stays for car travelers, often with very basic facilities. The rooms usually have direct access to an open parking lot. They are often smaller than most hotels. They are located on the outskirts of towns and cities.

2.7.1.3 All-suite hotels.

The guest rooms in these hotels are larger than normal hotel rooms, with separate areas for working, sleeping and relaxing. A living area or parlour is typically separated from the bedroom, and some properties offer a kitchen set-up in the rooms. The amenities and services can vary widely.

2.7.1.4 Boutique hotels.

Boutique hotels differentiate themselves from traditional hotels and motels by providing personalized accommodation and services/facilities. They are very different in their "look and feel" from traditional lodging properties. They are more intimate, and, perhaps, more luxurious, and stand out as an individual. The amenities vary greatly depending on what the hotel's environment and theme chosen.

2.7.1.5 Casino hotels.

They have gambling operations, which are the major revenue centers. They also provide live entertainment. A wide variety of luxury amenities, hotel services including fine and casual dining and shopping centers are typically available on site.

2.7.1.6 City Centre hotel.

These hotels are located within the heart of a city. The type may vary greatly from business, suites, residential, economy, mid-scale to luxury.

2.7.1.7 Conference or convention hotels.

These hotels can provide a large quantity of rooms. In addition to accommodation, they provide extensive meeting and function space for holding conventions. There are banquet areas within and around the hotel complex.

2.7.1.8 Extended stay hotels.

These properties cater to customers who stay for an extended period. They usually offer full kitchen facilities, shopping services, business services and limited housekeeping services.

2.7.1.9 Guest houses.

Guesthouses are similar to bed and breakfast inns. They range from low-budget rooms to luxury apartments. They tend to be like small hotels in bigger cities. Though the facilities are limited, most rooms are air-conditioned with in-suite shower and toilet.

2.7.1.10 Historic conversion hotels.

These properties have historic significance. They have been converted into lodging establishments with retention of their historic character.

2.7.1.11 Spa hotels.

They are located in resort-type settings or as part of city spa hotels. They provide accommodations, spa treatments, programs and cuisine. Programs offered vary widely. They may include relaxation/stress management, fitness, weight management, grief/life change and Pilates/yoga.

2.7.1.12 Resort hotels.

These hotels are located in picturesque, sometimes remote settings. Customers travel long distance to resorts. Usually, they tend to stay longer. Resorts typically provide a comprehensive array of recreational amenities, as well as a variety of food and beverage outlets ranging from informal to fine-dining restaurants.

2.7.2 Classification of hotels.

Hotel classification is the ranking of hotels, usually by using nomenclature such as stars (or diamonds), with one-star denoting basic facilities and standards of comfort and five stars denoting luxury in facilities and services. The purpose is to inform intending guests in advance, on what can be expected in order to reduce the gap between expected and experienced facilities and service delivery (World Tourism Organization, 2015).

Research Department of the Caribbean Tourism Organisation, (2002) reported the classification of hotels based on stars as;

2.7.2.1 One star hotels.

Hotels in this classification are likely to be small and independently owned, with a family atmosphere. The owner and family on an informal basis may provide services. There may be a limited range of facilities and meals may be simple.

2.7.2.2 Two star hotels.

In this classification, hotels will typically be small to medium sized and offer more extensive facilities than at the one-star level. Some business hotels come into the two-star classification and guests can expect comfortable, well-equipped, overnight accommodation, usually with an in-suite bath/shower room.

2.7.2.3 Three star hotels.

At this level, hotels are usually of a size to support higher staffing levels, and a significantly greater quality and range of facilities than at the lower star classifications. Reception and the other public rooms will be more spacious and the restaurant will normally also cater for non-residents.

2.7.2.4 Four star hotels.

Expectations at this level include a degree of luxury as well as quality in the furnishings, decoration and equipment, in every area of the hotel. Bedrooms will also usually offer more space than at the lower star levels, and well-designed, coordinated furnishings and decor. The in-suite bathrooms will have both bath and fixed shower.

There will be a high enough ratio of staff to guests to provide services like porterage, 24-hour room service, laundry and dry-cleaning. The restaurant will demonstrate a serious approach to its cuisine.

2.7.2.5 Five star hotels.

Here you should find spacious and luxurious accommodation throughout the hotel, matching the best international standards. Interior design should impress with its quality and attention to detail, comfort and elegance. Furnishings should be immaculate. Services should be formal, well supervised and flawless in attention to guests' needs, without being intrusive. The restaurant will demonstrate a high level of technical skill, producing dishes to the highest international standards.

2.8 Energy Consumption for Cooling in Hotels.

The hotel industry constitutes one of the most energy and resource-intensive branches of the tourist industry(Bohdanowicz, Churie-Kallhauge, Martinac and Rezachek, 2001). Industry studies show that heating, ventilation and air conditioning (HVAC) account for almost 50% of the total energy consumption in most hotel properties (Kapiki, 2012). CADDET, (1997), illustrated using chart shown in figure 2.9 below, the breakdown of energy consumption in a typical hotel.

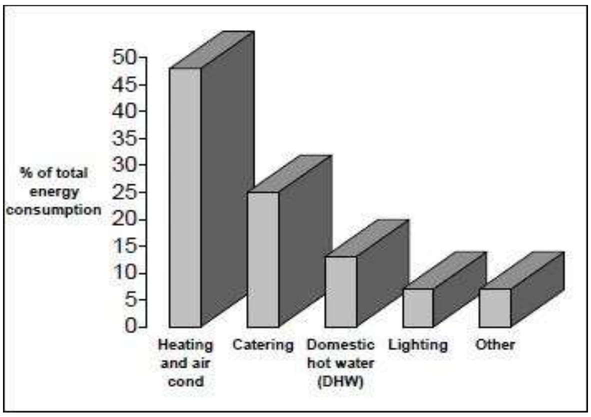


Figure 2-9: Breakdown of energy consumption in a typical hotel.

Source: CADDET, (1997).

Santamouris and Asimakopoulos (2001), indicated that air conditioning is associated with environmental problem (emission of greenhouse gasses in the atmosphere) and also economic problem (increase in cost of power).Hellomagazine, (2010) Highlighted some risk of too much air conditioning to the human body as; it has a drying effect on skin and mucous membranes. It adds to ambient noise, contributing to noise pollution. Air conditioning is associated with chronic rhinitis and pharyngitis, throat irritation and hoarseness. Air conditioning can exacerbate eye conditions such as conjunctivitis and blepharitis (eyelid disease (Rodriguez, 2013).

Ampatzi, Knight and Rhodes, (2008),claims that the energy efficiency of most hotel facilities are frequently low, and the resulting environmental impacts are typically greater than those caused by the excessive consumption of local/imported resources (e.g., water, food, electricity and fuels) as well as by emissions released to air, water and soil. The major part of this energy is produced by gas, coal and petroleum products, reducing the energy consumption would also contribute to decreasing greenhouse gas emissions, chiefly CO_2(Zhang, Joglekar and Verma, 2010). The tables 2.5 below showing the rate of energy efficiency in hotel buildings.

Table 2-5. Energy efficiency rating for large hotels.

Efficiency rating	**Good**	**Fair**	**Poor**	**Very poor**
Large hotels (more than 150 rooms) with air conditioning, laundry and indoor swimming pool				
Electricity (Kwh/sqm year)	<165	165-200	200-250	>250
Fuel (Kwh/sqm year)	<200	200-240	240-300	>300
Total (Kwh/sqm year)	<365	365-440	440-550	>550
Hotwater (kwh/sqm year)	<220	230-280	280-320	>320

Source: Zhang et al,(2010).

Table 2.6 below showing the number range of rooms that classifies a hotel to be ranked as a medium sized and its breakdown of energy efficiency in a medium sized hotel considering air conditioning of space, which is the main energy consumer in hotel facility, excluding the use of heating and laundry services.

Table 2-6: Energy efficiency rating in medium-sized hotels.

Efficiency rating	**Good**	**Fair**	**Poor**	**Very poor**
Medium sized hotels (50-150 rooms) without laundry and with heating and air conditioning, in some areas.				
Electricity (Kwh/sqm year)	<70	70-90	90-120	>120
Fuel (Kwh/sqm year)	<190	190-230	230-260	>260
Total (Kwh/sqm year)	260	260-320	320-380	>380
Hotwater (kwh/sqm year)	160	180-185	185-220	>220

Source: Zhang et al,(2010).

Table 2.7 below showing the number range of rooms that classifies a hotel to be ranked as a small sized hotel and the breakdown of energy efficiency in a small sized hotel considering air conditioning in some areas, excluding the use of heating and laundry services.

Table 2-7:Energy efficiency rating in small hotels.

Efficiency rating	**Good**	**Fair**	**Poor**	**Very poor**
Small hotels (4-50 rooms) without laundry, heating and air conditioning, in some areas.				
Electricity (Kwh/sqm year)	<60	60-80	80-100	>100
Fuel (Kwh/sqm year)	<180	180-210	210-240	>240
Total (Kwh/sqm year)	<240	240-290	290-340	>340
Total (Kwh/sqm year)	<120	120-140	140-160	>160

Source: Zhang et al,(2010).

2.9 Conclusion.

From literature, different strategies of shading device were fount out, which consisted of the external and the internal shading devices. The external shading device was identified as a more efficient strategy of reducing solar heat gain and it is dependent on orientation and the prevailing climate. The relationship between the shading device, thermal comfort and natural ventilation was identified and that different effects of the thermal comfort and ventilation would be observed by changing some variables. The variables of shading device include width, length of projection, color, material, angle of shading device, distance from wall, distance from each other etc.

Some strategies of cooling were also identified to be able to help in the proposed design of hotels. Classes of hotels were also identified and a summary of how hotel consume energy was found out as its highest energy consumption is as a result of cooling spaces which amounts to 50% of the energy in the building.

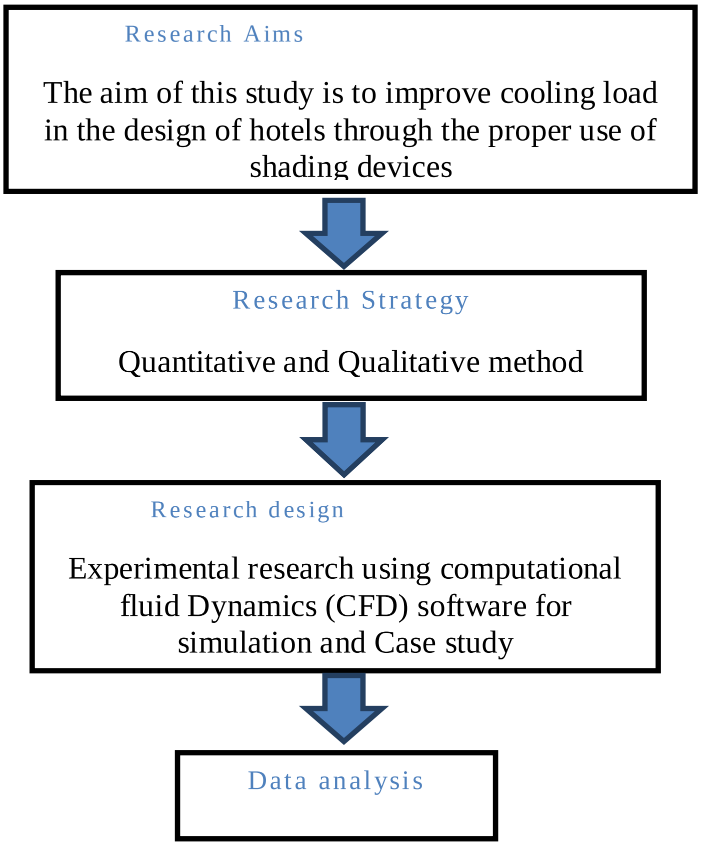
In conclusion, the research is wheeled into studying external shading devices and to test for variables identified to find out the most effective in cooling in hotel design in the area of study.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Introduction.

Rajaseker, Philominathan and Chinnathambi, (2013) Opined that, research is a logical and systematic search for new and useful information on a particular topic, hence it is to produce new output. The aim of this research is to evaluate the shading strategies and apply them to the design of hotel in a hot-dry climatic region particularly Bauchi state. This chapter provides information on how the research is to be conducted to achieve the set out aim, it also discusses the research design, the method of research taken, research design, data collection and instrument of data collection. Furthermore, this research would evaluate these strategies using case study and computer simulation to be able to apply more preferred strategies that would have great effect in the indoor temperature.



Source: Researcher, (2016).

3.2 Research Strategy

The research method adopted for this study is the combination of both the qualitative and quantitative approach in order to achieve the set out aim.

3.2.1 Qualitative research approach.

Qualitative research approaches are phenomenology, case study, ethnography, grounded theory, cultural studies. The purpose is to have an understanding, insight, contextualization and interpretation of the research. The data is to be in form of written documents from fieldwork, interviews, pictures, observations, objects, sketches, etc. (Castellan, 2010). Rajaseker et al, (2013), qualitative research is concerned with qualitative phenomenon involving quality. Some of the characteristics of qualitative research are;

i. It is non-numerical, descriptive, applies reasoning and uses words.
ii. Its aim is to get the meaning, feeling and describe the situation.
iii. Qualitative data cannot be graphed.
iv. It is exploratory.
v. It investigates the *why* and *how* of decision-making.

Research in such a situation is a function of the researchers' impression and insight; it usually uses techniques like in-depth interviews, focus group interviews, case study, and many other projective and observatory techniques, depending on the phenomenon under study (Kaplan and Maxwell, 2005).This method is used to investigate and gather data in the area of study that is used to create the scenarios in which the research variables are test.

3.2.2 Quantitative research approach.

Quantitative research approach is an experimental, quisi-experimental, single subject and descriptive, comparative, correlational, ex post factor. The purpose is generalizability, explanation, prediction. The data is to be in form of questionnaires, surveys, tests, etc. in the form of numbers and statistics (Castellan, 2010). Rajaseker et al, (2013), opined that, quantitative research is based on the measurement of quantity or amount. The result of this research is essentially a number or a set of numbers. It is characterized by;

i. It is numerical, non-descriptive, applies statistics or mathematics and uses numbers.
ii. It is an iterative process whereby evidence is evaluated.
iii. The results are often presented in tables and graphs.
iv. It is conclusive.
v. It investigates the *what, where* and *when* of decision-making.

This method is used to assess and observe the behavior of the variables tested in the scenario created from data obtained from the qualitative research method.Quantitative Research uses measurable data to formulate facts and uncover patterns in research(DeFranzo, 2011).

3.3 Research Design.

Research design is the structuring of investigation for the purpose of identifying variable and the relationship to one another (Asika, 2008). The research sets out to improve cooling efficiency in hot dry climate, which is based on anexperimental approach targeted at solving common but overlooked problem. Case study are carried out through purposive sampling to investigate passive cooling strategies adopted on some selected hotel building based on climatic region, typology, sizeand computer simulations used to achieve the set out aim. Once the experiment is well designed, the effect is likely lying in wait for variables could be measured and actively changes to observe the response(Wang, 2002).

3.3.1 Sampling method.

Sampling works with the objective to obtain accurate and reliable information about the universe with minimum of cost, time and energy and to set out the limits of accuracy of such estimates(Prabhat and Sakshi, 2015). The reason for a purposive sampling is to obtain samples that are peculiar to the area of study.This method is appropriate when the study places special emphasis upon the control of certain specific variables(Prabhat and Sakshi, 2015).Zhang etal, (2010), classified hotels into large , medium and small hotels, which would provide a criteria for case study selection base on scale, other criteria includes location (area of study), functional operation and ability to provide the information necessary to achieve the stated aim.

3.4 Dependent and Independent Variables.

Variable is a term frequently used in research projects. It is pertinent to define and identify the variables while designing quantitative research projects. Variables can be defined in terms of measurable factors through a process of operationalization. It will convert difficult concepts into easily understandable concepts, which then can be measured, empirically (Kaur, 2013).

3.4.1 Dependent variable.

These include:

i. Thermal comfort
ii. Natural ventilation.

3.4.2 Independent variables.

These include:

i. Angle of shading device.
ii. Positioning (distance from the wall).

3.5 Method of Data Collection.

The study being a mixed research strategy will employ the use case study, interview, and observations to obtain data from the fieldwork, which will give basis for the information needed to create a scenario for the computer simulation, which is the second means of data collection in order to achieve the set out aim of the study.

3.5.1 Visual survey.

The case study to this research would consider some cases within the area of study and this would involve observations, and assessment through the use of design checklist. However, to have a more comprehensive assessment of the selected cases in the research, some things have to be considered. The consideration may include;the type of shading device used, material of shading device, level of cooling of spaces, landscaping and orientation.

3.5.2 Instruments of data collection.

The instruments of data collections used in carrying out the research include sketchpad, measuring tape, thermo-hygrometer, camera, interview guide, note pad, computer software and checklist.

3.5.2.1 Digital Hygrometer

Thermo-hygrometer accurately takes humidity, temperature, dew point and wet bulb temperature inside of ducts and hard to reach areas. The push buttons allow the user to freeze the current reading or retrieve the minimum and maximum readings. It has an ambient temperature limit of zero (0) to 50°C (Dweyer, 2015).

Figure 3.1 below showing an example of a typical digital thermo-hygrometer, this instrument is used to collect the indoor temperature measurement of the room spaces during the researcher’s fieldwork.

Figure 3-1: Digital Hygrometer.
Source:Dweyer, (2015).

3.6 Data Analysis

Data analysis is a process by which the data is transformed into meaningful and useful information. For the purpose of this study, the descriptive and quantitative data analysis is used. The purpose of the quantitative data analysis is to be able to observe the responses and patterns following the changes in variables. The Computational Fluid Dynamics (CFD) is used as the simulation tool to obtain results indicating relationship of the shading device to indoor temperature. Moreover, data collected will be represented using tables, graphs and figures.

3.6.1 Computer simulation.

This deals with numerical and mathematical instrument of data analysis, which is the quantitative aspect of this research(Memon and Shaikh, 2017). This would evaluate cooling strategies, to specify which would drop the cooling load of the building to optimum result that would enhance cooling efficiency in hotel using the Computational Fluid Dynamics (CFD). The results from the analysis is represented using the following;

charts, graphs and percentage.Computer simulation software to be used is; Autodesk CFD. This determines the efficiency of natural ventilation through the percentage persons dissatisfied (PPD) and predicted mean vote (PMV).

3.6.1.1 Procedure of simulation.

There are steps and procedures to follow for simulation in the Autodesk CFD for natural ventilation and these include;

i. Step 1: model the based case model in Autodesk Revit and export the model as an ACIS (SAT) format for accessibility of the model by the Autodesk CFD as illustrated in figure 3.2below;

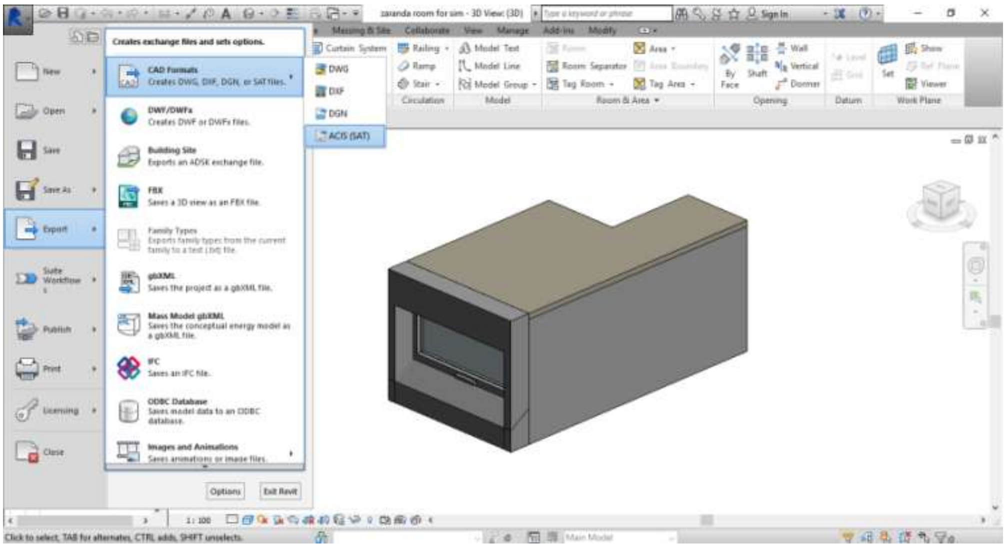


Figure 3-2: Exporting Autodesk Revit model as ACIS format.

Source: Autodesk Revit, (2015).

ii. Step 2: import the ACIS format into Autodesk simulation CFD. Then set scenario environment and assign materials. This step will include the input value of the building material as it is with their respective colors and u-values for more accuracy in the result of simulations.

Figure 3.3 below shows the image of material being added a model in a created scenario for simulating:

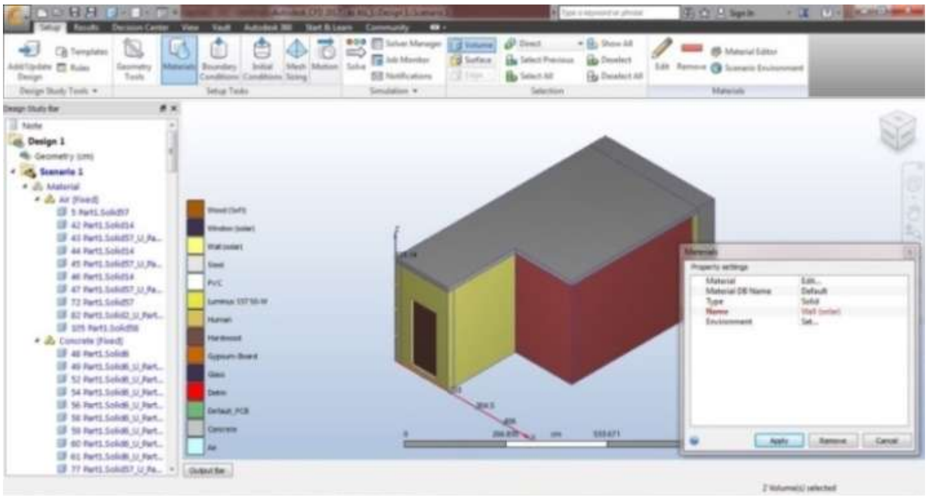


Figure 3-3: Assigning materials to based case model.

Source: Autodesk simulation CFD, (2015).

iii. Step 3: setting the boundary conditions on the model. The purpose of the boundary conditions is for the software to be able to differentiate between the indoor space and the outside environment. Figure 3.4 below showing a model with a set boundary condition.

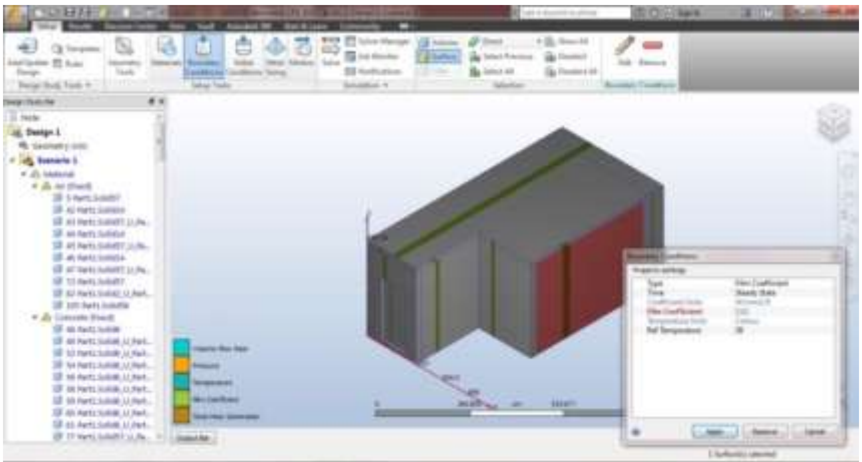


Figure 3-4: Assigning boundary conditions to model.

Source: Autodesk simulation CFD, (2015).

iv. Step 4:setting the auto meshing on model. This action helps in completely sealing the model in order to reduce any margin for error during the simulation as illustrated in figure 3.5 below:

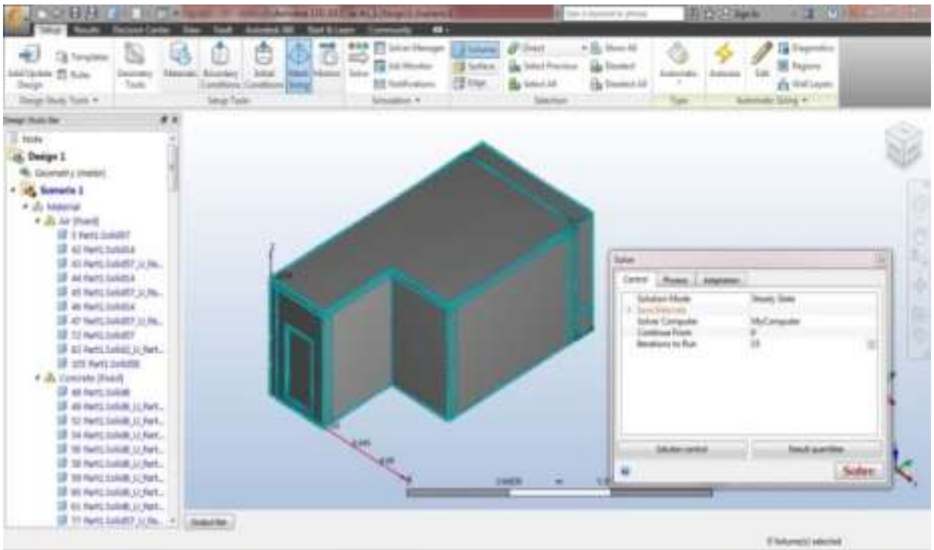


Figure 3-5: Auto meshing of model.

Source: Autodesk simulation CFD, (2015).

3.7 Conclusion

This chapter gave an overview of how the research is to be carried out by identifying a suitable method in approaching the study. The variables to be checked were stated hence creating a limited scope for the research and this was identified from a brief pilot study of the area of study. The chapter also discussed how data will be collected from the fieldwork and the instruments for data collection that would be used to create scenarios to be experimented.

CHAPTER FOUR

4.0 RESULTS AND FINDINGS.

4.1 introduction

This chapter presents the data collected from fieldwork. The aim of the case studies is to assess the current practice of hotel design, find out the extent to which thermal comfort have been considered, and later establish the relationship between shading device to indoor temperature and air velocity. Data collected from fieldwork includes; landscaping (both soft and hard landscape), site sketch, building materials, presence of shading devices, building description, natural ventilation, building orientation. All the data collected are used as input data to create a base case scenario for computer simulation.

4.2 Case Study One: Zaranda International Hotel, Bauchi.

The Zaranda international hotel Bauchi is located along the Jos-Bauchi road in the state metropolis, on longitude9°47'56.97"E and latitude 10°18'46.84"N. Plate I below showing the approach facade of the Zaranda international hotel Bauchi.

PlateI:Zaranda hotel, Bauchi.

Source; Researcher’s fieldwork, (2016).

4.2.1 Site planning of Zaranda hotel, Bauchi.

The site of the facility has been designed to support the main building. The site is landscaped properly with trees and shrubs to improve microclimate on site. The main building is accessed from the parking lot. The vehicular circulation on site was considerably designed while the pedestrian walkways are not defined on the site.

The facility has been oriented with its longer side along the east-west axis having minimal openings in this directions but the major window opening of this building are oriented to face the north and south directions in order to reduce heat gained by the building as shown in figure 4.1 below:

Figure 4-1:Site plan of Zaranda hotel, Bauchi.
Source: Google earth, (2016).

4.2.2 Structure and materials of Zaranda hotel, Bauchi.

The hotel facility is made of a structural system consisting of beams and columns. The walling materials of the hotel are made up of hollow blocks and concrete. The building has a form of window shading in which the windows are recessed to a distance 600mm and they are made of concrete.

The hotel rooms are classified according to their rate of luxury. The facility consists of 184 rooms, offices for administrative workers and halls. However, due to current renovation, 124 rooms are functional. Plate II below shows that the rooms are painted with a light colored matte paint, tiled with 600mm by 600mm (600x600mm) unglazed floor tiling with a 75mm skirting. The ceiling material are made of plaster of Paris (POP) Each room in the hotel consist of 1.5 horse power window air-condition unit which is operational at maximum capacity whenever the room has a guest

Plate II:Interior of a room in Zaranda hotel, Bauchi.

Source: Researcher's fieldwork, (2016).

The hotel also consists of six halls which are also air-conditioned with a combination of both split and standing air-condition units which 2.5 hpr and 5 tons respectively. Plate III below shows one of the halls, which is also tiled with 600x600mm floor tile with 75mm skirting. The ceiling materials of the hall are made up of perforated ceiling board.

Plate III:Interior space of a hall in Zaranda hotel, Bauchi.

Source: Researcher's fieldwork, (2016).

The facility is runned both on electricity by the Nigerian power company known as the Power Holding Company of Nigeria (PHCN) and also an alternative power supply (Generator) which runs on diesel.

In months with considerably high patronage of up to 55 percent, the hotel consumes at least ₦2 million naira on power generation/monthwith inconstant supply of power by the from the National Grid, the facility is billed to over ₦1.2 million while the alternative power supply cost ₦600,000 on diesel fuel. While other months with poor power supply, the cost of diesel needed to run the facility becomes well above ₦1.6 million while that of PHCN bill falls within the ranges of 300,000- 600,000 thousand naira.

4.2.3 Energy consumption of Zaranda hotel, Bauchi.

The energy consumption to be calculated in kilowatt-hour. The current tariff of power in Nigeria is ₦23.58 per 1KWH to convert currency into power consumption;

1KWH ⟶ ₦23.58

⟶ ₦2,000,000

For the purpose of this research, the highest estimated power consumption bill provided by the hotel was used to calculate the estimated energy consumption by the hotel facility using the current power tariff in Nigeria. The energy consumption of the facility for a month is 84,818 kWh/ month. The total consumption for a year is 1,017,812 kWh/m^2/year.

A checklist was used to assess some strategies for thermal comfort during case study using a scale factor of 5=Very good; 4= Good; 3= Moderate; 2= Poor; 1= Very pooras illustrated in the table4.1 below;

Table 4-1. A checklist to measure some variables from Zaranda hotel, Bauchi,

Variables	Description	Scale factor	Remark
Orientation	Positioning the building with respect to the sun path	4	The building was oriented with its openings facing the north and south axis.
Landscape	The presence of soft landscape on site in order to reduce in direct solar radiation	4	landscaped properly with trees and shrubs to improve microclimate on site
Shading device	The presence of shading device and its effectiveness in shading openings form direct sun light	3	There was an extrusion of 600mm from the wall at the window openings
Materials	The material use for shading device and wall	3	The shading device was made of concrete and hollow sand Crete blocks used for wall
Color	The color used (bright colors to repel solar radiation)	4	The color used on the façade was a bright color which would repel some level of solar radiation
Total		18	

Source: Researcher’s fieldwork, (2016).

4.3 Case Study Two: Jamil Guest Palace.

The Jamil guest palace hotel in Bauchi is located at government residential area of the state metropolis at longitude 9°48'12.29"E and latitude 10°17'54.23"N. Plate IV below showing the approach facade of the Jamil hotel Bauchi.

Plate IV: FaçadeJamil hotel, Bauchi

Source: Researcher’s field work, (2016).

4.3.1 Site planning of Jamil hotel, Bauchi.

The site which the hotel facility is located is not adequate for the facility as it is small. The site has no form of soft landscape. The entire site is landscaped with hard landscape of interlocking tiles. The hotel is accessed from the parking area. The vehicular circulation on site is not clearly defined while the pedestrian walkways are not even considered on site. The building is oriented on site in such a way that the building is exposed to a lot of solar radiation as shown in figure 4.2 below:

Figure 4-2:Site plan of Jamil hotel, Bauchi.

Source: Google earth, (2016).

4.3.2 Structure and materials of Jamil hotel, Bauchi.

The hotel facility consists of 55 rooms of different rate, level of affordability and level of comfort. The structural system of this facility is the basic beams and columns system. The walling materials of the facility are made up of sand crete hollow blocks and concrete. The exterior wall painting made of text coat paint while the interior painting of the facility is done with a light cream-colored matte paint. The ceiling material of the hotel is made up of the popular ceiling material known as the POP ceiling material as seen in Plate V below:

Plate V:Interior of a room in Jamil hotel, Bauchi.

Source: Researcher's fieldwork, (2016).

The windows are 1200x1200mm single glazed sliding windows with aluminum frame, the windows and walls have no any form of shading, hence exposing them to high level of both direct and indirect solar radiation as shown in Plate VI below:

Plate VI: Jamil hotel, Bauchi

Source: Researcher’s fieldwork, (2016).

Plate VII below shows the flooring material of the facility, which is made up of 300x300mm unglazed floor tile with 75mm skirting of the same material

Plate VII: Interior of a room in Jamil hotel showing floor tiles.

Source: Researcher’s fieldwork, (2016).

Each of the rooms in this facility is equipped with split air-conditioning system with a capacity of 240 volts (v). The facility is powered both by the national Grid and by the alternative power supply (generator).

A checklist was used to assess some strategies for thermal comfort during case study using a scale factor of 5=Very good; 4= Good; 3= Moderate; 2= Poor; 1= Very poor as illustrated in the table 4.2 below;

Table 4-2;A checklist to measure some variables from Jamil hotel, Bauchi

Variables	Description	Scale factor	Remark
Orientation	Positioning the building with respect to the sun path	2	The building is oriented such that a lots of its openings are exposed to solar radiation
Landscape	The presence of soft landscape on site in order to reduce in direct solar radiation	1	Hard landscape was used on the site
Shading device	The presence of shading device and its effectiveness in shading openings form direct sun light	1	There are no shading devices at the openings
Materials	The material use for shading device and wall	2	Hollow blocks used for walls.
Color	The color used (bright colors to repel solar radiation)	2	The color on the façade is not bright enough to repel solar radiation
Total		8	

Source: Researcher’s fieldwork, (2016).

4.4 Case Study Three: Fariah Suites.

The Fariah Suites hotel in Bauchi is located at state government avenue in the residential area of the state metropolis at longitude 9°48'38.90"E and latitude 10°18'35.27"N.Plate VIII below showing the approach facade of the Fariah suite, Bauchi.

Plate VIII: Façade Fariah suites, Bauchi.

Source: Researcher's fieldwork, (2016).

4.4.1 Site planning of Fariah suites, Bauchi.

The site which the hotel is on located is adequate for the facility the site has little form of soft landscape which consist of shrubs. The entire site is landscaped with hard landscape of interlocking tiles. The hotel is accessed from the parking area. The vehicular circulation on site is not clearly defined while the pedestrian walkways are not even considered on site. The building is oriented on site in such a way that the window openings are not to exposed to direct solar radiation.

Figure 4.3 below showing the Arial view of the site plan of the Fariah suite hotel Bauchi. Indicating the red shaded area as the buildup area of the hotel

Figure 4-3: Site plan of Fariah Suites, Bauchi.

Source: Google earth, (2016).

4.4.2 Structure and materials of Fariah suites, Bauchi.

The hotel facility consists of different rooms with different rate of level of affordability and level of comfort. The structural system of this facility is the basic beams and columns system. The walling materials of the facility are made up of sand Crete hollow blocks and concrete. The exterior wall painting is done with the text coat paint while the interior painting of the facility is done with a light colored matte paint. Plate IX below showing the ceiling material of the hotel is made up of the popular ceiling material known as the POP ceiling material.

Plate IX:Interior of a room in Fariah hotel, Bauchi.

Source: Researcher's fieldwork, (2016).

The windows are 1200x1200mm single glazed sliding windows with aluminum frame, the windows and walls have no any form of shading, hence exposing them to high level of both direct and indirect solar radiation.

A checklist was used to assess some strategies for thermal comfort during case study using a scale factor of 5=Very good; 4= Good; 3= Moderate; 2= Poor; 1= Very poor as illustrated in the table 4.3 below;

Table 4-3; A checklist to measure some variables from Fariah hotel, Bauchi.

Variables	Description	Scale factor	Remark
Orientation	Positioning the building with respect to the sun path	2	The building is positioned in a way that its longer side is exposed to solar radiation.
Landscape	The presence of soft landscape on site in order to reduce in direct solar radiation	2	The soft landscape is not adequate enough to reduce solar radiation
Shading device	The presence of shading device and its effectiveness in shading openings form direct sun light	3	The windows were designed not to face solar radiation
Materials	The material use for shading device and wall	3	Concrete was used for the shading and hollow blocks for the wall
Color	The color used (bright colors to repel solar radiation)	4	The color is bright to repel solar radiation
Total		14	

Source: Researcher's fieldwork, (2016).

4.5 Summaryof Case Study

The summary of the evaluation of the three local case studies conducted, considering some design requirements and elements, which would improve energy efficiency through cooling. Results from the checklist, shows zaranda hotel bauchi ranking higher as some approach of cooling were included in the design of the building. It had the best orientations amongst the three local case studies conducted. It possesses shading device of 600mm projection at window openings. From the case study the material used for shading device in hotels are made of concrete.

In light of the result and observations made from the local case studies, considering some design requirements, the zaranda hotel is selected for the computer simulations.

Varying the angle of the shading device, its distance from wall, thickness of the shading device, its depth, its distance from each other, its material andcolorof shading device can affect its ability to shade the building from solar radiation and extension improving natural cooling of the building.

4.6 Conclusion

In chapter discussed the case studies, assessed them and results from the data collected from the case studies gave rise to the background information for the experiments to be carried out using computer simulations which tests for different variables.

CHAPTER FIVE

5.0 DISCUSIONSANDDATA ANALYSIS

5.1 Introduction.

This chapter discusses the findings and observations from the case studies and assesses the variables of shading device with the aid of a computer simulation tool to be able to as the research questions.

5.2 Assessment of Current Practices.

For the purpose of this study, three case studies were conducted within the area study, this section discusses the result, and observation of the case study and this includes:

i. The window opening of rooms in the Zaranda hotel in Plate X shows the practice of shading device in the hotel. The hotel was designed in such a way that the windows are recessed and the extrusion serves as a projection of shading device, made up of concrete material with a depth of 600mm.

Plate X: Recessed windows of Zaranda hotel, Bauchi.

Source: Researcher’s fieldwork, (2016).

ii. The Jamil hotel design did not take into consideration any form of external shading as the building envelope shown in Plate XIexposes the building to high solar radiation, which will increase the heat gain into the building. It was also observed that the building materials used in the construction are thermally responsive.

Plate XI: Exposed windows and walls of the Jamil hotel, Bauchi.

Source: Researcher's fieldwork, (2016).

iii. The Fariah hotel design has no external shading device;however, the window openings of the hotel room are place in such a way that they are not exposed to direct solar radiation. However, the lack of external shading device might not optimize the comfort in indoor space. The building envelope was covered with tiles to reduce the heat gain is as shown Plate XII

Plate XII: Window exposure of the Fariah hotel, Bauchi.

Source: Researcher's fieldwork, (2016).

5.3 Assessment for Specific Shading Device Strategy to Improve Cooling In Hotels.

The aim of the research is to explore for a more suitable shading device strategy for cooling to be incorporated into the design of hotels in the area of study. In addition, this section will evaluate different strategies by varying the shading device variables through the computer simulation.

5.3.1 Simulation.

The existing base case model (Zaranda international hotel, Bauchi) is compared with a proposed case model of proffered shading device.The simulation is going to focus on varying the angles of shading device and the distances from the wall while adopting some variables from the case study such as the materials of the shading device (concrete) and the depth of the shading device (600mm).The model of the selected case study done with Autodesk Revit 2015 as shown in figure 5.1 below;

Figure 5-1: Model of Zaranda Hotel Bauchi.
Source: Autodesk Revit Architecture, (2015).

Selected floor plan of the case study hotel was modeled with Autodesk Revit architecture as seen in Figure 5.2 and Figure 5.3. This serves as the bases of the simulation.

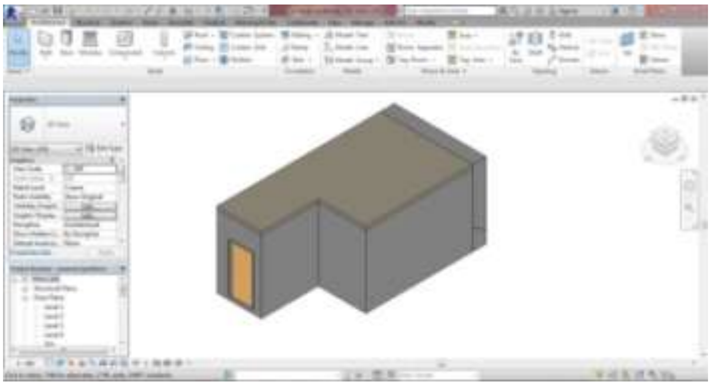


Figure 5-2: Based case model of a room in Zaranda hotel for simulation.
Source: Autodesk Revit Architecture, (2015).

Figure 5.3 below shows the interior arrangement of a roomspace for the based case model, the special arrangement of a typical hotel room.

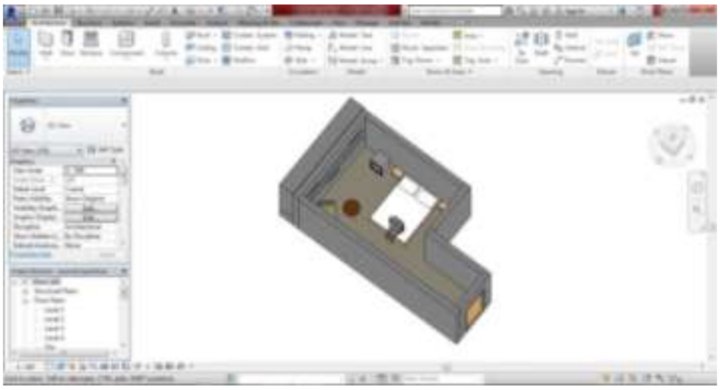


Figure 5-3: Based case modelof a room in Zaranda hotel for simulation.
Source: Autodesk Revit Architecture, (2015).

5.3.1.1 Assessing Natural Ventilation Using Percentage Persons Dissatisfaction (PPD) and Predicted Mean Vote (PMV) For Based Case Model

The hotel room space of the base case model is located on the sixth (6^{th}) floor of the building. In addition, it will be assessed using PPD and PMV as indicators. The data to be used for Autodesk Simulation CFD include; material selection, boundary conditions and scenario environment shown in Table 5.1

Table 5-1: Data input for based case model.

	inputs	variables	notes
1	Materials selected.	Human, concrete, brick, air, glass and wood.	
2	Boundary conditions	Air velocity, pressure, film coefficient, total heat generation and temperature.	*Assign the air inlet and outlet (volume flow rate and pressure) respectively. *Film coefficient represents U-values of materials (W/m^2-K). Wall (concrete block 230mm) 3.11, Window (glass) Single panel 1.22, Door (wood) 0.64. *Metabolic rate of a human seated is 60W
3	Scenario environment	Summer condition	Indoor air temperature 31^{o}c and outside air temperature 39^{o}c

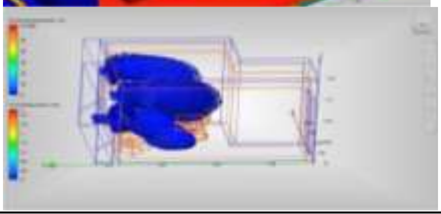
Source: Author, (2017).

The table above shows the data collected from case study that is used as input data for the simulation software to be able to run successfully.

Step 3: Run simulation and prepare results

At the end of this step, result from the simulation will be graphically represented in table 5.2 and this assists the user of the software to visuallyobserve the effects of the changes made the model and variables of shading device to the indoor temperature and its corresponding effect on occupant within the space.

Table 5-2:Results of base case simulation.

S/N	Angle of shading	Distance from the wall	indicators	Results
1		0	PMV +2.4 (warm)	
			PPD 78%	
			Air Flow	

Source: Author, (2017).

The temperature distribution graph shows acrosssection of the average temperature reading in the room space of the based case model as shown in figure 5.4 below:

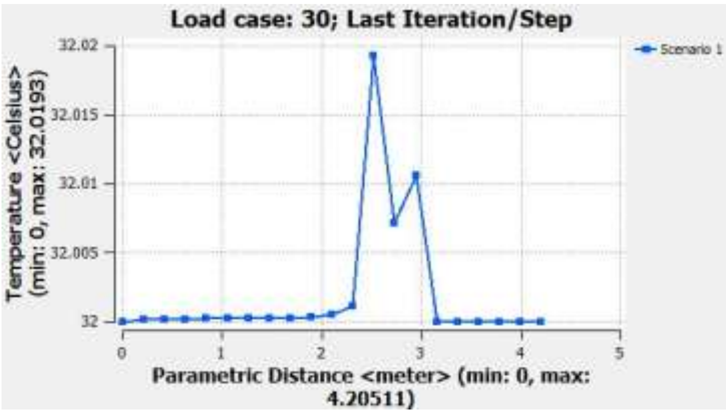


Figure 5-4: Temperature graph of the based case.

Source: Autodesk Simulation CFD, (2015).

The result from the simulated based case model indicated a level of discomfort in the space with a PMV of +2.4 which is warm and a PPD of 78%, with the PMV given as +2.4 (warm) and an average temperature of 32.01°C which gives rise to the coolthe space to achieve comfort, thereby leading to increase in cooling load.

5.3.1.2 Simulation using Ecotect

The same-based case model of thehotel was simulated using the Autodesk Ecotect to support the result gotten from the CFD simulation. This was done in order to compare result for more accuracy of data.

5.3.1.3 Procedure of simulation.

The steps in running the simulations in Ecotect are as follows;

i. Step 1: import the based case model into Ecotect with ASCII format and place model at the height and orientation as the existing building.

ii. Step 2: apply materials to the model as it is from case studies and assign the schedule hours of operation.

iii. Step 3: input the climate data file into Ecotect and run simulation as shown figure 5.5 below:

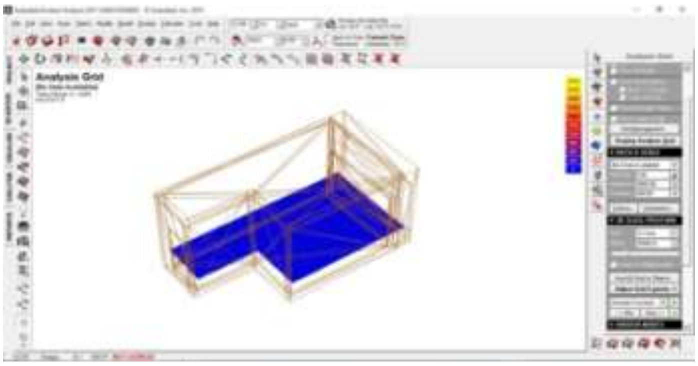


Figure 5-5: Based case simulation using Ecotect.

Source: Autodesk Ecotect, (2011).

From the analysis, the based case model records an average temperature distribution of 31.91°C.

5.3.1.4 Assessing Natural Ventilation Using PPD and PMV for Different Angles and Distances of Shading Device.

Different angle and distance from wall of the shading device was integrated to the based case model for the simulations. The input data for the simulation are shown in the table 5.3 below:

Table 5-3: Input data for creating scenarios for simulation.

	inputs	**variables**	**notes**
1	Materials selected.	Human, concrete, brick, air, glass and wood.	
2	Boundary conditions	Air velocity, pressure, film coefficient, total heat generation and temperature.	*Assign the air inlet and outlet (volume flow rate and pressure) respectively. *Film coefficient represents U-values of materials (W/m^2-K). Wall (concrete block 230mm) 3.11, Window (glass) Single panel 1.22, Door (wood) 0.64. *Metabolic rate of a human seated is 60W
3	Scenario environment	Summer condition	Indoor air temperature 31^oc and outside air temperature 39^oc

Source: Author, (2017).

5.3.1.5 Representation of simulated result.

The simulation results of the angle of shading devices and their respective distances from the wall will be represented using charts as shown below.

i. The simulation result of shading device strategy with no distance from the wall isrepresented in figure5.6 and figure 5.7 respectively.

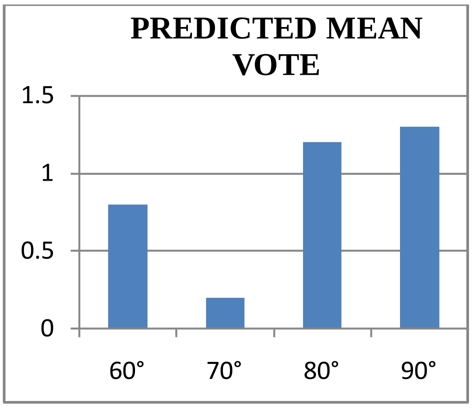


Figure 5-6: Predicted Mean Vote (PMV) of angles of shading device with no distance from the wall.

Source: Autodesk Simulation CFD.

Figure 5.6 above shows the PMV of the shading device with no distance from the wall, have the 90° angle with +1.8(warm) and the 70° angle with +0.2(slightly neutral) and provides comfort. While the 60° with +0.8(slightly warm) and 80° angle with +1.2 (warm). In addition, the shading device placed at angle 70° attached to the wall proves to be more comfortable than the other angle of shading devices.

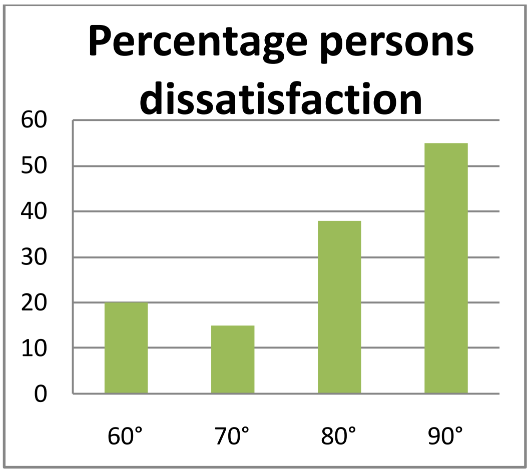


Figure 5-7:Percentage Persons Dissatisfaction (PPD) of angles of shading device with no distance from the wall.

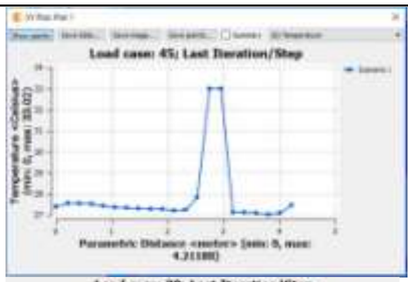
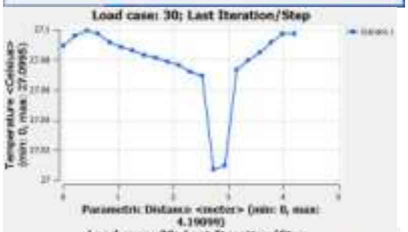
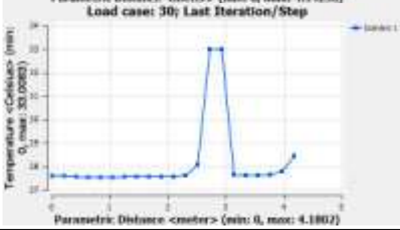
Source: Autodesk Simulation CFD.

Figure 5.7 above shows the percentage to which the person is dissatisfied in the space. The 90° has the highest percentage of 55% to which the occupant would be dissatisfied. The

70° has the lowest percentage of 15% dissatisfaction, while the 60° with 20% and 80° with 38%. In addition, the occupant in space feels more comfortable in the simulation result with angle 70° with no distance from the wall.

Table 5.4 below shows the graphical representation of average temperature distribution across simulated from space, with an exterior shading device attached to the wall.

Table 5-4: Results of temperature from the simulation.

	Angle of shading device in degree(°)	Distance from wall	Temperature graph	Average temperature in Celsius (°C)
1	60	0		30.2
2	70	0		27.01
3	80	0		30.1
4	90	0		30.4

Source: Author, (2017).

ii. The simulation results of shading device strategy placed at 200mm distance from the wall are represented in figure5.8 and figure 5.9 respectively.

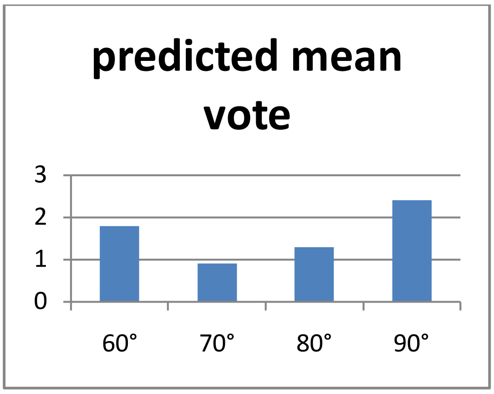


Figure 5-8:Predicted Mean Vote (PMV) of angles of shading device with 200mm distance from the wall.

Source: Autodesk Simulation CFD.

Figure 5.8 above shows the PMV of the shading device with 200mm distance from the wall, have the 90° angle with +2.4(warm) and the 70° angle with +0.9(slightly warm), while the 60° with +1.3 (warm) and 80° angle with +1.3 (warm). The 70° shading device place at 200mm from the wall is comfortable however, the 70° shading device attached to the wall is more comfortable.

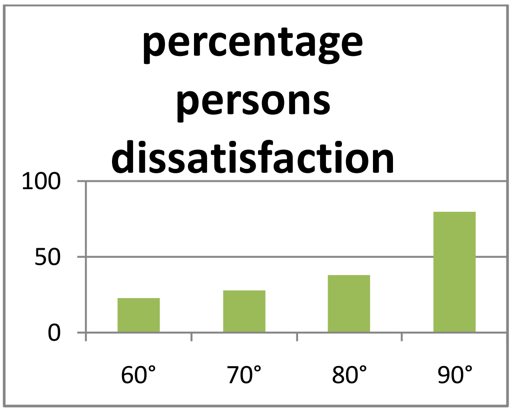


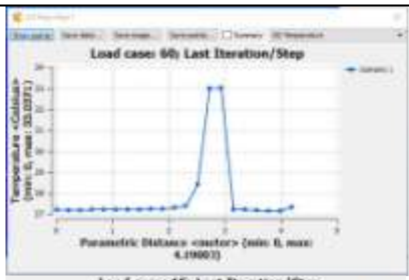
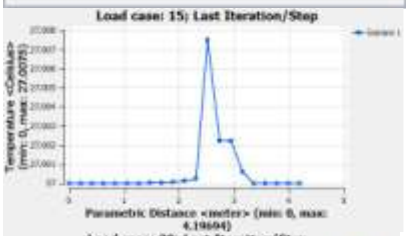
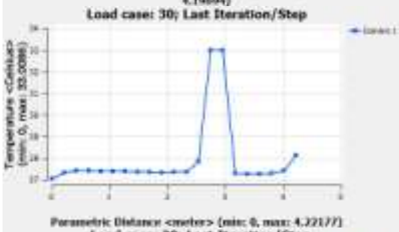
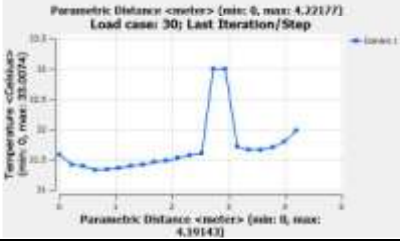
Figure 5-9: Percentage Persons Dissatisfaction(PPD) of angles of shading device with 200mm distance from the wall.

Source: Autodesk Simulation CFD

Figure 5.9 above shows the percentage to which the person is dissatisfied. The 90° has the highest percentage of 80% to which the occupant would be dissatisfied. The 60° has the lowest percentage of 23% dissatisfaction, while the 70° with 23% and 80° with 38%. In this sets of simulation, the 70º shading device placed at 200mm from the wall provides more satisfaction. However, the 70° shading device attached to the wall provides a more suitable satisfaction to the occupant.

Table 5.5 below shows the graphical representation of average temperature distribution across simulated from space, with an exterior shading device place at a distance of 200mm from the wall.

Table 5-5: Results of temperature from the simulation.

	Angle of shading device in degree(°)	Distance from wall	Temperature graph	Average temperature in Celsius (℃)
1	60	200		30.05
2	70	200		27.05
3	80	200		30.0
4	90	200		32.0

Source: Author, (2017).

iii. The simulation results of shading device strategy placed at 300mm distance from the wall are represented in figure 5.10 and figure 5.11 respectively

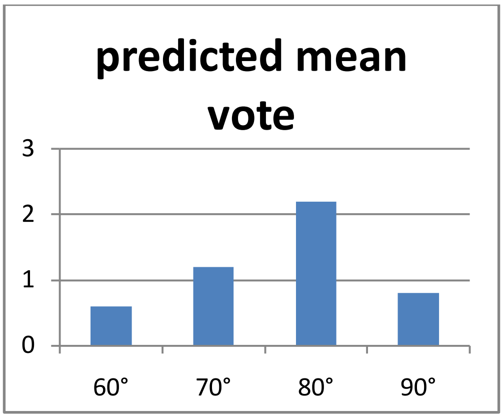


Figure 5-10:Predicted Mean Vote (PMV) of angles of shading device with 300mm distance from the wall.

Source: Autodesk Simulation CFD.

Figure 5.10 above shows the PMV of the shading device with no distance from the wall, have the 80° angle with +2.2(warm) and the 60° angle with +0.6(slightly neutral), while the 70° with +1.2 (warm) and 90° angle with +0.9 (slightly warm). In this set of simulation, the 60° shading device with 300mm distance from the wall proves to be more thermally comfortable. However, the 70° shading attached to the wall provides more comfort.

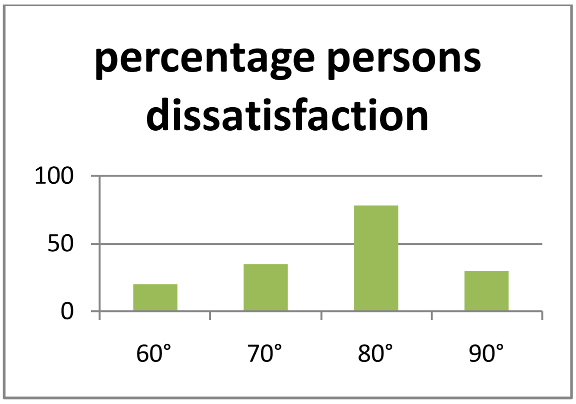


Figure 5-11:Percentage Persons Dissatisfaction (PPD) of angles of shading device with 300mm distance from the wall.

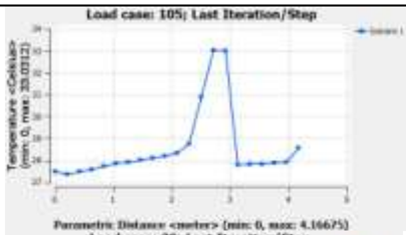
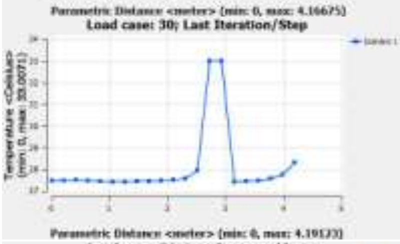
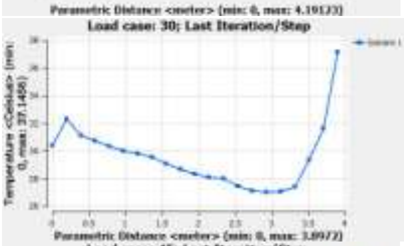
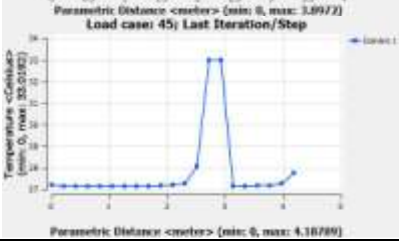
Source: Autodesk Simulation CFD

Figure 5.11 above shows the percentage to which the person is dissatisfied in the space. The 80° has the highest percentage of 78% to which the occupant would be dissatisfied.

The 60° has the lowest percentage of 20% dissatisfaction, while the 70° with 35% and 90° with 30%. Occupant in this set of simulation is more comfortable within the space with exterior shading device at angle 60 ° placed at 300mm from the wall.

Table 5.6 below shows the graphical representation of average temperature distribution across simulated from space, with an exterior shading device place at a distance of 300mm from the wall.

Table 5-6: Results of temperature from the simulation.

	Angle of shading device in degree(°)	Distance from wall	Temperature graph	Average temperature in Celsius (℃)
1	60	300		30.1
2	70	300		30.0
3	80	300		32.0
4	90	300		30.01

Source: Author, (2017).

iv. The simulation results of shading device strategy placed at 400mm distance from the wall are represented in figure 5.12 and figure 5.13 respectively

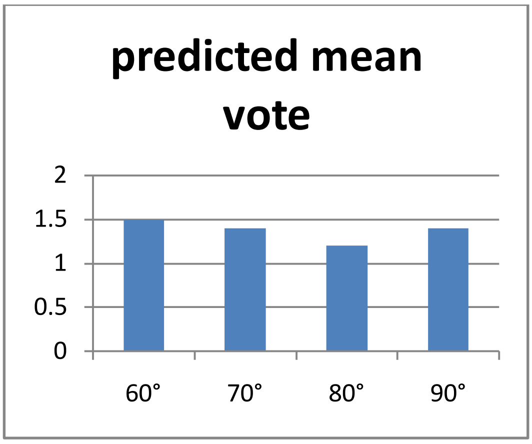


Figure 5-12:Predicted Mean Vote (PMV) of angles of shading device with 400mm distance from the wall.

Source: Autodesk Simulation CFD.

Figure 5.12 above shows the PMV of the shading device with no distance from the wall, have the 90° angle with +1.5(warm) and the 80° angle with +1.2(warm), while the 60° with +1.4 (warm) and 70° angle with +1.4 (slightly warm). In this set of simulation, the 80º shading device with 400mm distance from the wall proves to be more thermally comfortable. However, the 70° shading attached to the wall provides more comfort

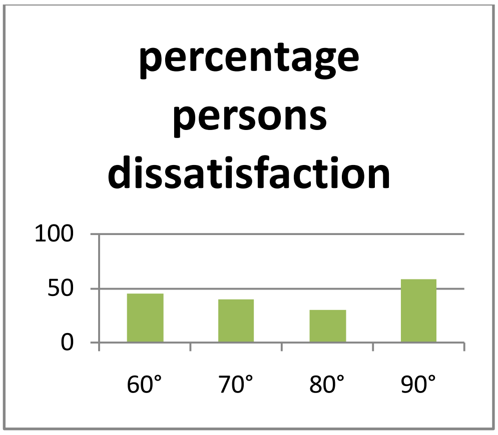


Figure 5-13:Percentage Persons Dissatisfaction (PPD) of angles of shading device with 400mm distance from the wall.

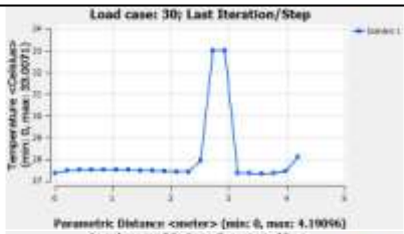
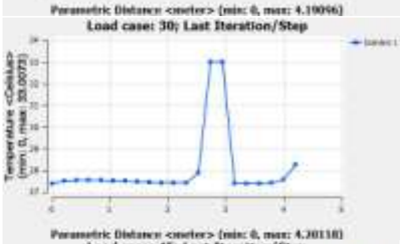
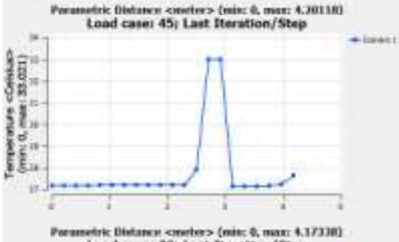
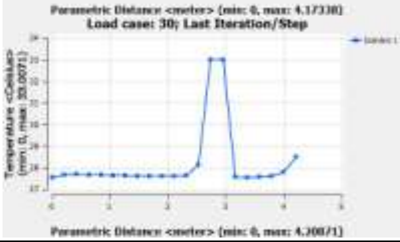
Source: Autodesk Simulation CFD.

Figure 5.13 above shows percentage to which the person is dissatisfied in the space. The 90° has the highest percentage of 58% to which the occupant would be dissatisfied. The

80° has the lowest percentage of 30% dissatisfaction, while the 60° with45% and 70° with 40%.Occupant in this set of simulation is more comfortable within the space with exterior shading device at angle 80 ° placed at 400mm from the wall.

Table 5.7 below shows the graphical representation of average temperature distribution across simulated from space, with an exterior shading device place at a distance of 400mm from the wall.

Table 5-7: Results of temperature from the simulation.

	Angle of shading device in degree(°)	Distance from wall	Temperature graph	Average temperature in Celsius (℃)
1	60	400		30.3
2	70	400		30.5
3	80	400		30.1
4	90	400		30.3

Source: Author, (2017).

See appendices I, II, III and IV forgraphical representation of simulation results, which shows the PMV, PPD and airflow of the different shading device strategy.

5.4 Summary from Simulations

The results of the simulations are summarized in tabular format asshown in table 5.8 below;

Table 5-8: Summary of the simulations result.

	Angle of shading device in degrees	Distance from the wall in (mm)	Indicators		Average Temperature **(°C)**
			PMV	PPD (%)	
1	60	0	+0.8 (slightly warm)	20	30.2
		200	+1.3 (slightly warm)	23	30.05
		300	+0.6 (slightly neutral)	20	30.1
		400	+1.5 (slightly warm)	45	30.3
2	70	0	+0.2 (slightly neutral)	15	27.01
		200	+0.9 (slightly warm)	28	27.05
		300	+1.2 (slightly warm)	35	30.0
		400	+1.4 (slightly warm)	40	30.5
3	80	0	+1.2 (slightly warm)	38	30.1
		200	+1.3 (slightly warm)	38	30.0
		300	+2.2 (warm)	78	32.0
		400	+1.2 (slightly warm)	30	30.1
4	90	0	+1.8 (slightly warm)	55	30.4
		200	+2.4 (warm)	80	32.0
		300	+0.8 (slightly warm)	30	30.01
		400	+1.4 (slightly warm)	58	30.3

Source: Author, (2017).

From table 5.8 above, the simulation result of the angle 70°(0mm) shading device has provided a more suitable condition for the occupant of the space, having a PMV of +0.2 (slightly neutral) and a PPD of 15% which is quite satisfactory.it also indicates an increase in air flow into space, with an average temperature of 27.01°C. While the 80°(300mm) and

90°(200mm) are recorded as dissatisfactory having PMV and PPD of +2.2(warm), 78% and +2.4(warm), 80% respectively.

The temperature difference from the based case model that is 32.01℃ and the most suitable shading device strategy of 27.1℃ is 5°C. The temperature reduction in percentage is:

$percentage\ reduction = \frac{difference\ \ in\ temperature}{original\ \ temperature} * 100\%$This is 15.6%

5.5 Assessment of Identifies Shading Device with Building Form in Hot Dry Climate.

According to Maleki (2011), one of the most effective ways of reducing cooling load and achieving energy efficiency is by ensuring that solar heat is not build up in the building. Terry, Palmer and Cooper, (2012),opined that building forms with more surface area gain heat and lose heat much more quickly than those with less surface area.

For the purpose of this study, the research will not test for building forms, however it will consider researches carried out on building forms in the hot dry climate and use to assess the specify shading device on the most suitable identified building form by other researchers in the hot dry climate.

According to European Union (2013),cylindrical building forms have lower surface area to volume ratio, which will neither gain nor loss heat easily. Hence, a good building form to adopt in hot climatic region. Gatta, (2017), in his study on “Evaluation of Architectural Forms For Improving Energy Efficiency In Shopping Mall Design, Abuja” tested for different building forms in hot dry climate and found out that the cylindrical building has lower rate of energy consumption through cooling. In addition, he went on to recommend a cylindrical building form as a more suitable building form to enhance energy efficiency as shown in Figure 5.14 below:

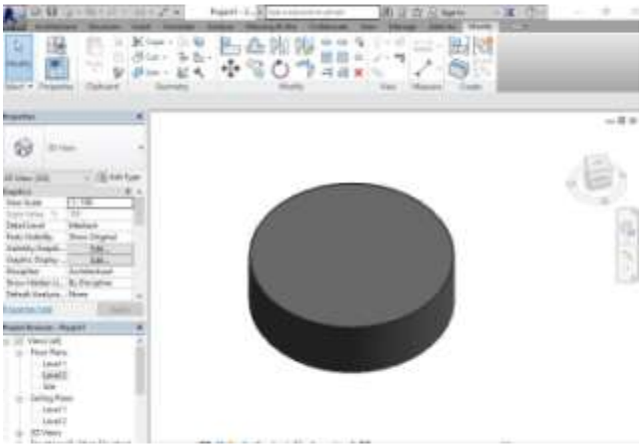


Figure 5-14: Cylindrical building form.

Source: Autodesk Revit Architecture, (2016).

For the purpose of this study, the cylindrical building is segment into facing the different orientations, with the shaded area as selected portion for testing as shown in figure 5.15 below:

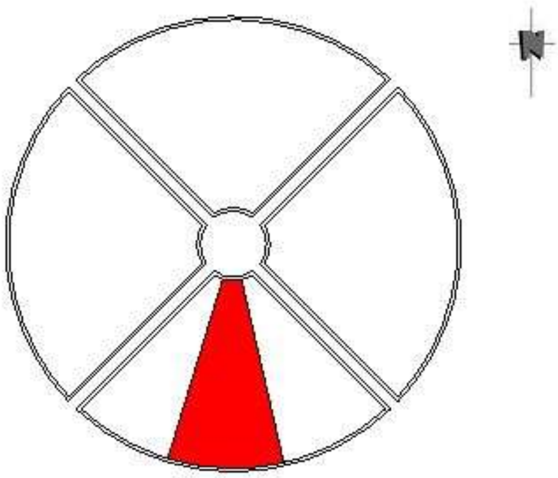


Figure 5-15: Segmented building form.

Source: Autodesk Revit Architecture, (2016).

Figure 5.16 below show the picture of the room space to be tested as base case for the cylindrical building form without the preferred shading device strategy.

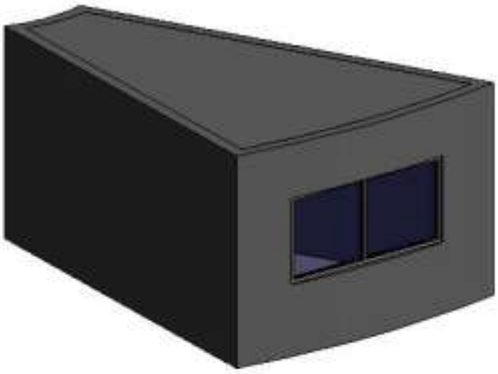


Figure 5-16: Segmented space of the cylindrical building form.
Source: Autodesk Revit Architecture, (2016).

Figure 5.17 below shows the room space, whichis simulated as base case for the cylindrical building form without the preferred shading device strategy, using the Ecotect simulation tool.

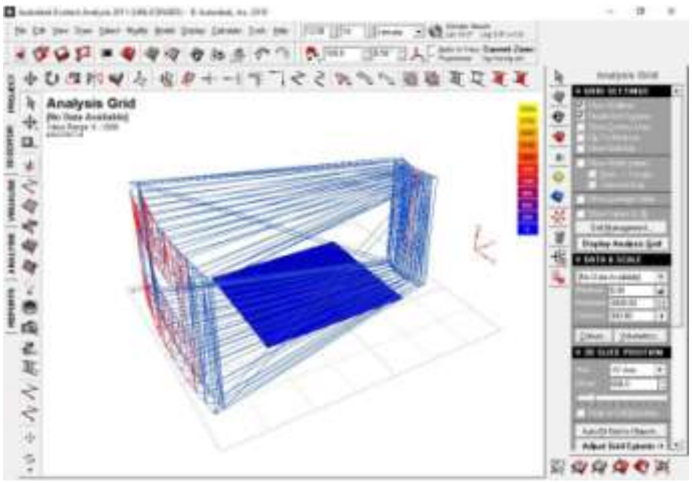


Figure 5-17: Room simulation without shading device using Ecotect.
Source: Autodesk Ecotect, (2011).

From the analysis, the model records an average temperature distribution of 27.9℃.

Figure 5.18 below shows a room space from the cylindrical building form with which the angle 70º shading device has been incorporated.

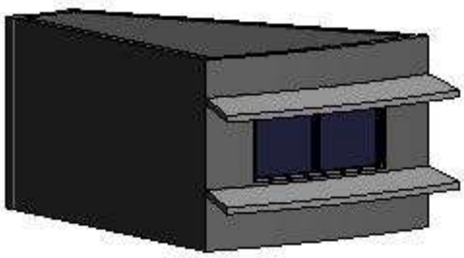


Figure 5-18:Model with shading device at window opening.

Source: Autodesk Revit Architecture, (2016).

Figure 5.19 below shows the segment of room space from a cylindrical building form with angle 70° shading device attached to the wall at window opening, which is simulated using the Ecotect simulation tool.

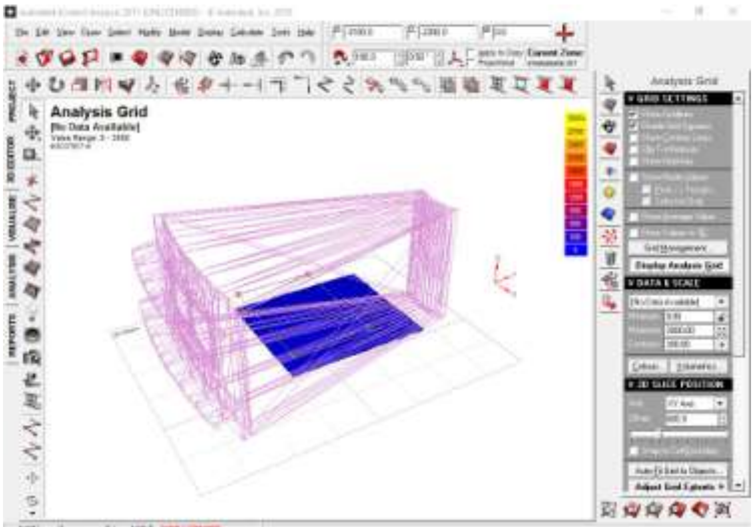


Figure 5-19: Room simulation with shading device using Ecotect.

Source: Autodesk Ecotect, (2011).

From the analysis, the model records an average temperature distribution of 26.30°C.

5.6 Conclusion.

The result from each variable gave different level of thermal comfort of the occupant in the space and shows the amount of natural ventilation getting into space the space, with its individual temperature distribution indicating a direct relationship between shading device with natural ventilation and temperature.

In conclusion, the most suitable shading device for the area of study was identified and the shading device for worse conditions were identified and discouraged.

CHAPTER SIX

6.0 DESIGN REPORT.

6.1 Introduction.

This chapter gives a preliminary insight to the site conditions of the proposed site on which is to be designed on. The chapter gives an overview of the conditions on site. This conditionincludes site climatic condition, the site topography, and vegetation on site.The chapter also gives a summary of the architectural design of a proposed five star hotel in Bauchi. With overviews on some efficient strategies for a more sustainable design in the construction, building material, building form and orientation, shading device, landscape elements and fire safety measures.

6.2 Study Area.

Bauchi is located is the northeastern part of Nigeria at latitude 10º 17'N and longitude 9º 49'E. High temperatures and low humidity characterize the climate in the dry season. The diurnal temperature varies from an average daily maximum of 31.6ºC to a daily minimum of 13.1ºC.The mean relative humidity is highest in August (66.5%) and lowest in February (16.5%). The mean annual rainfall ranges between 800-900mm per annum in the southern part and only 700mm per annum in the extreme north. The dry season occurs between September and May, while the rainy season is between May and September. The hottest month in Bauchi is April with 40.5ºC, while the coldest months are December and January, with 6.11ºC and 7.22ºC respectively (Akande, 2010).

6.3 Site Selection Criteria.

Site selection criteria are considered one of the crucial aspects of any building design and this has to be made at the early design stage. For a hotel design, it is important to choose a suitable site for the facility. And in order for that to be possible, some criteria have to be met, some which are; accessibility, size of site, proximity to airport, availability of local attraction, possibility for future expansion. For the sake of this research, three sites are considered for the proposed design. Figure 6.1 below shows the map of site from Google earth, which is located at latitude 10º19′06.36″N and longitude 9º 48′05.37″E,which is long a major express road coming into the metropolis from Jos having the an eye altitude of 1.68km.

Figure 6-1:Maps of proposed site A.

Source Google earth, (2017).

Figure 6.2 below shows the map of site from Google earth, which is locate at latitude 10º 21′00.52″N and longitude 9º 49′56.80″E, which is long two major express road coming into the metropolis from Jos and the other coming from Jigawa state, having an eye altitude of 1.59km.

Figure 6-2:Maps of proposed siteB.

Source Google earth, (2017).

Figure 6.3 below shows the map of site from Google earth, which is locate at latitude10º 20′18.27″N and longitude 9º 51′35.63″E, which is within the state metropolis, having an eye altitude of 1.59km.

Figure 6-3: Maps of proposed site C.
Source Google earth, (2017).

Table 6.1 below shows the rating of the sites of which a site will be selected for the proposed design of the five star hotel using a weighing scale of; 5- very good, 4- good, 3- moderate, 2- poor and 1- very poor.

Table 6-1:Site selection criteria.

S/N	**Selection criteria**	**sites**			**remark**
		Site A	Site B	Site C	
1	accessibility	4	5	1	Site B is more accessible with access road on both sides
2	size of site	3	4	5	Site c has the largest size.
3	proximity to airport	2	4	2	Site B is closer to the international airport.
4	availability of local attraction	2	2	2	All sites are poor in their closeness to local attraction.
5	possibility for future expansion	5	4	1	Site A has more possibilities for future expansion.
6	Land use	3	2	2	Site A is fair on da land use map.
	Total	19	21	13	

Source: Author, (2017).

6.4 Site Location.

Bauchi state is located in the north eastern part of Nigeria, bordered by some states like Gombe, Plateau, Jigawa, Yobe and Kano state. The site is located on latitude 10°20'51.54''N and longitude 9°50'19.83''E. Figure 6.4 below shows the location of site on map.

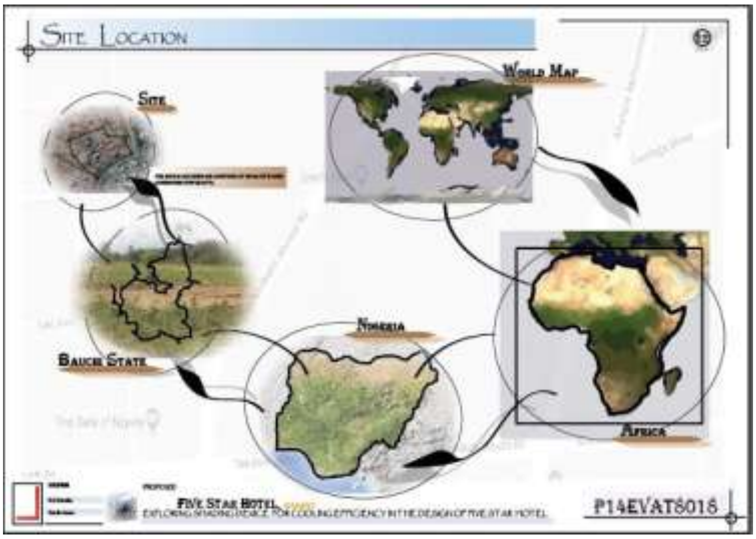


Figure 6-4:Proposed site location.

Source: Author (2018).

6.5 Site Analysis.

Site analysis gives an analysis of the site conditions such as the climatic conditions, topography and geology of site. Figure 6.5 show the climatic analysis of the site;

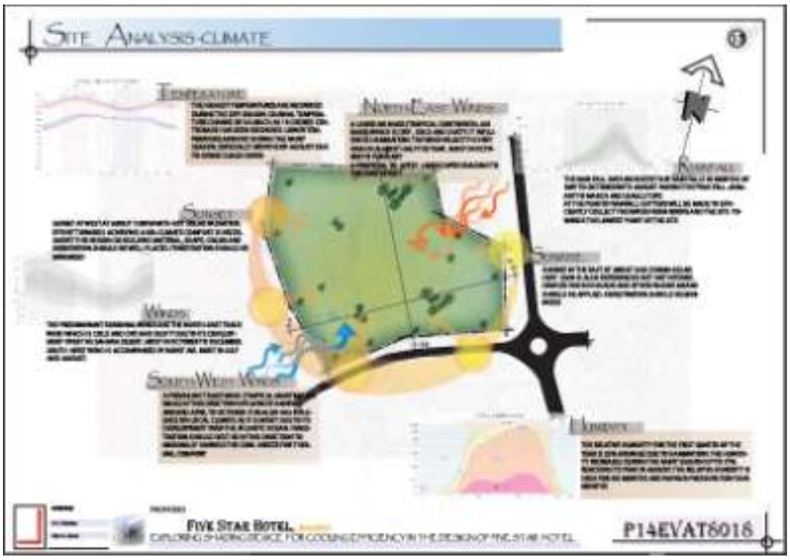


Figure 6-5:Proposed site climatic analysis.

Source: Author,(2018).

6.5.1 Climatic analysis.

The climatic analysis deals with the general atmospheric condition of the site and its environment in relation to the general climate. This will help the researcher in designing a more environmentally friendly building. This would include parameters such as; temperature, rainfall, humidity and wind speed.

6.5.1.1 Temperature.

Bauchi is characterized with hotseason lasting for 2.5 months, from February 28 to May 10, with an average daily high temperature above 36°C. The hottest day of the year is April 6, with an average high of 38°C and low of 23°C. The cool season lasts for 2.6 months, from July 15toOctober 1, with an average daily high temperature below 30°C. The coldest day of the year is January 1, with an average low of 14°Cand high of 31°C. Figure 6.6 shows the temperature scale;

Figure 6-6: Temperature graph reading of Bauchi, Bauchi state.

Source:Weatherspark, (2016).

6.5.1.2 Rainfall.

Bauchi experiences seasonal variation in monthly rainfall. The rainy period of the year lasts for 6.7 months, from April 3 to October 27, with a sliding 31-day rainfall of at least 13 millimetres. The most rainfalls during the 31 days cantered around August 12, with an average total accumulation of 180 millimetres. Figure 6.7 below shows the rainfall in Bauchi state;

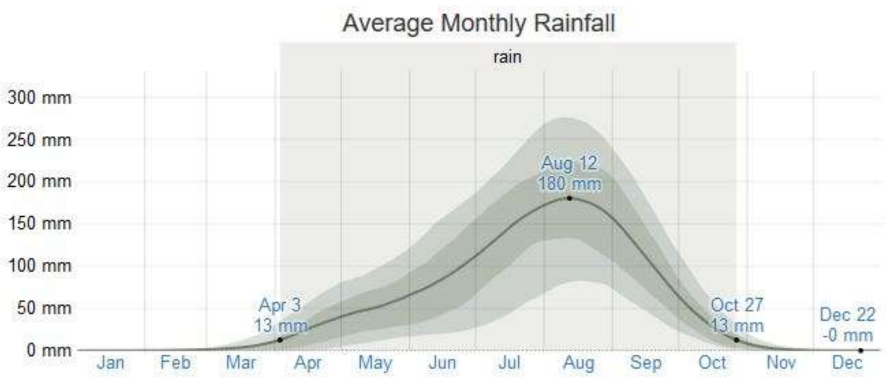


Figure 6-7: Rainfall graph reading of Bauchi, Bauchi state.

Source:Weatherspark, (2016).

6.5.1.3 Humidity.

Bauchi experiences extremeseasonal variation in the perceived humidity. The muggier periodof the year lasts for 6.7 months, from April 10 to November 2, during which time the comfort level is muggy,oppressive, or miserable at least 24% of the time. The muggiest day of the year is August 29, with muggy conditions 98% of the time. The least muggy day of the year is January 5, when muggy conditions are essentially unheard of. Figure 6.8 below shows the humidity in Bauchi state

Figure 6-8: Humidity graph reading of Bauchi, Bauchi state.
Source:Weatherspark, (2016).

6.5.1.4 Wind speed.

The average hourly wind speed in Bauchi experiences significantseasonal variation over the course of the year. Thewindierpart of the year lasts for 6.3 months, from November 13 to May 22, with average wind speeds of more than 3.2 meters per second. The windiest day of the year is January 30, with an average hourly wind speed of 4.1 meters per second. The calmer time of year lasts for 5.7 months, from May 22 toNovember 13. The calmestday of the year is September 2, with an average hourly wind speed of 2.2 meters per second. . Figure 6.9 shows the wind speed in Bauchi state

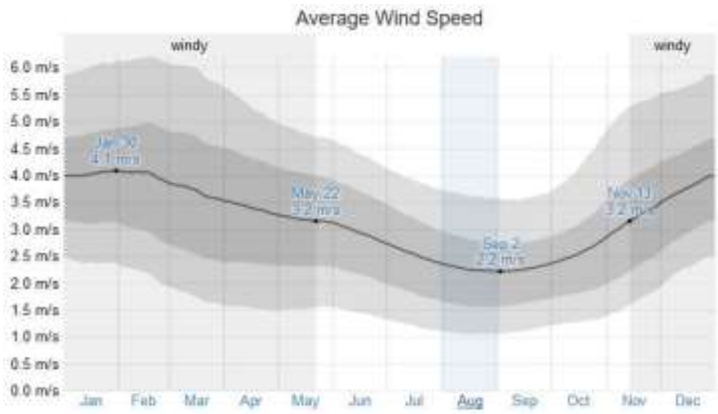


Figure 6-9: Wind speed graph reading of Bauchi, Bauchi state.

Source:Weatherspark, (2016).

6.6 Sunrise and Sunset.

The length of the day in Bauchi does not vary substantially over the course of the year, staying within 43 minutesof12 hours throughout. In 2017, the shortest day is December 21, with ***11*** hours, 31 minutes of daylight; the longest day is June 21, with 12 hours**,** 44 minutes of daylight. The earliest sunrise is at 5:57 AM on May 29, and the latest sunriseis46 minutes later at 6:43 AM on January 26**.** The earliest sunset is at 5:54 PM on November 16, and the latest sunsetis52 minuteslater at 6:46 PM on July 11**.** Figure 6.10 below shows the sunrise and sunset of Bauchi;

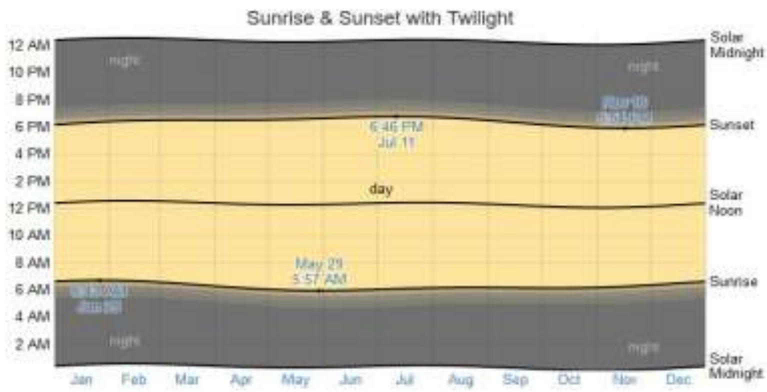


Figure 6-10: Sunrise and sunset reading of Bauchi, Bauchi state.

Source:Weatherspark, (2016).

6.7 Physical Site Analysis.

The physical site analysis indicates the visible conditions that would affect the design on site. These conditions include the topography, source of noise and vegetation. Figure 6.11 below indicates the physical site analysis.

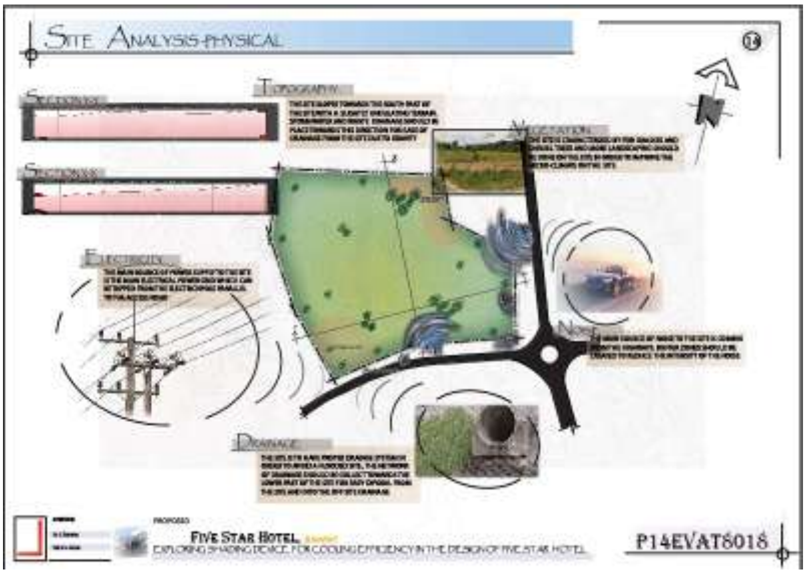


Figure 6-11: Physical site analysis for proposed design.

Source: Author (2018).

6.7.1 Topography.

Bauchi are 10°310 latitude, 9°844 longitudes, and 609 m elevation. The topography within 3 kilometresof Bauchi contains only modestvariations in elevation, with a maximum elevation change of 141 metersand an average elevation above sea level of 617 meters. Within 16 kilometrescontains only modest variations in elevation(685 meters). Within 80 kilometres containslarge variations in elevation (1,176 meters). The area within 3 kilometres of Bauchi is covered by artificial surfaces(51%*)* and cropland(*23*%), within 16 kilometres by cropland (*68*%) and grassland (10%), and within 80 kilometres by cropland (59%) and shrubs(18%***).***

The site slopes to the south- western part of the site with a slightly rough terrain. Storm water drainages should be designed towards this direction to enable the site to drain.

6.7.2 Vegetation.

The site is sparsely vegetated with shrubs and grass. The site should be properly landscaped. Trees and shrubs should be planted on the site in order to create cover and improve the micro climate of the site.

6.7.3 Source of noise.

The major source noise to the site is the access road, which are on both sides of the site. The building should be designed in such a way that the rooms should be placed where noise would not affect the occupants of the building.

6.8 Schedule of Accommodation.

Schedule of accommodation gives an approximate number and size of spaces that would be required within the proposed facility. The table6.2, table 6.3, table 6.4, table 6.5, table 6.6, table 6.7and table6.8 shows the schedule of accommodation of the proposed building.

Table 6-2: Schedule of accommodation for room spaces.

S/N	**Accommodation spaces**			
	Room types	**Room area (sqm)**	**Number**	**Total area (sqm)**
1	Standard room	24	103	2472
2	Double room	36	43	1548
3	Business suite	72	12	864
4	Executive suite	110	5	550
5	Presidential suite	140	2	280
	Total		165	5164sqm

Source: Author, (2017).

Table 6-3: Schedule of accommodation for room spaces commercial spaces.

S/N	Commercial facilities			
	Facilities	**Area of space (sqm)**	**Number**	**Total area (sqm)**
1	Fast food	15	2	30
2	Mini mart	40	1	40
3	Cyber cafe	48	1	48
4	Barbing saloon	24	1	24
5	Beauty parlour	35	1	35
6	Boutique	24	2	48
7	Let able space	25	5	125
	Total		13	350 sqm

Source: Author, (2017).

Table 6-4:Schedule of accommodation for halls.

S/N	Conference halls			
	Room types	**Area of space (sqm)**	**Number**	**Total area (sqm)**
1	Multipurpose hall	1.2 /person	300	360
2	Seminar hall	1.2 /person	15(2)=30	36
3	Control room	18	1	18
4	Stage	37	1	37
5	Back stage	22	1	22
6	Projection room	14	1	14
7	Ticket office	12	1	12
8	Restrooms	1.8	10	18
9	Stores	15	1	15
	Total		346	534

Source: Author, (2017).

Table 6-5: Schedule of accommodation for catering facilities.

S/N	Catering facilities			
	facilities	**Area of space (sqm)**	**Number of persons**	**Total area (sqm)**
1	Restaurant	1.2 /person	250	300
2	Outdoor eating	1.2 /person	80	96
3	Tea and coffee	1.2 /person	50	60
	Total		380	456sqm

Source: Author, (2017).

Table 6-6: Schedule of accommodation for back house.

S/N	Back house			
	facilities	**Area of space**	**Number**	**Total area**

		(sqm)		(sqm)
1	Main kitchen	216	1	216
2	Stores	36	4	144
3	Laundry	72	1	72
4	House keeping	6.25	26	1625
	total		32	2057sqm

Source: Author, (2017).

Table 6-7:Schedule of accommodation for sports and fitness facilities.

S/N	**Sports and fitness**			
	facilities	**Area of space (sqm)**	**Number**	**Total area (sqm)**
1	Tennis court	18.27x36.57m	2	1336.27
2	Badminton court	9.1x17.4	2	316.68
3	Gymnasium	80	1	80
4	Swimming pool	16.66x25m	1	416.50
5	Changing rooms	1.8	6	10.8
	Total		12	2160.25

Source: Author, (2017).

Table 6-8:Schedule of accommodation for offices.

S/N	**Offices**			
	offices	**Area of spaces (sqm)**	**Number**	**Total area (sqm)**
1	General manager	27	1	27
2	Secretary	13.5	1	13.5
3	Account office	13.5	1	13.5
4	Cash office	13.5	2	27
5	Front desk office	20	2	40
6	Reservation office	27	1	27
7	Personnel manager	13.5	1	13.5
8	Maintenance office	13.5	1	13.5
9	Staff office	13.5	3	108
10	Human resource manager	13.5	1	13.5
11	Record office	13.5	1	13.5
	Total		15	310sqm

Source: Author, (2017).

6.9 Concept Development.

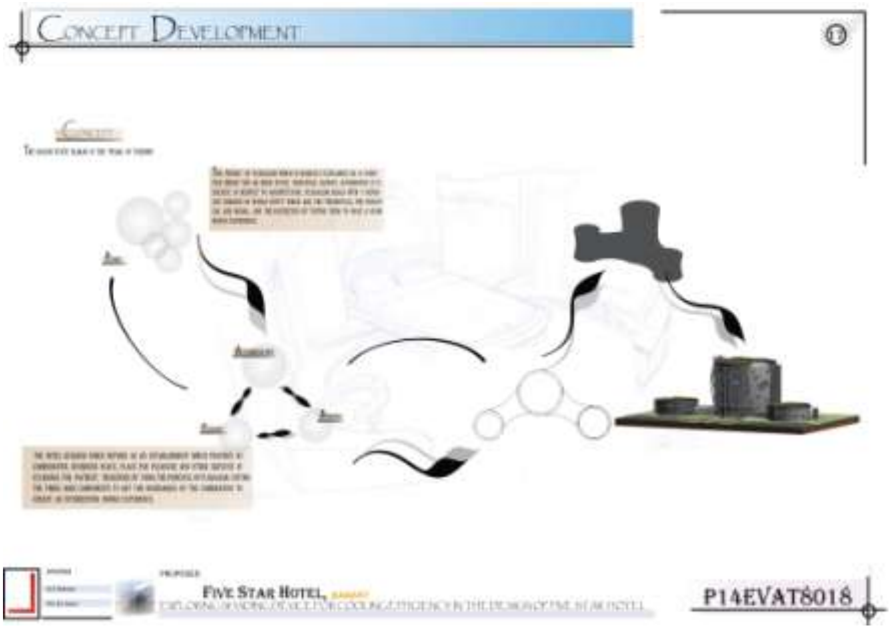


Figure 6-12: Concept development for proposed design.
Source, Source: Author, (2018).

Figure 6.12 above shows the concept, which is derived from the theory of pluralism, which explains as a condition where two or more state, principles, groups, authorities and so on coexist. in respect to architecture, pluralism deals with 3 separate domains of human entity which are the theoretical, the practical and moral, and the aesthetics by uniting them to have a good human experience.

the hotel building which defined as an establishment which provides accommodation, business place, place for pleasure and other services in exchange for payment. therefore by using the principle of pluralism, uniting the three main components to get the boundaries of the combination to create an interesting human experience.

6.10 Construction of proposed hotel design, Bauchi.

The structural system is made of beams and columns, which are placed at a segment angle of 15° due to the circular shape of the building. The structural systems are made up of concrete and have a size of 600mm in diameter.

The building is designed in segments with openings on its sides for more natural ventilation and natural day light into the building.

The building consist of a total of 192 rooms, having the single rooms 108, 54 double rooms ,18 business suites, 8 executive suites and 4 presidential suites, with a helipad at the roof of the building. The connector between the three circular buildings is a shell structure made of lattice pinned support. The building has an atrium with a lattice roofing system, which aids in bringing light to the building, with a high-level vent for hot air to escape.

The simulation of the proposed design with the identified shading device strategy applied and with the introduction of an atrium covered low emissivity fiberglass with u- value of 1.25 to be analyzed using the Autodesk Ecotect 2011 as shown in figure 6.13:

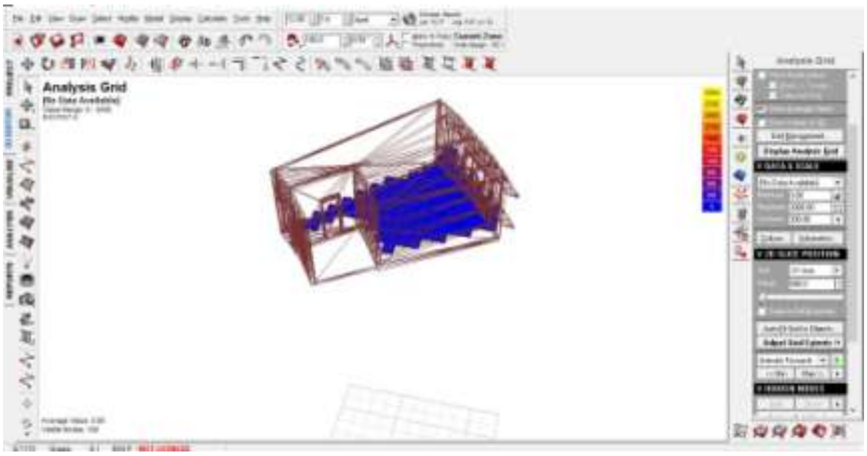


Figure 6-13: Proposed design space with the proposed shading device and introduction of an atrium.

Source: Autodesk Ecotect, (2011).

Thermal comfort zone according toNicol and Hunphreys, (2001) as cited in Batagarawa, (2013)concluded that an appropriate comfort range should be 22°C to 27°C.

The result from the analysis indicate that introduction of the atrium covered with fiber glass of low emissivity also has an effect on the indoor temperature as it allows hot air to rise through the high level vent and an average temperature of 24.90°C.Hence, having a temperature difference 6.01°C from the based case model as earlier analyzed.

6.11Building materials of proposed hotel design, Bauchi.

For more efficient responsive building, low-Emissivity glazing was used on the windows of the building, translucent material at the roof, composite aluminum roofing, and flexible Illuminant semi-translucent polycarbonate material. The building exterior was painted with a light colored paint in order to reduce some heat through radiation.fire retardant materials were used in the interior spaces of the building.

6.12Building form and orientation of proposed hotel design, Bauchi.

The building form was chosen due to its less exposure to solar radiation on the building envelope. In addition, this is a form of shading from solar rays and reduce cooling load by not allowing heat gained by the building. The building is oriented with its longer side along the east-west axis.

6.13Shading device used on proposed hotel design, Bauchi.

The horizontal fixed shading device made of concrete was used on the building in order to improve natural ventilation and to reduce direct solar heat gain by the building envelope. The application of the 70° angle-shading device with no distance from the wall is used to achieve optimum ventilation, and they are made of concrete as shown in the figure 6.14

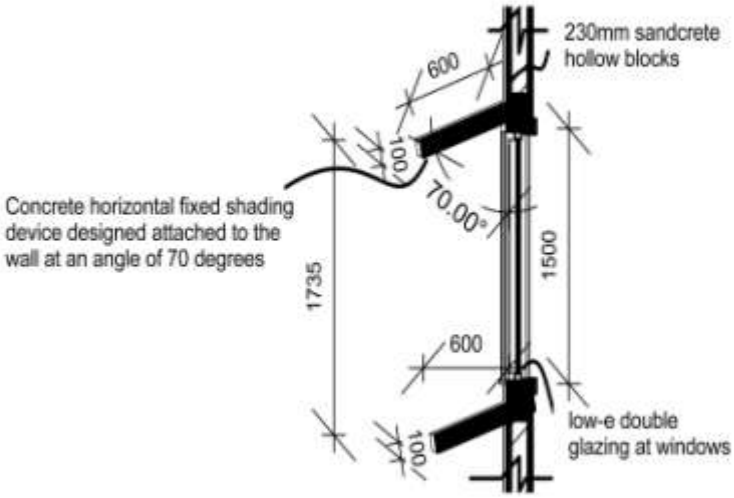


Figure 6-14: Showing a cross section of the applied shading device on the proposed building.

Source: Autodesk Revit Architecture, (2016).

On the east and west side of the building, there are perforated panels of Illuminant semi-translucent polycarbonate material that enables various light effects which are also used as form of reducing direct solar heat gain into the building.

6.14Landscape elements of proposed hotel design, Bauchi.

Properly arrangement of landscape plants around buildings can substantially reduce both heat loss and cold air infiltration through walls and floors and can lower home heating and cooling costs by as much as 20%(Frank, 2003). The site is properly landscape with trees and shrubs to reduce the heat gain on site. The soft landscape increases the level of humidity on site and helps purify the air. Body of water was also used in the landscaping of the site in order to improve the microclimate of the site through evaporative cooling.

6.15Fire safety measures of proposed hotel design, Bauchi.

Fire escape staircases have been strategically placed in the building in case of fire incidence. The building has been designed in segment such that in a situation of fire incidence, the fire cannot transfer throughout the building, which is a passive means of fire safety measure.

6.16 Conclusion.

This chapter discussed the entire design of the proposed hotel. A radial grid structural system was used for the frame structure of the building, passive fire measure were taken into consideration in the design and the use of low heat transmittance glazing were used at window opening to be able to reduce heat from entering the building.

The identified shading device was applied to the proposed building ad simulated to find out whether its indoor temperature falls within the allowable thermal comfort zone.

In conclusion, this chapter gave overview information of the proposed to the design of both macro spaces as well as micro spaces.

CHAPTER SEVEN

7.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS.

7.1 Summary.

A hotel building consumes a lot of energy in providing a wide range of services to the customers.it rank top 5 of consumption buildings in the world. In addition, the major cause of this energy consumption is cooling load.

The study is aimed at improving cooling efficiency through proper use of shading device strategy in the hot-dry climate ofBauchi with the major problem of heat gained through walls and openings. In addition, it was found out that this problem could be greatly reduced through the proper design of shading device with respect to climate, orientation, building forms etc.

From literature, it was found that different variables could affect the effectiveness of the shading device, such as, thickness, angle, distance from wall etc. and as this variables changes so does its effect in natural ventilation and thermal comfort of the space.

Case studies were carried out, which provided the information necessary for validations and to find out the current practices of shading device used and other strategies used in addressing the problem of heat gain. An experimental method was used to test for the variables and to find out the most suitable strategy for the area of study. The result of the computer simulation was incorporated into the proposed design.

7.2 Conclusion.

The research set out to develop a preferred shading strategy to be employed in the design of hotel in Bauchi state. The case studies that were carried out in the area of study provided a base case scenario that was simulated based on the climatic condition, orientation and shading device type.it was evaluated and found out the different level of effect the angle of shading device have and its respective distances from wall has on the building for the study area.

The case study and literature has given guidance in order to achieve an energy efficient building through cooling. The strategies employed are construction system, materials, orientation, shading devices, landscaping. The results from the computer simulations carried out in Autodesk simulation CFD indicate concrete horizontal shading device placed at an angle of 70° and (0mm) distance from the wall (attached to wall) as a more satisfactory strategy with PMV +0.2(neutral) and PPD of 15% and also an indicated increase in airflow into space in the area of study. In addition, this shading device strategy indicates an improved level drop in temperature. Furthermore, a space from the proposed design was simulated considering some other passive design strategies and using the identified strategy, has tested to have an improved drop in temperature. The study discourages the use of 90° angle shading device with 200mm from wall with a PMV of +2.4 and a PPD of 80%, which has high discomfort level in the space.

7.3 Contribution to Knowledge.

The major contributions of this research are:

i. The study contributes by generating a shading device framework for incorporating into hotel designs in hot dry climate.

ii. A concrete horizontal shading device on the north and south put at an angle of 70° attached to the wall reduces 5°C which amounts to 15.6% reduction of the indoor temperature.

iii. The use of atrium covered with low emissivity fiberglass having a u- value of 1.25 can further reduce the indoor temperature by 6.01°C.

7.4 Recommendation.

i. The use of horizontal shading device 600mm at angle 70° attached to the wall should be incorporated in the design of hotels in the hot-dry climate of Bauchi.

ii. The use of cylindrical building form in the hot-dry climate exposes less surface of the building to direct solar radiation hence, reducing the heat gained by the building and by extension reduce the energy needed to cool the building.

iii. The use of energy efficient building materials at window openings such as low-E glazing, polycarbonate material to reduce heat gain.

iv. The site should be well landscaped with trees and shrubs in order to improve the micro climate on site and also to improve the air.

v. The use of water body on site for evaporative cooling of the environment.

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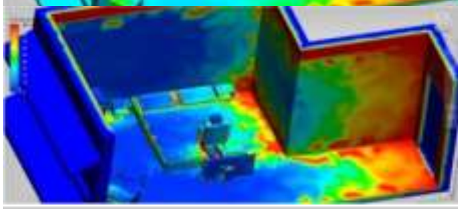
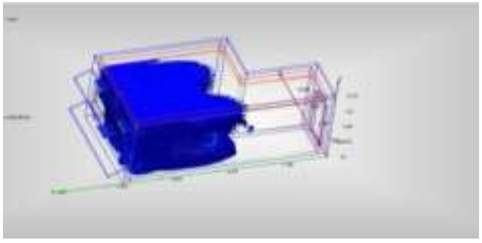
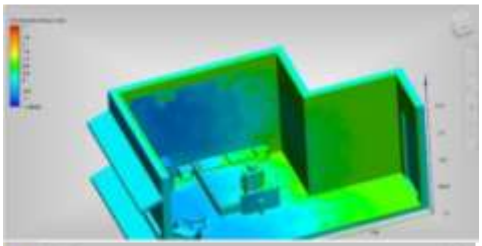
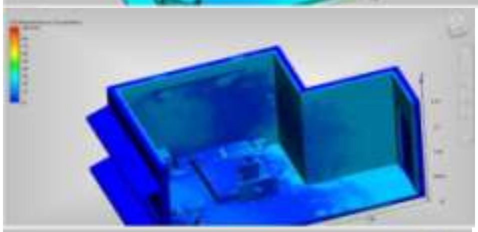
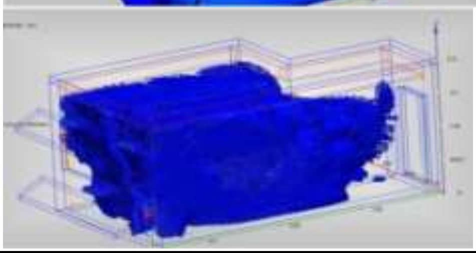
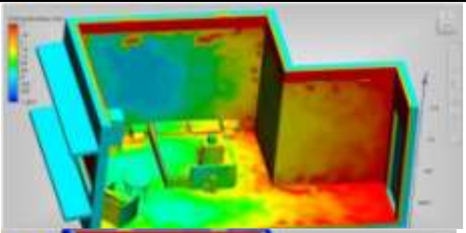
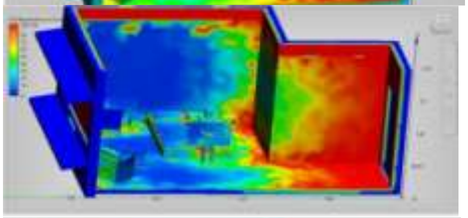
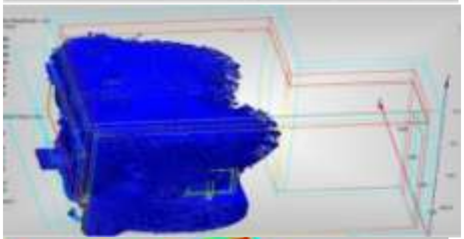
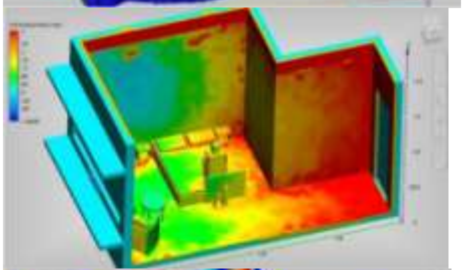
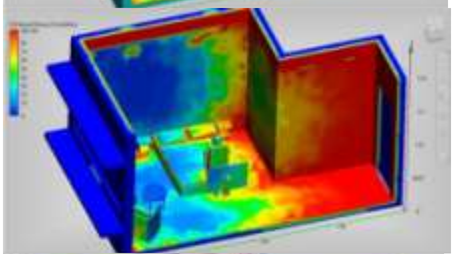
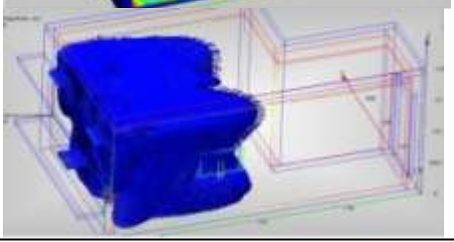
APPENDICES

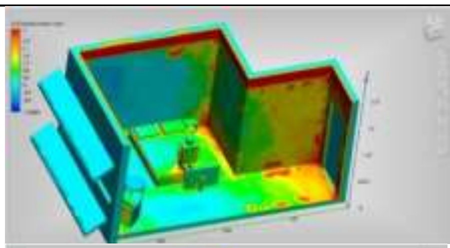
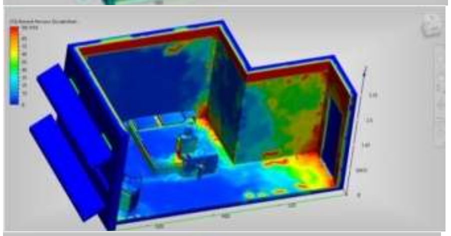
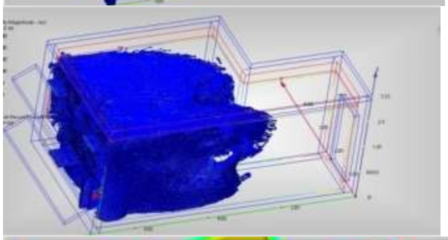
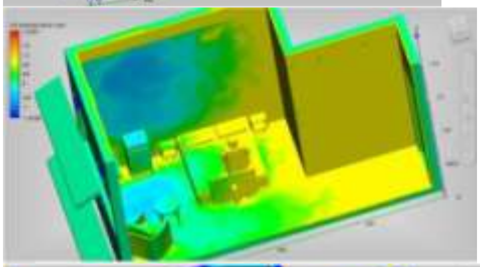
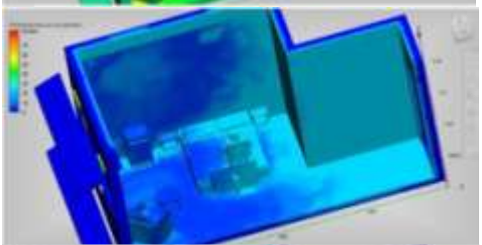
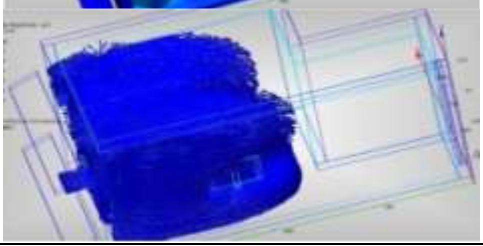
Appendix I:Showing simulation illustration of shading device with no distance from the wall.

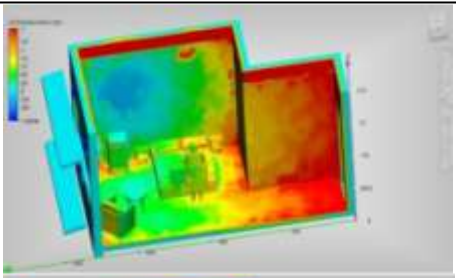
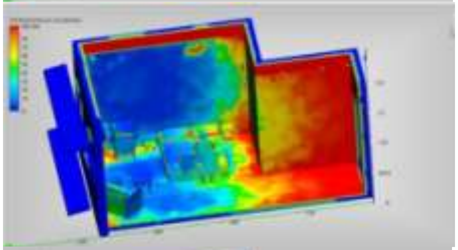
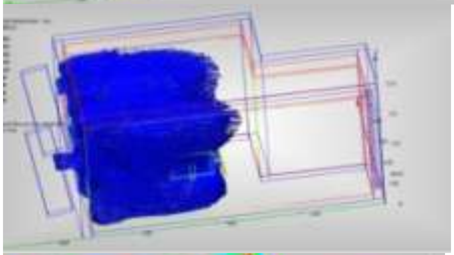
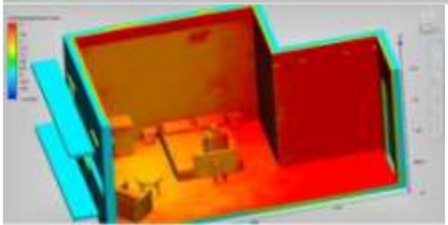
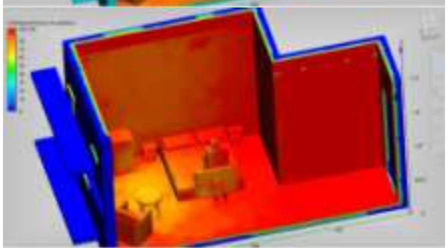
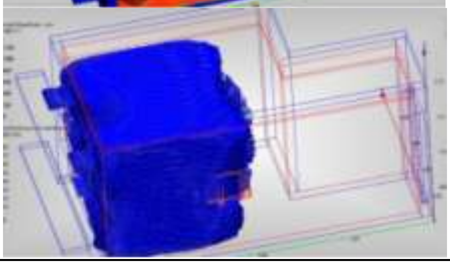
S/N	Angle of shading in degree	Distance from the wall in mm	indicators	Results
1	60	0	PMV +0.8 (slightly warm)	
			PPD 20%	
			Air flow	
2	70	0	PMV +0.2 (slightly neutral)	
			PPD 15%	
			Air flow	

3	80	0	PMV +1.2 (slightly warm)	
			PPD 38%	
			Air flow	
4	90	0	PMV +1.8 (slightly warm)	
			PPD 55%	
			Air flow	

Source: Author, (2017).

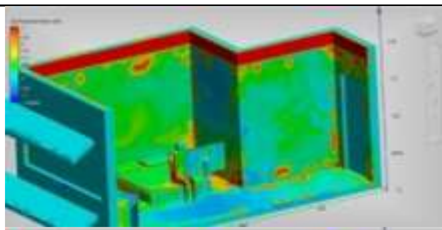
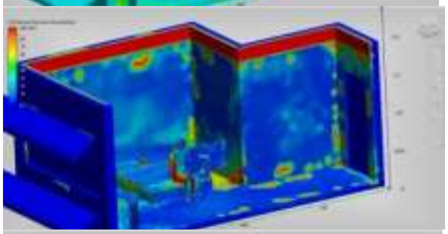
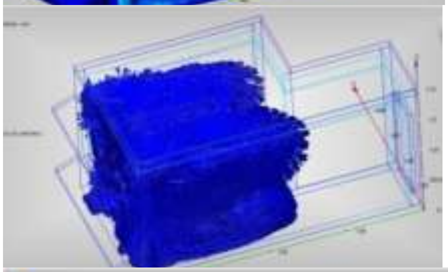
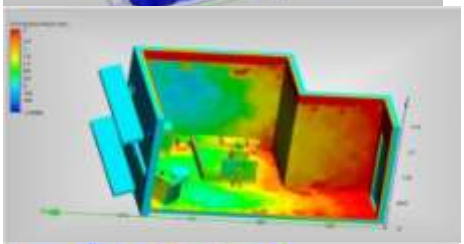
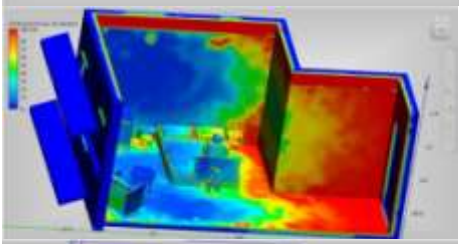
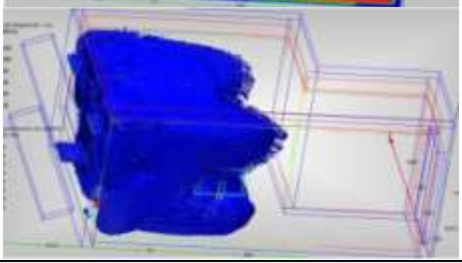
Appendix II:Showing simulation illustration of shading device with 200mm distance from the wall.

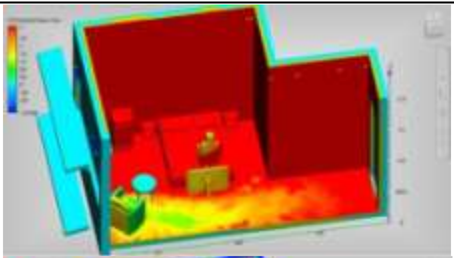
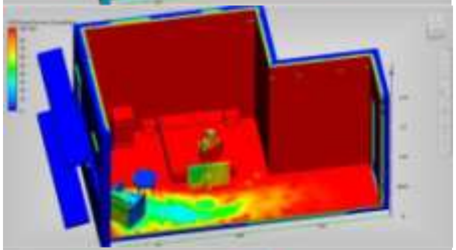
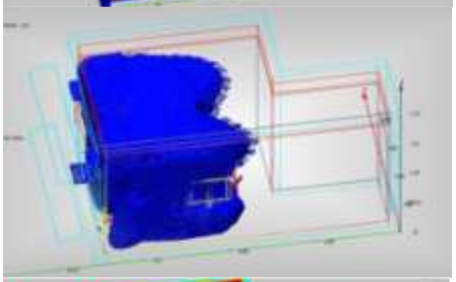
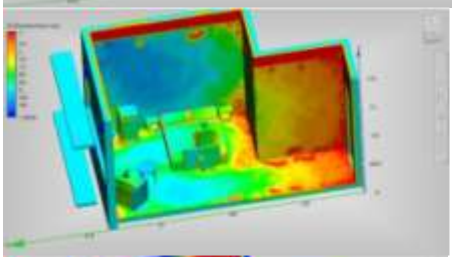
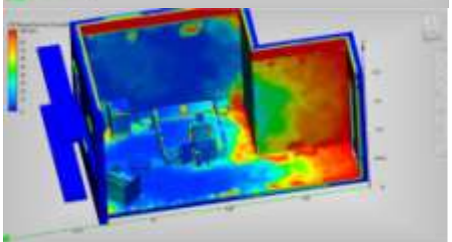
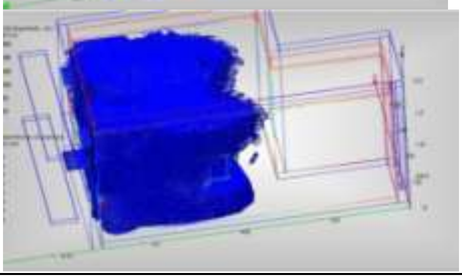
S/N	Angle of shading in degree	Distance from the wall in mm	indicators	Results
1	60	200	PMV +1.3 (slightly warm)	
			PPD 23%	
			Air flow	
2	70	200	PMV +0.9 (slightly warm)	
			PPD 28%	
			Air flow	

3	80	200	PMV +1.3 (slightly warm)	
			PPD 38%	
			Air flow	
4	90	200	PMV +2.4 (warm)	
			PPD 80%	
			Air flow	

Source: Author, (2017).

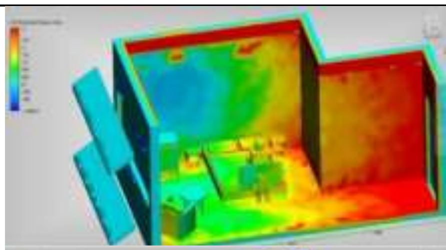
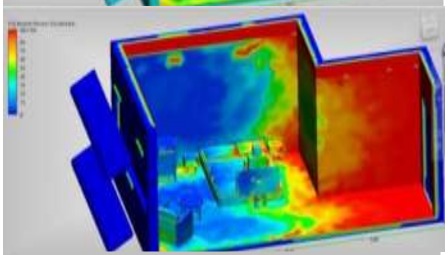
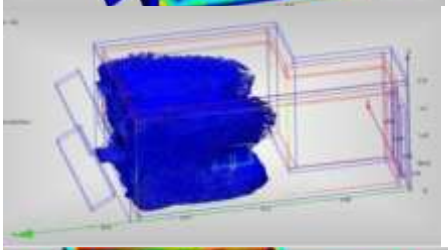
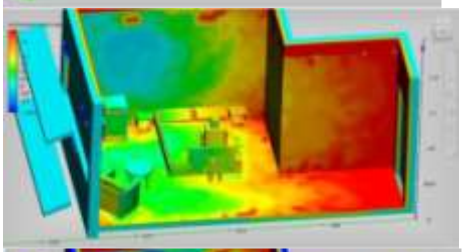
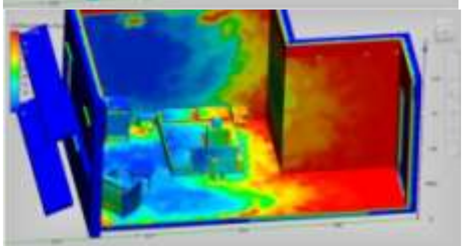
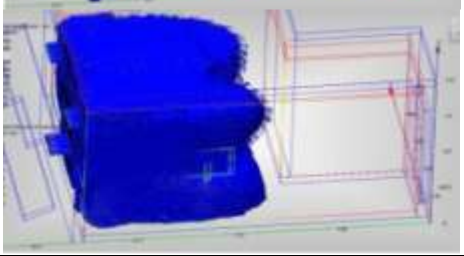
Appendix III:Showing simulation illustration of shading device with 300mm distance from the wall

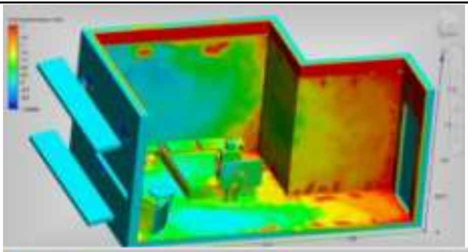
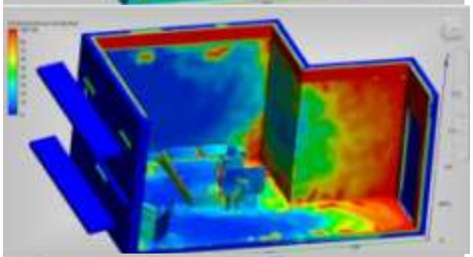
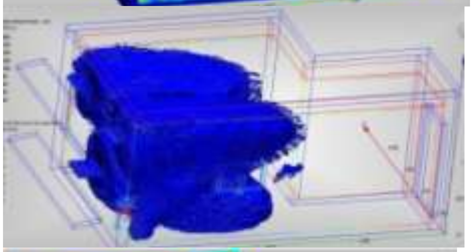
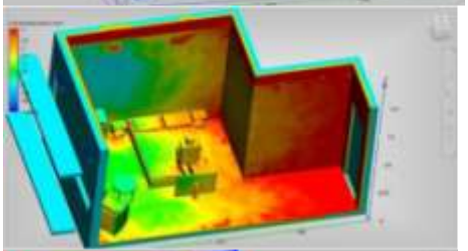
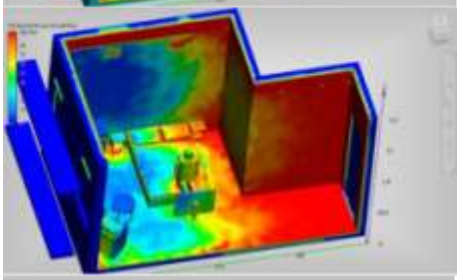
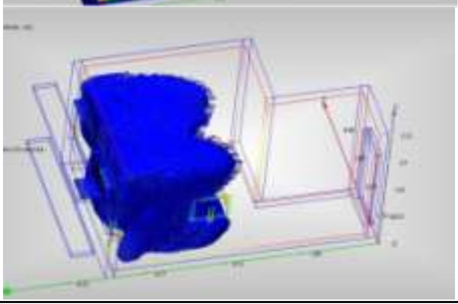
S/N	Angle of shading in degree	Distance from the wall in mm	indicators	Results
1	60	300	PMV +0.6 (slightly neutral)	
			PPD 20%	
			Air flow	
2	70	300	PMV +1.2 (slightly warm)	
			PPD 35%	
			Air flow	

3	80	300	PMV +2.2 (warm)	
			PPD 78%	
			Air flow	
4	90	300	PMV +0.8 (slightly warm)	
			PPD 30%	
			Air flow	

Source: Author, (2017).

Appendix IV:Showing simulation illustration of shading device with 400mm distance from the wall

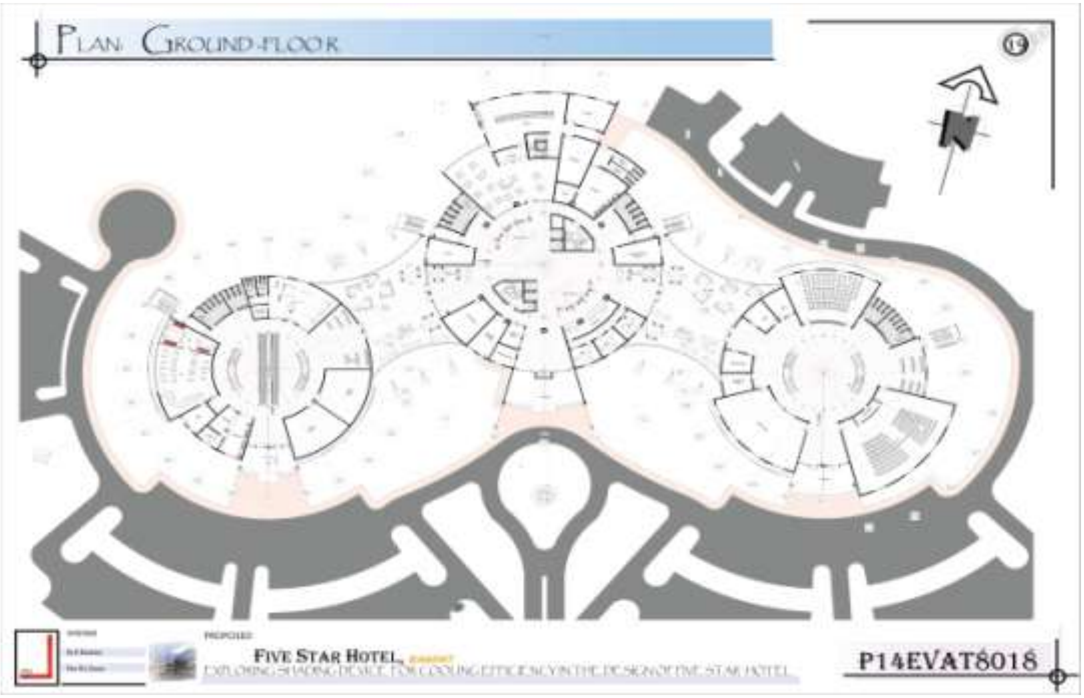
S/N	Angle of shading in degree	Distance from the wall in mm	indicators	Results
1	60	400	PMV +1.5 (slightly warm)	
			PPD 45%	
			Air flow	
2	70	400	PMV +1.4 (slightly warm)	
			PPD 40%	
			Air flow	

3	80	400	PMV +1.2 (slightly warm)	
			PPD 30%	
			Air flow	
4	90	400	PMV +1.4 (slightly warm)	
			PPD 58%	
			Air flow	

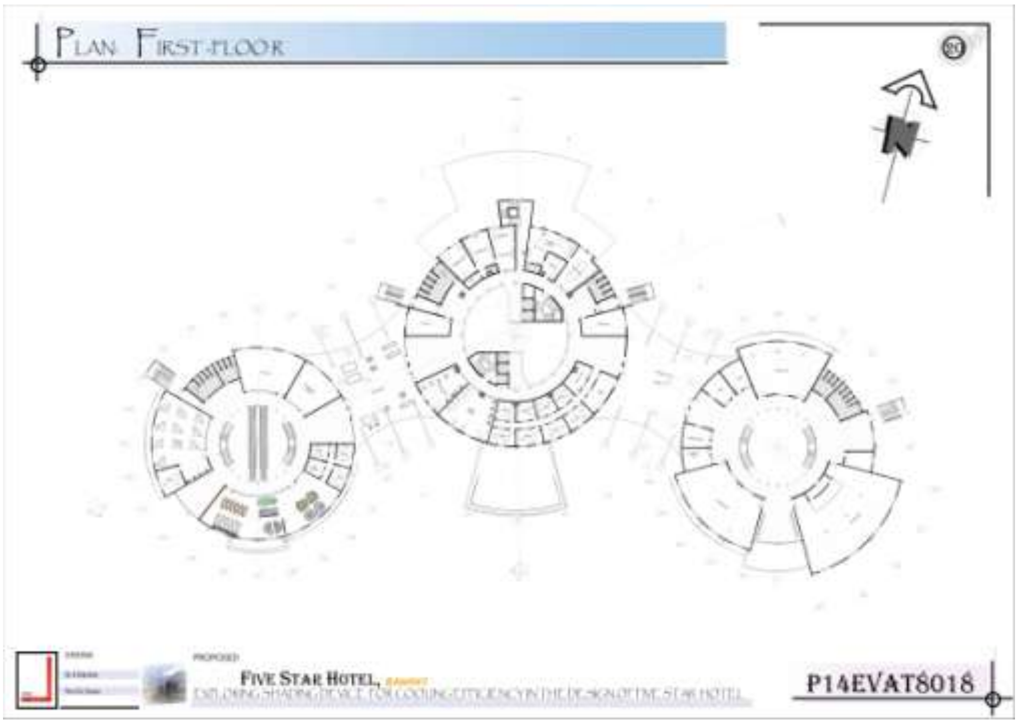
Source: Author, (2017).

Appendix V:Proposed Site Plan.

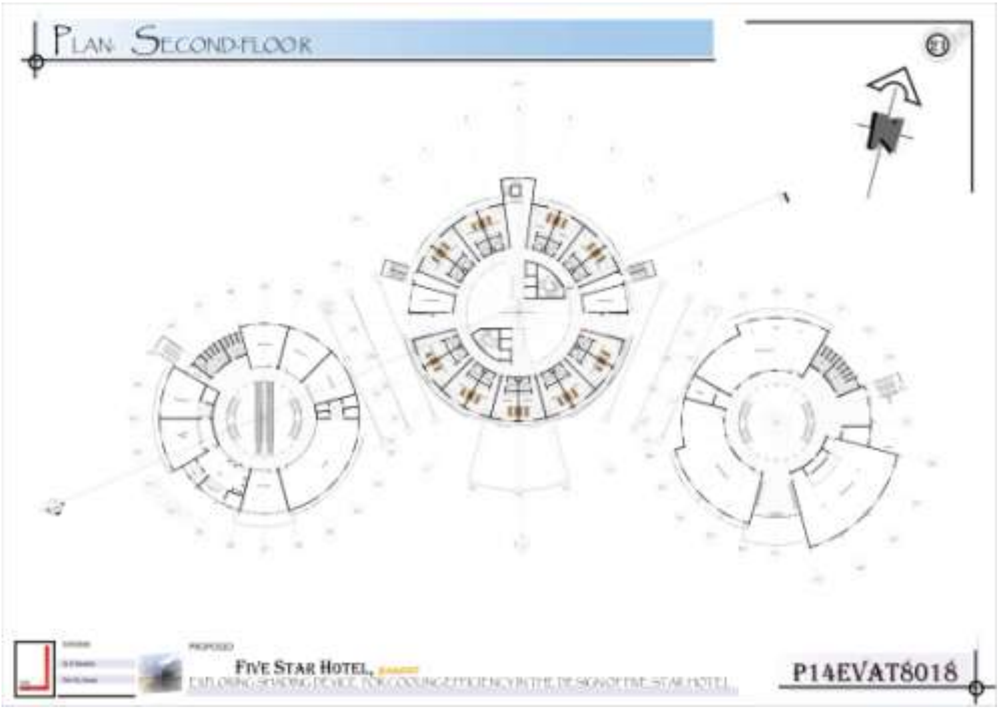
Appendix VI: Ground floor plan of proposed hotel, Bauchi.



Appendix VII: First floor plan of proposed hotel, Bauchi.



Appendix VIII: Second floor plan –seventh floor of proposed hotel, Bauchi.



Appendix IX: Twelfth floor plan – thirteenth floor plan of proposed hotel, Bauchi.

Appendix X: Fourteenth floor plan –fifteenth floor plan of proposed hotel, Bauchi.

Appendix XI: Elevations of proposed hotel, Bauchi.

Appendix XII: Elevations of proposed hotel, Bauchi.