

**ENHANCING PASSIVE COOLING IN HEALTHCARE BUILDINGS  
USING COURTYARD FORMS IN THE DESIGN OF WOMEN AND  
CHILDREN HOSPITAL IN KADUNA STATE, NIGERIA**

**BY**

**ALIYU KABIR**

**(P14EVAT8013)**

**DEPARTMENT OF ARCHITECTURE  
AHMADU BELLO UNIVERSITY, ZARIA  
NIGERIA**

**November, 2019**



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**By  
ALIYU KABIR (B.sc ARCH)  
P14EVAT8013**

**A DISSERTIFICATION SUBMITTED TO THE SCHOOL OF  
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AHMADU BELLO UNIVERSITY  
ZARIA**

**November, 2019**

### **DECLARATION**

I declare that the work in this dissertation titled ‘‘ENHANCING PASSIVE COOLING IN HEALTHCARE BUILDINGS USING COURTYARD FORMS IN THE DESIGN OF WOMEN AND CHILDREN HOSPITAL IN KADUNA STATE, NIGERIA’’ has been carried out by me in the Department of Architecture, Ahmadu Bello University, Zaria. Information derived from literature has duly been acknowledged in the text and a list of reference has also been provided, no part of this thesis was previously presented for another degree or diploma at this institution or any other.

Aliyu Kabir

Name of Student

Students signature

Signature/ Date

## CERTIFICATION

This desertification entitled “ENHANCING PASSIVE COOLING IN HEALTHCARE BUILDINGS USING COURTYARD FORMS IN THE DESIGN OF WOMEN AND CHILDREN HOSPITAL IN KADUNA STATE, NIGERIA” by Aliyu Kabir meets the regulation of award of masters of science in Architecture of Ahmadu Bello University Zaria and its approved for its contribution to knowledge and literary presentation.

Prof M.L. Sagada

|                                |           |       |
|--------------------------------|-----------|-------|
| _____                          | _____     | _____ |
| Chairman supervisory committee | Signature | Date  |

Dr. R.B. Tukur

|                               |           |       |
|-------------------------------|-----------|-------|
| _____                         | _____     | _____ |
| Member, supervisory committee | Signature | Date  |

Dr. A.S. Salisu

|                    |           |       |
|--------------------|-----------|-------|
| _____              | _____     | _____ |
| Head of Department | Signature | Date  |

Prof. Sani Abdullahi Rabah

|                                       |           |       |
|---------------------------------------|-----------|-------|
| _____                                 | _____     | _____ |
| Dean, School of post graduate studies | Signature | Date  |

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## **ABSTRACT**

Buildings consume more than 40% of primary energy in most countries and healthcare facilities have been identified as one of the highest consumers of energy. These is due to its heavy dependence on HVAC systems for controlling indoor temperatures as well as general operations. It was further observed that the situation is more critical in developing countries like Nigeria, due to insufficiency in power supply, a factor which in turn increases the hospitals running cost. Studies have shown that the situation can be significantly improved by exploring passive means of cooling the buildings such as courtyards. It was also revealed that it's performance can be improved by giving special consideration to courtyards design variants such as form, aspect ratio, orientation, wall enclosure and elements within it. Hence, the research was aimed at improving passive cooling in hospitals using courtyard forms in the design of a women and children hospital in Kaduna state, Nigeria. This was achieved through qualitative and quantitative methods. A case study was carried out to ascertain the level of applications of courtyard design variants in existing hospitals in the study area. Also base case models were designed using Autodesk Revit architecture to depict existing courtyard scenarios with enclosed and semi enclosed forms. This forms were also varied into different ratios ranging from 1:1.2 to 1:2, the models were subsequently simulated using ECOTECH energy software to record the annual energy load of each model. The results showed that a U shape courtyard of ratio 1:2 in a two storey building in the hot dry climate of Kaduna state can reduce a buildings annual energy consumption by up to 44.03%. It is therefore hoped that designers can adopt these findings in the design of future buildings most especially healthcare facilities with the hope of improving passive cooling as well as providing the conducive environment necessary to aid faster patient recovery.

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## **CHAPTER ONE**

### **1.0 INTRODUCTION**

#### **1.1 Background of Study**

Hospitals consume large amounts of energy because of how they are run and the many people that use them. They are open 24 hours a day; thousands of employees, patients, and visitors occupy the buildings daily. As such, sophisticated ventilation and air conditioning (HVAC) systems control the temperatures and air flow in the hospital wards so as to maintain cooling.

In Nigeria, effective healthcare delivery service is a very important and a desirable social service. Efficient healthcare service delivery is heavily dependent on reliable and adequate power supply, However the energy demand of these facilities are hardly met by the national power supply. As a result, most healthcare facilities are heavily dependent on artificial and alternative means of power supply such as diesel and petrol generators. A factor which places a burden on its daily operational costs (Nwanya, Sam-Amobi, & Ekechukwu, 2016).

The issue of energy efficiency is a call for concern in the world at large most especially in institutional buildings such as Hospitals. While the building sector is responsible for about 40 % of energy use. According to Shchuchenko, Lie and Thorgeirharsem, (2013) Hospitals represent 6 % of the total energy consumption in the public building sector and are one of the most energy intensive building categories. They further opine that; a hospital uses 2.5 times more energy than a similar sized office building.

However, many studies have been conducted on how cooling can be better optimized in hospitals, through passive means such as courtyards. In architectural design and practice, the courtyard is mostly used in buildings in all the climatic regions due to its passive

tendencies for low energy consumption in buildings. Its benefits cut across; social, cultural, religious, environmental and even therapeutic reasons (Bulus, Evaluation of courtyard usage and design requirement in residential buildings in Nigeria hot dry climate, 2016).

It has also been observed that in hot climatic regions, courtyard buildings performed more effectively in the reduction of cooling energy loads in buildings. Scholars have conducted studies on courtyard design concepts explaining how the form can be manipulated to act as a microclimate modifier to the built environment. According to Huang, Niu and Chung (2014) the deeper courtyard form will generate more shadow within the courtyard in hot seasons which will have serious influence on its thermal performance, whereas narrow courtyard form will behave well in cold seasons. Manioglu and Ora (2015) further opine that the width to length ratio applied for different courtyard forms has a significant effect on the cooling and heating loads, as well as solar gain. This is due to the W/L ratio effect of courtyard building form which results in low energy requirement for cooling in hot dry climate, in order to minimize the area affected by the solar radiation, compact forms are arranged with courtyards as Building energy loads are influenced also by the courtyard shape and therefore recommend that the heating and cooling loads for different courtyard shapes be evaluated. According to El-Deeb, Sherif and El-Zafarany (2014) in multi storey courtyard buildings, the courtyard results in more height and self-shading on the facades overlooking the courtyard. This will have a direct effect on the energy consumed for cooling and heating, as well as on that consumed by artificial lighting. In a similar view, Markus (2016) stressed that the courtyard form and size have a significant effect on the shading conditions and this also has a major impact on the building cooling loads. The study further added that due to the differences in climatic requirements of diverse climatic regions such as; hot-dry, hot-humid, cold, and temperate climates, detailed simulation

studies are required for the appropriate form and size for a particular climatic zone. These studies have shown that the courtyard form and configuration can greatly influence the cooling energy performance of a building and also the combined effect of the building depth surrounding the courtyard has also great effect on the energy consumed for cooling, heating and lighting of a building. Hence the need to explore the passive tendencies of courtyard as a microclimatic modifier

## **1.2 Problem Statement**

Hospitals are institutional buildings that use up large amounts of energy for cooling and ventilation through HVAC systems such as fans and air conditions. This is due to its daily activities as well as the need to provide cooling for patients and staffs. The heavy reliance on these mechanical appliances, places a burden on the Hospitals running and operational cost (Nwanya *et al*, 2016). Studies by Bulus, Hamid and Wah, (2017) on Courtyard as a passive cooling strategy in Buildings have been conducted on how passive strategies such as courtyards can be used to enhance the cooling of buildings, through the courtyards variants such as aspect ratio, form, configuration, as well as orientation. However, architects most times ignore the application of courtyard design variants at the design phase, which leads to undesirable effect such as still airs and air turbulence (Bittencourt & Peixoto, 2001) and it's also been found that a study that attempts to find out how cooling can be enhanced in healthcare buildings through courtyard forms in hot dry climate of Kaduna state Nigeria, has not been recorded. It is in line with this that the researcher was motivated to carry out the research.

## **1.3 Research Aim**

The research aims to find a passive way to enhance cooling in Healthcare Buildings, using courtyard forms in the design of a Women and Children Hospital in hot dry climate of Kaduna state, Nigeria.

#### **1.4 Objectives**

- i. To ascertain the application of courtyard as a passive cooling strategy in buildings
- ii. To ascertain the level of application of courtyard design variants for cooling in existing Hospitals in Kaduna State.
- iii. Determine the most3 efficient courtyard form for cooling in hot dry climate of Kaduna State through simulation.
- iv. To utilize the findings in the design of a Proposed Women and Children Hospital in the hot dry climate of Kaduna State.

#### **1.5 Research Questions**

- i. What is the effect of courtyard design on passive cooling in Buildings?
- ii. What is the level of application of courtyard design on cooling in existing hospitals in Kaduna State?
- iii. What is the most effective courtyard form for cooling in Kaduna State?

#### **1.6 Justification**

- i. Hospitals consume large amount of energy for cooling in order to provide the conduciveness for patients, staffs and visitors. This results in heavy reliance on alternative power supply such as generators. As a result, increases the daily operational cost of the Hospital. The research will therefore provide a passive alternative to optimize cooling energy in Hospitals through courtyard forms.
- ii. According to UNICEF Nigeria as cited by Enogholase (2017), every single day, Nigeria loses about 2,300 under-five year olds and 145 women of childbearing age. This makes the country the second largest contributor to the under-five and maternal mortality rate in the world. Similarly, it was revealed that a woman's chance of dying from pregnancy and childbirth in Nigeria is 1 in 13. Although many of these deaths are preventable. It has also been observed that the coverage

and quality of health care services in Nigeria continue to fail women and children. Presently, less than 20 per cent of health facilities offer emergency obstetric care. Inadequate health facilities have been blamed as one of the major factors plaguing the health of Women and Children in Nigeria, most especially in the North-east and North-west geopolitical zone where the situation is recorded to be more critical. It is hence paramount to provide a Women and Children Hospital to meet the ever growing needs of Women and Children healthcare in Nigeria.

### **1.7 Scope**

The scope of the research will be limited to healthcare facilities in Kaduna State metropolis, Nigeria. With a special focus on the courtyards form and aspect ratio as well as its usage as a passive cooling strategy. The research will also emphasis on the pediatric and maternity units of the Hospital. The design phase shall also in cooperate care givers accommodation to promote healing.

## **CHAPTER TWO**

### **2.0 LITERATURE REVIEW**

This Chapter was focused on studying previous researches on the subject matter, to get a broader understanding on the concepts of courtyards as a passive cooling strategy, and how it can enhance a buildings energy efficiency most especially healthcare facilities. The chapter also focused on Hospital design philosophies, requirements and overall guidelines for effective healthcare design. The chapter is structured in to follow chronology of the research aims and objectives.

#### **2.1 Concept of Energy Efficiency**

Energy efficiency is a global issue that is raising concerns most especially in the construction industry where energy consumption is high. More than 90 per cent of our time is spent in buildings i.e. either in the office or at home. The basic requirement of a building is to provide thermal comfort to its occupants. In modern buildings this is usually accomplished with the help of mechanical cooling or heating. With the advent of energy crisis, there has been a need to develop climatic design tools which will provide thermal comfort in a building without or with minimum expenditure of energy (Praharaaj, 2014). Energy used in buildings (residential and commercial) accounts for a significant percentage of a country's total energy consumption. This percentage depends greatly on the degree of electrification, the level of urbanization, the amount of building area per capital, the prevailing climate, as well as national and local policies to promote energy efficiency, Sustainable energy regulation as well as policy making for Africa. According to the Environmental Engineers (2007) the non stop function of the hospitals is an important factor why there is such a big energy consumption in Hospitals. According to U.S Department of energy, (2008), Today's building industry appears to be entering another era of change, with a view toward minimizing a different kind of footprint: the

energy, carbon, and environmental footprint of commercial and residential buildings. The growing demand for alternative energy sources to curb the rise in energy consumption in commercial buildings such as Hospitals, has challenged architects and other construction allies to devise passive strategies to enhance energy efficiency for cooling, lighting as well as ventilation. The courtyard has been utilized, as one of the passive means for optimizing cooling energy in the built environment.

## **2.2 Passive Cooling Strategies**

Cooling is the transfer of energy from a space or from the air, to a space, in order to achieve a lower temperature than that of the natural surroundings. In recent years, air conditioning systems are used to control the temperature, moisture content, circulation and purity of the air within a space, in order to achieve the desired effects for the occupants. The shortage of conventional energy sources and escalating energy costs have caused the re-examination of the general design practices and applications of air conditioning systems and the development of new technologies and processes for achieving comfort conditions in buildings by natural means (Geetha & Velraj, 2012). This topic, natural and passive cooling, covers all natural processes and techniques for cooling buildings. It is cooling without any form of energy input, other than renewable energy sources. Passive cooling strategy are also closely linked to the thermal comfort of the occupants. Geetha and Velraj (2012) also classified passive cooling into two major categories namely Heat prevention/reduction (reduce heat gains), Heat Modulation Heat dissipation (remove internal heat gains)

### **2.2.1 Heat prevention/reduction**

This is a passive cooling technique, that prevents heat surrounding the building from entering the building. It involves cooling measures of limiting the hotness of the surrounding heat, such that the surrounding heat is cooled off, when it comes in contact

with the cooling measures around the building. Some of this measures outlines by (Geetha & Velraj, 2012) includes;

#### *2.2.1.1 Building orientation*

This involves placing the building on the site taking cognizance of the sun path so as to minimize surfaces exposed to solar radiation. Proper building orientation plays an important role in reducing cooling loads in tropical climates where there is a high level of radiation from the sun. This can be achieved by reducing exposure of buildings to the sun, with the longer axis of the building facing the East-West direction. This will not only minimize the hot radiation received from the sun by building walls, but also enhance cooling breeze penetration (Ogunsote & Prucnal-Ogunsote, 2010)

#### *2.2.1.2 Shading devices:*

Shading is the first line of defence to reduce the ingress of solar gain, and it can also reduce the effective temperature experienced by an occupant by up to 8oC (Nick & Koen, 2005) This includes; overhangs, awnings, exterior shades, venetian blinds, curtains and drapers

#### *2.2.1.3 Landscaping:*

This include all soft landscape such as plants, trees etc., which absorbs most of the solar radiation incident on to the building by lowering the air and surface temperatures as well as increase the relative humidity of the surrounding air thereby making the air cold (Geetha & Velraj, 2012). Modification of the surrounding climate and irradiance reduction achieved by plants is an efficient means of lowering energy usage for space cooling and it has been shown that about 25-80% savings on air conditioning can be achieved with proper landscaping (C.Yu & Nyuk, 2009)

#### 2.2.1.4 *Building insulation:*

Heat naturally flows from a warmer to a cooler space; insulation provides resistance to heat flow, thereby reducing the amount of energy needed to keep a building warm in the winter and cool in the summer. Building Insulation is frequently discussed in terms of its ability to resist heat flow, or its R-value. A variety of insulation options exist, including blanket, concrete block, insulating concrete forms, spray foam, rigid foam, and natural fibre insulation (Geetha & Velraj, 2012). According to Taleb, (2014) passive design must include insulation to reduce heat loss or gain throughout the Building envelope.

#### 2.2.2 Heat modulation

Modulation of heat gain deals with the thermal storage capacity of the building structure. This strategy provides attenuation of peaks in cooling load and modulation of internal temperature with heat discharge at a later time. The larger the swings in outdoor temperature, the more important the effect of such storage capacity (Ogunsote & Prucnal-Ogunsote, 2010)

#### 2.2.3 Heat dissipation

This is a passive cooling technique which removes excess heat from the interior of a building by the use of natural heat sinks. Heat dissipation techniques deal with the disposal of the excess heat in a building to a heat sink characterized by lower temperature, like the ambient air, the water, the ground and the sky. Some of the heat dissipation measures stated by Geetha (2012) includes;

##### 2.2.3.1 *Natural ventilation*

Night ventilation strategies use the cool external air to decrease the indoor air temperature as well as the temperature of the building's structure. The cooling efficiency of night ventilation is based mainly on the relative difference between the indoor and outdoor

temperature during the night period, the air flow rate as well as on the thermal capacity of the building (Zinzi & Citterio, 2010). Natural ventilation systems rely on pressure difference to move fresh air through buildings. Pressure difference can be caused by wind or the buoyancy effect created by temperature difference or differences in humidity. In either case, the amount of ventilation will depend critically on the size and placement of openings in the building (Walker, 2010)

According to Haggag and Elmasry, (2011), the wind tower, atrium and Courtyard, have been used to increase the air flow in Buildings. It was also revealed that the courtyard have been adapted to enhance stack effect and speed up indoor air.

#### *2.2.3.2 Evaporative cooling*

A fountain can cool the air when it combines with water and evaporates leading to a reduction in air temperature in order to obtain the best effect from cooling by this method, the interaction between water and air needs to be as widespread as possible. If water is distributed well, this will be more effective in cooling the air. (Taleb, 2014)

#### *2.2.3.3 Green roofs*

Green roofs, or eco roofs, are becoming an appealing technique because they affect building aesthetics, improve of the air quality in urban areas and mitigate the urban heat island. Green roofs improve the building insulation thanks to the soil layer thermal resistance but also improve the building solar control, with most of the incident solar radiation being absorbed d by the vegetation layer for photosynthesis, respiration and evapo-transpiration. Performances of green roof are strongly affected by the used materials, building characteristics and use and climatic conditions. (Zinzi & Citterio, 2010)

#### 2.2.4 Courtyard as a passive cooling strategy

A courtyard can be defined as a covered outside space that is open to the element at its apex (Abass, Ismail, & Solla, 2016). Mishra and Ramgopal (2013) also defined a courtyard as an open room into the sky, bordered by a group of buildings or most important rooms. Courtyard housing is one of the oldest forms of vernacular architecture dating back to at least 5,000 years before present and occurring in distinctive form in many regions of the world (Taleghani, 2014). Courtyards were often the primary meeting places for specific purposes including gardening, cooking, working, playing, sleeping, or even in some cases as places to keep animals (Mohammadian & Sharghi, 2015). Courtyards belong to a specific type of space, called 'transitional space. This term covers a wide range of spaces from a passageway and a corridor to a balcony or porch. Transitional zones are the in-between architectural spaces where the indoor and outdoor climate is moderated without mechanical control systems. In these spaces the occupant may to a certain extent experience the dynamic effects of changes in the outdoor climate (Taleghani, 2014). A courtyard can provide security, privacy, and a comfortable place within the building. The courtyard not only provides comfortable condition and beautiful setting but also, offers a private and isolated space through which all rooms grouped around it receive sunlight, natural ventilation and visual as well as physical communications (Tabesh & Sertyesilisik, 2015). According to Zamani, Taleghani, & Hoseini (2012) the simple idea of including an open space like a courtyard in a building comes to mind when we need natural lighting, heating, cooling and ventilating in a solid building. Courtyard as a building component was initiated originally from the hot and dry climatic regions of the world. Thus, its application is most suitable in the tropics, even though it is applicable to all climatic regions (Edwards, Sibley, Hakmi, & Land, 2006). Antonio & Carvalho, (2015) further opine that the courtyard has a major impact on the

thermal characteristics of a building and can also be used as a space to stimulate the healing process, such as in Hospitals due to its natural healing environment. They continued that the Courtyard also contribute in a major way by modifying the climatic setting and thereby inducing mental and physiological sensation to its end users. Courtyards have often been adopted in buildings for different functions and benefits, which include Architectural benefits, social benefits, climatic benefits, cultural benefits, religious benefits as well as economic benefits (Almhafdy, Ibrahim, Ahmad, & Yahya, 2013). According to Tabesh and Sertyesilisik (2015) the courtyard as a passive design strategy evolved mainly in response to climatic requirements but inappropriate design may create challenges for controlling temperature, glare, and energy consumption in buildings. According Wadah (2006) there are three main factors in the climatic function of a courtyard building, these are sun, wind and humidity:

#### *2.2.4.1 Suns function on a courtyard climatic Building*

It is discussed that courtyard buildings somewhere are sun collector and somewhere sun protector. According to Sabzevar, Ahmad and Gharakhani, (2015) when solar radiation touches the surface, it is absorbed, transmitted or returned. Solar radiation absorbed by building surfaces, without shading, increases the surface temperature above that of the ambient air and add up to the cooling loads. They also added that the amount of received irradiation is dependent on some factors, which includes the Climatic conditions and site, the time and design of the courtyard form, in this regard, it is important to consider sunlight in addition to the thermal effect of the sun. Therefore, the correct orientation of the buildings and its courtyard and the proper position of the void (courtyard) in a solid mass (building) should be taken into account.

#### 2.2.4.2 *Winds function on a courtyard climatic Building*

Wind has two effects on a courtyard building. First it circulates between exterior space and inside the court; second it ventilates the interior building by the court air. In this regard, in hot areas during the night, warm air rises and exits from the court. Then, the cooler air will enter to replace the existing air. Hence, during the hot day, cool air is circulated to the rooms and the court can be a source of fresh and cool air

#### 2.2.4.3 *Humidity function on a courtyard climatic Building*

Humidity is needed in arid areas to achieve comfort by increasing the relative humidity of the air, the evaporation and corresponding increase of humidity are a result of sun and wind

### **2.3 Courtyard Design Variants**

The courtyard is a universal design element which has been put into practice for many centuries globally, particularly in houses. Its design has become an area of interest in recent times. Scholars have conducted numerous studies and offered the basic courtyard design variants for its optimum environmental potentials (Bulus, Evaluation of courtyard usage and design requirement in residential buildings in Nigeria hot dry climate, 2016). Architecturally, for the courtyard to really perform optimally certain design variables must be considered by the architect at the design stage (Almhafdy *et al* 2013, Ubbelohde & Louis, 2014). According to Bittencourt and Peixoto (2001) buildings with courtyards, require adequate attention when designing for natural ventilation as they can produce undesirable effects, like still areas, air currents and turbulent zones, depending on the relation between the size of the courtyard and the buildings height. Rempel, Gates, Shaw, (2016) revealed that the factors that influences design of courtyard for optimum microclimate or its environmental performance include; the area, number of floors, its degree of exposure, types of wall, orientation, natural elements within it and many more.

Sthapak and Bandyopadhyay (2014) also added that the courtyard shape, proportions, size, orientation, finishing materials, landscape, as well as the design of windows opening onto it, the internal spaces enveloping it and the housing cluster around it integrate to constitute the thermal performance of the courtyard house. Almhafdy *et al.*, (2013), developed a checklist for courtyard design as shown in table 2.1 below, in their studies on “Analysis of Courtyard Functions and its Design Variants in the Malaysian Hospital” as; Form, Shape, Area, Number of floors, Orientation, shading device, Water ground ratio, Vegetation, ground ratio and courtyard plan aspect ratio. Ghaffarianhoseini and Berardi (2015) also opined that, courtyard optimization through analysis of its design variants could contribute in reducing the duration of hours of discomfort to the barest level in a building. The major courtyard variants identified from previous studies includes courtyard configuration, orientation, wall enclosure, natural elements within the courtyard. (Almhafdy *et al*, 2013, Rempel, Rempel, Gates, & Shaw, 2016)

**Table 2.1** Showing checklist used in accessing courtyard design variants

**Source:** (Almhafdy *et al*, 2013)

| Courtyard Design Variants         |                                           |
|-----------------------------------|-------------------------------------------|
| FORM                              | Fully enclosed<br>Semi enclosed           |
| SHAPE                             | O- Shape<br>U-Shape<br>L-Shape<br>I-Shape |
| AREA                              |                                           |
| NOs OF FLOORS                     |                                           |
| ORIENTATION                       |                                           |
| SHADING DEVICES                   |                                           |
| WATER GROUND RATIO                |                                           |
| FUNCTIONS VEGETATION GROUND RATIO |                                           |
| HEALING PROPERTIES                |                                           |
| COURTYARD PLAN ASPECT RATIO       |                                           |

## **2.4 Courtyard Configuration**

A courtyard does not have a fixed plan. Although the basic plan of it, is usually rectangular or square, it can also be circular or curvilinear (Almhafdy, Ibrahim, Ahmad, & Yahya, 2013). Through history, this basic plan of the courtyard has been modified to fulfil many environmental aspects such as topography, site restriction, building orientation and function (Reynolds, 2002). Berkovic, Yezioro and Bitan, (2012) also asserted that the geometry (shape, size, area) and material composition of the courtyard are the basic determinants in designing courtyard with optimum microclimate. Courtyard building geometry is a product of a complex relationship of many parameters such as culture, size of the spaces, aesthetics, and landscape that have influenced the form of the courtyard (Sabzevar, Ahmad, & Gharakhani, 2015). According to (Morton, 1990) there are six possible courtyard dwelling configuration which are the I, L, U, T, H and O. the study revealed that the L shaped house is the most flexible form and the only courtyard configuration which satisfies design requirements of privacy, space, courtyard size, expansionpotential and density. The study howevr revealed revealed that there is limited flexibility in expanding plans. Further stressing that , orienting the plan for proper solar access becomes difficult most expecially in temperate climates. Bittencourt and Peixoto, (2001), further added that the courtyard configuration plays a critical role in naturally ventillating a building, suggesting that the use of natural ventilation has effects like still areas , air currents and turbulent zones which are heavily dependant on the relation between the width of the courtyard and the building height.

#### 2.4.1 Courtyard form

According to Rapoport (2007) form refers to the fundamental organization of space (as well as time, meaning and communication) he also opine that It follows that a courtyard can be square, rectangular, round or amorphous, and its boundaries can be defined in different ways. According to Abass *et al* (2016) the first design of courtyard housing is usually rectangular, square and circle. These forms have been converting to accomplish ecological aspects such as site limitation, topography, building orientation and function to produce new form such as U shape, L shape, T shape, V shape, H shape or Y shape. In addition, the design form of courtyard can be fully enclosed (four sided) as seen in figure 2.1 below

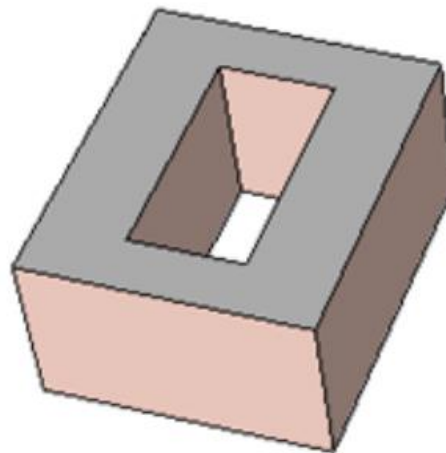


**Figure 2.1:** Showing an enclosed courtyard

**Source:** (Ahmed & Muhaisen, 2006)

The semi-enclosed (three sided) is boarded on three sides as can be seen in fig 2.2 However in some cases the courtyard can be two sided (Meir, Pearlmutter, & Etzion). Meir, *et al.* (1995) studied the effect of three sided courtyards on the microclimate in hot dry regions. The courtyard created better microclimatic condition; particularly when

some variables are taken into consideration such as the orientation, attach volume and ventilation.

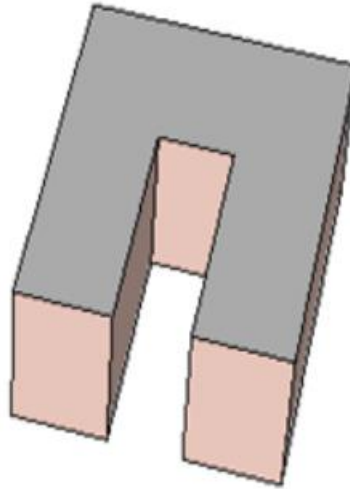


**Figure 2.2:** Showing semi enclosed courtyard

**Source:** (Ahmed & Muhaisen, 2006)

Mohammadian and Sharghi (2015) in their Comparative study of the central courtyard typology for sustainability in traditional hot arid and cold arid climates opine that the structure of the central courtyard (fully enclosed) is the best option to adjust the sunlight, amount of shading, distribution of light and other relevant factors in hot arid and cold arid regions. According to Muhaisen (2006) the courtyard building form can be an efficient modifier to the different climatic conditions if special arrangements are made at the early stages of the building design. This includes the internal envelope finishing and materials, as well as the proportions and physical parameters of the courtyard form. Numerous studies have tried to discover the best size of geometric shape such as: round, polygon, quadrilateral and right-angled form of courtyard in diverse climates (Markus, 2016). Tabesh and Sertyesilisik (2015), indicated that altering the form's sizes in circular model expressively effects shading or exposure possibility of the courtyard interior and that shallow courtyards do well than the deeper ones in cold climates. The study developed a mathematical model to calculate the produced shaded and sunlit areas in a circular

courtyard geometry. The results showed that changing the form's proportions significantly influences the shading or exposure potential of the internal courtyard envelope, concluding that courtyard exposure to radiation can significantly affect cooling and heating. Again, Muhaisen and Gadi (2006) used computer simulation studies to investigate the effect of solar heat gain on courtyard form with diverse sizes in temperate climate of rome. The study discovered that courtyards with deep forms need low energy for cooling in summer. In another study on polygonal courtyard form with pentagonal, hexagonal, heptagonal and octagonal plans, (Ahmed & Muhaisen, 2006) opined that courtyard with deeper forms with any kind of shape can be suggested for obtaining optimum internal shading in dry regions. But in cold regions, shallow forms were recommended for optimum sunlit areas. In similar view Baboli, Ibrahim and Sharif (2015) opine that the courtyard height is the leading element among the rest, the increase in the height of the courtyard reduces amount of solar radiation exposed to outer surface, and hence, significantly increases self-shaded areas. Muhaisen and Gadi (2005) conducted a modelling study to investigate the effect of rectangular courtyard sizes on the shading circumstances on the interior covering of the form in four different settings comprising of hot humid, hot dry, temperate and cold climatic regions. The results showed the optimum courtyard height to obtain a reasonable performance in summer and winter which was found to be three-storey in hot humid climates, two-storey in hot dry and temperate climates, and one-storey in a cold climate. The study also concluded that the sun location has a direct relationship to the generated shading conditions in the considered form, recommending that for efficient courtyard performance, the form's surfaces and its surroundings must be protected from intense solar radiation and the hot dusty winds (Yasa & Ok, 2014). The courtyard buildings, which we face either as a regulator of inter-building microclimate or as a climatic regulator at urban scale especially in hot climate

regions, and which constitute one of the fundamental characteristic building styles of such climatic regions, should be applied in a form compatible with the features of the climatic region it is used.

#### 2.4.2 Courtyard aspect ratio

There are several aspects that affect the performance of the courtyard. The courtyards length, shape and height are among the most important factors that have to be taken into consideration. The use of natural ventilation has effects, like still areas, air currents and turbulent zones, depending on the relation between the width of the courtyard and the buildings height (Bittencourt & Peixoto, 2001). As far as courtyard length and depth is concerned, it is one of the subjects which affect courtyard performance in terms of solar gain and also the total energy load of the rooms surrounding the courtyard (Alwetaishi, 2016). The aspect ratio is defined as the ratio of height to width of the courtyards (Alvarez, Sanchez, & Molina, 1998 ). Sthapak and Bandyopadhyay (2014) defined Aspect ratio as “the degree of openness to sky”. Also stating that the greater the aspect ratio, the more exposed the courtyard is to the sky. They also provided its formula as:

$$\text{Aspect ratio} = \frac{\text{Area of the courtyard floor}}{\text{Average height of the surrounding walls}}$$

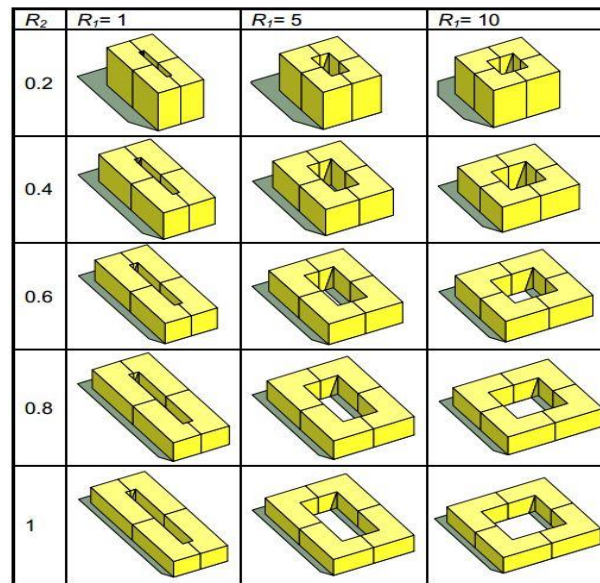
Their study further revealed that if the courtyard is wide and shallow (high aspect ratio), it performs as sun collector. On the other hand, the narrow and deep courtyard (low aspect ratio) performs as a sun protector, in which orientation has a weak effect on the house. Tablada (2013) observed that in low rise residential building, the aspect ratio (W/H) of the courtyard influences the indoor air speed values, with the exception of the air speed inside the upstream rooms. A single courtyard with W/H = 0.66 provides higher indoor air speed than a narrow courtyard with W/H = 0.33. Two consecutive wider courtyards of the ratio (W/H = 0.66) will provide higher indoor air speed than two courtyards of W/H

= 0.33 for the central rooms. The study also stated that buildings with a wide courtyard ( $W > 6\text{m}$ ) could have a maximum height of 11 m (3 - 4 floors). If one or two wide courtyards ( $W \geq 7\text{m}$ ) are linked with the street, the maximum height of the building could be 14m. The study further recommended that wider courtyards ( $0.6 \leq W/H \leq 1.0$ ) should have proper sun shadings over windows and courtyard walls (e.g. exterior horizontal louvers or pergolas with vines), the use of movable louvers as part of the window system is recommended for the main rooms on every floor, Sun shadings should protect, at least, the top floor rooms facing the narrow courtyards ( $0.3 \leq W/H \leq 0.5$ ), the use of transitional spaces around courtyards like galleries and balconies should be promoted in order to avoid direct solar radiation and brusque changes in radiant temperature and daylight values. Meir (2000) on his study on Courtyard microclimate in hot arid region opine that the degree to which the given surface of the courtyard is cooled at night by long-wave outgoing radiation depends on its exposure to the sky dome. Thus, urban spaces with a high H/W ratio, or a limited sky view factor, cool more slowly due to their restricted long-wave radioactive potential. Manioglu and Ora (2015) in their study of the ‘‘Effect of Courtyard Shape Factor on Heating and Cooling Energy Loads in Hot-Dry Climatic Zone’’ observed that in hot dry climatic regions the geometry of the courtyard and the building form affects considerably the façade area of the courtyard, and consequently the solar radiation gain and the cooling and heating loads of the building. Further stating that the best indicator describing the façade area of the courtyard is the shape factor which can be defined as the ratio of courtyard width (W) to courtyard length (L), the study concluded that W/L ratio applied for different courtyard building forms has a significant effect on the cooling and heating loads and solar gain, which is due to the W/L ratio effect of courtyard building form which -results in low energy requirement for cooling. Farzaneh, Mehdi and Seyed (2016) in their study of Passive cooling strategies of

traditonal Iranian courtyards states that the length to width ratio of courtyard varies between 1.09 to 1.68. Muhaisen and Gadi (2006) in their study of the effect of courtyard proportion on solar heat gain and energy requirement in temperate climate of rome, tested courtyards with different ratios as shown in fig.2.3 below

**Figure 2.3:** Showing different tested courtyard ratios

**Source:** Muhaisen and Gadi, (2006)



This was done by varying ratios  $R_1$  and  $R_2$  with  $R_1$  representing the courtyard floor perimeter ( $p$ ) to the forms height ( $h$ ) which ranged from 1-10 in one degrees step,  $R_2$  on the other hand indicates the ratio of the rectangular courtyard width to length ( $W/L$ ) which varies from 0.1 and 1 in one degree step. The minimum width of the courtyard was assumed, in this study, 1m, which is the distance unit used to represent the forms real dimensions. Therefore a courtyard form with ratio  $R_2$  equal to 0.1 means that the form has, for example, 1m width and 10m length. If ratio  $R_1$  for this form is 1, the height of the courtyard will be 22m. area of all the forms investigated in the study (100 cases) were taken as having a constant wall surface area of (484m<sup>2</sup>), fig. 2.4 below shows the effect of changing  $R_2$  at the different values of  $R_1$  on the required heating and cooling load through out the year.

Muhaisen and Gadi (2006) concluded that deeper courtyard forms were the most preferable, which was due to the reduced amount of irradiation received in deep forms in summer which results in low energy requirement for cooling whereas, in winter, deep forms ensure minimum heat loss and thus the need for heating.

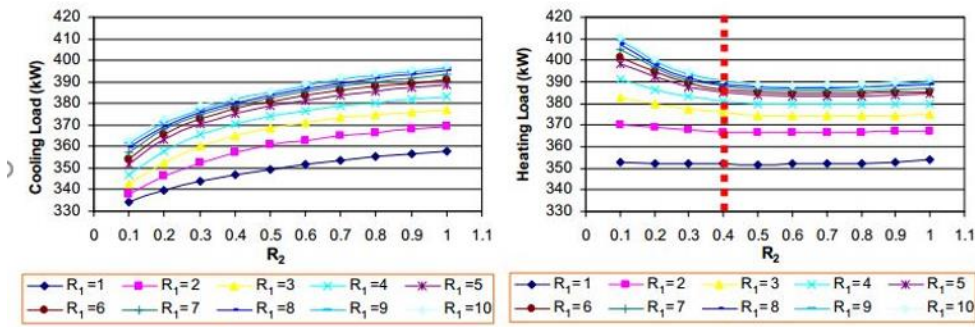


**Figure 2.4:** Showing cooling and heating charts of simulated courtyard ratios

**Source:** Muhaisen and Gadi, (2006)

### 2.4.3 Courtyard Orientation

The first response to local climate is orientation in reference to sun or wind. The sun might be the principal source of comfort or discomfort, thus determining the orientation of buildings and spaces if possible (Pulido, 2012). The main aim of orientation of the buildings in hot climate is to produce shading in the exterior living spaces and minimize the temperature inside building. There are two main objectives that should be considered in design which is wind direction and sun position. In other words, the sun angle and declination in all the seasons and each hour in the day have to be considered in design (Baiz & Fathulla, 2016). Orientation of courtyard depends on the building layout. Variables that can positively affect the microclimate condition within the courtyard are sun location, wind direction, shading performance and solar gain (Almhafdy, Ibrahim, Ahmad, & Yahya, 2013). In terms of orienting courtyards, in hot and humid climate, orienting the long axis of the courtyard toward northwest-southwest is recommended as well as north-south axis (Alwetaishi, 2016). Baboli, *et al.* (2015) also shared the same

view in terms of the recommended orientation of courtyards. This orientation will ensure a breeze to cross the courtyard in summer and also to open access for sunlight in winter in order to warm up the courtyard passively. Tablada, (2013) in his study of the Design recommendations for new courtyard buildings in compact historical centre of Havana in tropical humid climate states that the orientation of the courtyard's main axis should prioritize the climatic factors of (prevailing winds, solar radiation). He also stressed that windows orientation on top-floor rooms should be taken into account according to the function of the room. Daytime rooms like living -rooms should preferably be oriented towards the SSE-NNW. Berkovic *et al* (2012) continued that elongated east-west rectangular courtyard has the smallest portion of shade and consequently, not recommended for effective shading strategy for cooling. Reynolds (2002) also made the points that which side of the courtyard receives direct sun and at what time of the day determines where and when maximum daylight and optimum thermal comfort is available for people and plants. In rectangular but non-square courtyards oriented to the cardinal compass, those that are elongated east-west and have their longer sides face north and south, direct sunlight in summer can be prevented from entering the longer sides with shallow overhangs, leaving the openings available for wind. The shorter sides, however, get strong direct sun across the length of the courtyard in the morning or evening of dry seasons. In cold seasons, when strong sunlight is welcome, it is almost absent. Courtyard orientation is another vital design requirement. Although past studies have not proved the best orientation, the common assumption is that courtyard orientation with its longest axis facing north-south will improve thermal performance (Almhafdy *et al.* 2013).

#### 2.4.4 Natural elements within the courtyard

Natural elements are applied as soft landscapes to enhance visual comfort of the built environment. It is used both as indoor and outdoor elements. Shokouhian, Soflaee and

Nikkhah, (2007) described the courtyard, as an organism and ecosystem is made up of bodies. These bodies can be separated from each other in two major categories. The first category is natural bodies that consist of soil (other minerals), sky, water, plants and human. The second category consists of man-made bodies such as frame, architectural material and human products which complement each other. In similar view, Muhaisen (2006), opines that vegetation in a courtyard can significantly affect the thermal performance of a courtyard as it provides shade and increase humidity level most especially in hot-dry climatic regions. Al-hemiddi and Al-saud (2001) also revealed in a study on the impact of applying a water pond in a courtyard that the interior courtyard with a pool during sunny hours delivered substantial cooling impact within the internal courtyard envelope. Also, placing natural elements within a courtyard would produce environmental benefits. For instance, Safarzadeh and Bahadori, (2005) found that trees, shrubs and flower plants (as a garden elements) within a courtyard can significantly affect the thermal comfort as they provide shaded area with the wall of the courtyard. Proper Landscaping can be one of the important factors for energy conservation in buildings. Vegetation and trees in particular, very effectively shade and reduce heat gain. Trees can be used with advantage to shade roof, walls and windows. According to Kamal (2012) shading and evapotranspiration (the process by which a plant actively releases water vapour) from trees can reduce surrounding air temperatures as much as 5°C. Different types of plants (trees, shrubs, vines) can be selected on the basis of their growth habit (tall, low, dense, light permeable) to provide the desired degree of shading for various window orientations and situations.

#### 2.4.5 Wall enclosure surrounding a courtyard

Wall enclosure refers to all components that form the courtyard within the building and separate its semi-enclosed conditioned space and fully closed condition space. Courtyard

wall enclosure components such as walls, doors and windows need to be considered during the design stage (Almhafdy, Ahmad, Ibrahim, & Yahya, 2016). Courtyards enclosing walls varied from one region to the other. The variations are caused by the social, cultural, economic and eco-friendly conditions. Even though the design remains analogous, the requirements of the design are determined by usage and location (Meir, 2000). Wall enclosure can be defined as the summation of the courtyard components within the building. These components include; walls, doors and windows. They play a significant role in the microclimate performance of the courtyard through natural ventilation strategies. They can also be influenced by opening or closing of the openings and by altering the wall to window ratio. According to Al-hemiddi and Al-saud (2001), insignificant cooling is observed when all windows are closed. But, opened windows and doors improve natural ventilation in courtyard. Other scholars such as; Muhaisen, (2006) and Bagneid, (2006) agreed that other factors to be looked into when optimizing courtyards are the choice of the component material, colour and specifications.

## **2.5 The Role of Courtyards in Hospitals**

The courtyard's benefits extend beyond being a micro climate modifier but also functions as a multi-purpose outdoor space that brings all sorts of benefits to institutional spaces like the Hospital (Agnes, 2005). Amongst public institutions, the large buildings and complicated intervening and surrounding areas of hospitals usually tend to be seen by the public as removed from the urban context, as spaces to be feared, which one only accesses in emergencies or out of necessity. However, this psychological perception of their distance and separation can be decreased by today's more hospitable approaches to their content and design. As a result of this new, holistic approach to medicine which entails alleviating the fears and disorientation of patients that may hinder medical treatment, the hospital has come to be seen today as a necessarily comforting and stress-free

environment, created with a broader, patient-oriented sense that encompasses both master planning and landscaping. This means that the outdoor as well as the indoor spaces of hospitals are understood as crucial to patients' physical, psychological and social recuperation and wellness (Agnes, 2005). According to Yücel, (2013) Courtyards are traditionally enclosed zones that can help to channel and direct the overall airflow and thus modify the microclimate around the buildings like Hospitals. Based on the relative position of wards and corridor to the courtyard, this type of natural ventilation system can be divided into the inner corridor and outer corridor as shown in Figure 2.5

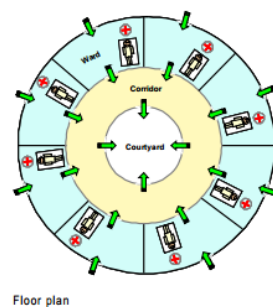


**Figure 2.5:** Hospital floor plan showing impact of courtyard space on air movement

**Source:** Yucel, (2013)

This system can supply more ventilation than the others, as long as the courtyard is sufficiently large. The outer corridor type has an advantage over the inner type, because it can avoid cross-infection via connected corridors by delivering clean outdoor air into the corridor as seen in figure 2.6 below

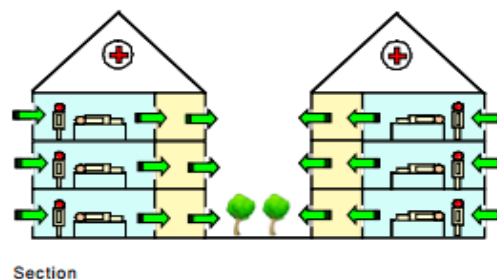


**Figure. 2.6:** Section showing movement of air through courtyard space

**Source:** Yucel (2013)

### 2.5.1 Benefits of courtyard in Hospitals

The outdoor as well as the indoor spaces of hospitals are understood as crucial to patients' physical, psychological and social recuperation and wellness. Evidence-based research has drawn a clear connection between natural views in the healthcare setting and improved patient outcomes. Also, benefits of providing access to nature extends to hospital staff in the form of reduced stress and enhanced sense of well-being. The importance of outdoor spaces like courtyards can be broken down to:

#### 2.5.1.1 *Physical benefits of courtyard*

Research shows that rehabilitative structures and procedures enhance both the physical endurance and the physical well-being of patients. Interaction with a natural environment has a positive effect on patients' feeling of well-being, which in turn has a salutary effect on their physical health. In addition to subjective evidence, there are theoretical and practical studies illustrating the positive effects of interaction with nature on blood pressure, cholesterol levels and stress-reduction : a study by Ulrich, (1984) concluded that patients recovering from operations were discharged earlier, took fewer analgesics and were evaluated less negatively by nurses when they had windows in their rooms overlooking nature, compared to patients in similar rooms facing brick walls and a study of the home environment similarly found that a living context with windows overlooking a natural scene produced "micro-restorative experiences" that enhanced a sense of well-being, as against a context with views of built elements

#### 2.5.1.2 *Psychological benefits of courtyard*

Being able to choose between having privacy and interacting socially may assist in the process of recovery of patients, for most of whom the rigid regulation of time and activity in the hospital can have negative psychological effects, such as loss of self-esteem or the feeling of control, and a resulting increase in stress. Research shows that high blood

pressure and heart activity caused by stress can be decreased if patients are exposed to natural scenes, because such scenes engage them, draw their focus away from themselves and disturbing thoughts, and so contribute to their recovery. Research conducted in London by the Bow centre, (2018) used flower and cutting gardens for horticultural therapy; patients are overwhelmingly in favor of well-designed hospital landscapes, because of their positive psychological effects and the chance to pass time there

#### *2.5.1.3 Social benefits of courtyards*

Everyone, regardless of age or ailment, needs recreation and social support; participation in social activities may also be the only means of family and community interaction and integration, and of sharing similar experiences, for the physically disabled. Studies have shown that patients with strong social support networks typically experience less stress and better health, as well as better recovery and survival rates for various conditions, than those who are isolated. Social support improves immune functions and moods, and results in better compliance with treatment. Natural environments in health care facilities contribute to social integration by providing spaces for social interaction and support; evidence indicates that they significantly help increase access to social support for patients, families, and staff

## **2.6 Concept of A Hospital**

Hospital is an institution for the care, cure and treatment of the sick and wounded, for the study of the diseases, and for the training of the doctors and nurses (Williams & Wilkins, 2005). In olden days, hospitals were guest houses for the shelter of the homeless and of the treatment of travelers. In modern times, the chief function of the hospital is to provide care and treatment to the sick. The World.Health.Organization, (2003) defines the term "hospital" as an institution that provides in-patient accommodation for medical and nursing care. It further elaborates the definition to cover hospitals that assume additional

functions i.e., curative, rehabilitative and preventive services, directly or in a consultative capacity, also participating in the training of personnel and in research work.

#### 2.6.1 Hospital design philosophy

As a place dedicated to health, a hospital building must first be a healing, life-affirming space that plays an active role in helping patients and their families return to health. Hospitals of the future will need to plan for higher patient acuity, shorter stays, and must deal with aging patients (and staff). Because of their long term operational costs and long life cycle, hospitals have to be designed for improved performance and work flow, and with a high degree of flexibility and adaptability for constant change (Hussain, Kamal, Babalghith, & Omer, 2014). The detailed architectural and interior design philosophy of the future hospital needs to start with this feeling of hospitality, and of providing a link to nature and the world beyond. The facility design has to provide a safe, comfortable environment, and reduce stress and confusion for patients, families, and staff. A successful design will recognize the dimensions of life as well as the needs of efficient operations and include art as well as technology. The design team needs from the outset to plan for sustainable design and reduced energy usage, which in a building that operates continuously is a major opportunity for lowering the carbon footprint of the service. To maintain a feeling of wellbeing and positive support for the needs of people, the hospital must also have clear, intuitive way finding and an easily understood layout (Carr, 2017)

#### 2.6.2 Hospital design goal

According to Sprow (2015) clearing the decks for a new approach to the ideas of hospital planning begins by keeping five key goals firmly in mind, this includes Patient centeredness, Efficiency, Flexibility, Healing Environment, Sustainability as shown in Table 2.7 below

**Table 2.7:** Hospital design goal

**Source:** Sprow (2015)

| <b>Hospital Design Goals</b> |                                                                                                                                     |
|------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| Patient centred              | Patient centered care and family as part of the care process, since the patient is the hospital's reason for being                  |
| Efficiency                   | Efficient operations, clinical safety, optimal functional relationships, value for money, modern systems, low upkeep requirements   |
| Flexibility                  | Flexibility for expansion and new technology in unexpected ways over long useful life.                                              |
| Healing Environment          | The hospital should be conducive to patient, staff and visitors. Healing environment should include greenery, water bodies, art etc |
| Sustainability               | Sustainable design approach and reduced energy usage,                                                                               |

### 2.6.3 Types of Hospital

According to the PSS Central Institute of Vocational Education, (2014) Hospitals are generally distinguished by their ability to admit and care for patients. These classification includes.

#### 2.6.3.1 District Hospital

This types of Hospitals are usually the first referral Healthcare facility that is responsible for the healthcare delivery of a particular geographical location containing a defined population and Governed by a politico-administrative organization such as a district health management team. It is possible that the term “District Hospital” may vary in definition from region to region but remains unique in its functions and operation (World.Health.Organization, 2003).

#### 2.6.3.2 General Hospital

This type of Hospital is set up to deal with all sorts' diseases and injuries and usually has an emergency unit that caters for the main objective of General Hospital is to provide medical care, whereas teaching is secondary (World.Health.Organization, 2003).

#### *2.6.3.3 Specialized Hospital*

These hospitals concentrate on giving medical and nursing care in a specific area, e.g., ophthalmic hospital (deals with eye related problems), orthopedic hospital (deals with bone related problems), cardiac hospital (deals with heart related problems) (Carr, 2017).

#### *2.6.3.4 Teaching Hospital*

The primary objective of teaching hospital is teaching and training of doctors. For example, Medical Colleges (Carr, 2017).

#### *2.6.3.5 Isolated Hospital*

This is a hospital in which clients requiring isolation or clients suffering from communicable diseases are taken care of.

#### *2.6.3.6 Rural Hospitals*

These hospitals are located in rural areas, permanently staffed by at least one or more physicians, which offer inpatient accommodation and provide medical and nursing care for more than one category of medical disciplines (Agnes, 2005).

#### 2.6.4 Hospital structure/system

Hospitals are patronized for their aim of meeting the Healthcare needs of the society. The concept of the Hospital is basically classified into four categories as shown in Fig 2.7 below

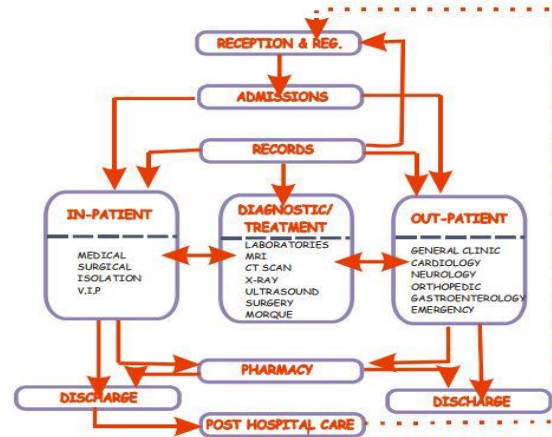


**Figure 2.6:** Hospital design frame work

**Source:** Carr, (2017)

- i. The out- patient units
- ii. The in-patient units
- iii. Administrative units
- iv. Diagnostic and therapeutic units
- v. Auxiliary services

##### 2.6.4.1 The outpatient ward

This is the first point of contact with the Hospital, outpatient care may be delivered in a medical office or a Hospital, but most commonly it is provided in a medical office or outpatient medical unit. The outpatient ward consists of the reception/inquiries, Clinics,

waiting area, emergency units and also auxiliary facilities like shops, cafes, pharmacy etc. The outpatient area is the first point of contact as such requires careful and detailed design (Agnes, 2005).

#### *2.6.4.2 Inpatient ward*

An inpatient is admitted to the hospital and stays overnight or for an indeterminate time, usually several days or weeks. Treatment provided in this fashion is called “inpatient care”. This unit is concerned with patients whom may require close monitoring and may need to stay overnight. It also specializes in nursing and monitoring ill patients that need prompt attention (Carr, 2017).

#### *2.6.4.3 The administrative unit*

The coordination and running of the hospital is conducted here. This includes the finance, records, personnel, maintenance etc.

#### *2.6.4.4 Diagnostic/Treatment unit*

In addition to the direct care of inpatients and ambulatory patients, hospitals routinely provide centralized technical services to assist in the diagnosis and treatment of patients, which need to be accessible easily to both types of patients without mixing the two. As in direct healthcare, the essence of the program requirement here is for relatively small, highly specific rooms in which specific services are performed (Carr, 2017). This is the most critical and vital component of the Hospital. It is concerned with the diagnosis of the different ailment and also treatment. The diagnosis may be in form of scanning in different forms ranging from x-rays, CT scan, and MRI etc. it also comprises of laboratories for test, chemical storage, equipment storage and most vital surgical unit's theatre procedure rooms, preparation rooms, recovery room, sluice room, supply storage

etc. The design of these units requires careful analysis and understanding of the services and all the specialized units. (Hussain *et al*, (2014)

#### 2.6.4.5 Ancillary services

These are supportive facilities required for the support and proper functioning of all the other units. This is a less-technical space which supports the other functions, with the ability to deal with the needs of patients, visitors, and staff members and traffic which vary over the 24 hour, 7 days' cycle of hospital operations. Support services include staff facilities such as lockers, education and training, on-call rooms for on-site medical staff, lounges and staff rooms for employees who often cannot leave their work areas for breaks, and overall administration and office activities. They also include back-of-house hotel type services such as dietary kitchens and services, materials management for clean supplies and equipment, pharmacy services, housekeeping, loading bays, waste management, and engineering and maintenance functions. Separation of circulation (Hussain *et al*, (2014).

## 2.7 Findings from Literature Review

This chapter was set out to study previous researches on the subject matter, to get a broader understanding on the concepts of courtyards as a passive cooling strategy, and how it can enhance a buildings energy efficiency most especially healthcare facilities. The chapter also focused on Hospital design philosophies, requirements and overall guidelines for effective healthcare design. It was found that the courtyard configuration of form, aspect ratio, orientation, wall enclosure and natural elements within the courtyard, plays a fundamental role in courtyard performance. The rectangular courtyard form was also identified to be the most applicable in hot and dry climates. It was also found that a two storey building will give the courtyard an ideal height for efficient performance in the hot and dry climatic regions. The study further went on to identify key

design variants for healthcare facilities, such as accessibility to facilities, proper zoning of the Hospital complex and the relationship between the core sections of the hospital, comprising of the outpatient ward, Inpatient ward, the clinical ward, administrative area and the ancillary areas. The studies reviewed further went on to establish the design framework, relating this core spaces and how it can be harmonized in the design of a women and children Hospital that will meet the research aim.

## **CHAPTER THREE**

### **3.0 METHODOLOGY**

#### **Introduction**

This chapter described the methodology adopted and how it was used to achieve the research aim and objectives. This section shed light on the study area, sampling procedure, collection of data and its analysis. It also revealed the design variables considered such as the courtyard configuration and its design variants and its effect on passive cooling. The study was also conducted in such a way that future researchers can adopt the strategies used.

#### **3.1 Research Design**

The study employed a mixed research strategy by exploring both qualitative and quantitative approach, first a case study was conducted by visiting some selected hospitals in the study area, these hospitals were selected purposively and it includes The Ahmadu Bello University teaching Hospital, Shika, Gwamna Awan general Hospital, Kakuri, Kaduna and the Barau Dikko specialist Hospital, these Hospitals were studied using a checklist of courtyard design variants affecting passive cooling and these variants were identified from literature review. Secondly, base case models were developed, and the models were assumed to be located in Kaduna State, the models were designed with different courtyard ratios to identify the ideal courtyard form that has the best effect on passive cooling in the study area.

##### **3.1.1 Case study**

For the purpose of this research an analytic and comparative study was applied and it was done by purposefully selecting health care facilities some in the study area. It involved

an in depth study of the selected Hospitals with the aid of a checklist, which was gotten from previous studies.

### 3.1.2 Case study selection criteria

Sampling is the act, process, or technique of selecting a suitable sample, or a representative part of a population for the purpose of determining parameters or characteristics of the whole population (Fridah, 2002). For the purpose of this research, a non-probability sampling was used. For a case to be selected as observed by (Oluigbo, 2010), it must possess some intrinsic features or qualities which are in relation with the phenomenon under investigation. Hence the adopted sampling technique adopted for this research was purposive. Some selected Hospitals which have related peculiarities to the topic under consideration were selected, the cases were selected based on their potentials to supply the necessary information needed for the purpose of the research. it includes, The Ahmadu Bello University teaching Hospital, Shika, Gwamna Awan general Hospital, Kakuri, Kaduna and the Barau Dikko specialist Hospital,

### 3.1.3 Study population

According to the University of Missouri, a population study comprises of a complete set of elements (persons or objects) that possess some common characteristic defined by the sampling criteria established by the researcher. For the purpose of this research, the population consists of the buildings of the selected Hospitals which included Ahmadu Bello university teaching Hospital, Barau Diko general Hospital Kaduna, Gwamna Awan General Hospital, Kakuri, Kaduna.

### 3.1.4 Variables of study

According to Kaur (2013) 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. In these endeavors, one variable is hypothesized to be the cause and the second variable is the effect. The term for the cause is the independent variable; the term for the effect is the dependent variable (Indiana University, 2016) The dependent Variable for this research is the buildings cooling load as a factor of energy efficiency. whilst the independent variable will be the courtyards form which consisted of its form, aspect ratio and orientation. the courtyards aspect ratio is defined as its width to length ratio W/L.

### **3.2 Data Collection**

According to Maina (2014) several data collection instruments exist for Case studies and Surveys in architectural research. These include but are not limited to personal observation, photographs/sketches, physical scaled drawings, interviews and questionnaires. But for the purpose of this research, case studies were selected and data was collected through visual survey which was conveyed through a checklist, also a block model of the most qualified cases study was developed using Revit design software and simulated with ECOTECT for validation purpose.

#### **3.2.1 Visual Survey**

Visual survey involved visit by the researcher to the selected Hospitals and it entailed the careful observation of various design features with emphasis on the courtyard variables affecting cooling in the Building. These variables were outlined from studied literature. Data was obtained by descriptive write-ups, photographs and sketches where necessary. The information gathered was used in assessing the outlined variables. The Hospitals were studied and analyzed individually by using a checklist. The checklist was focused on the courtyard design variants affecting passive cooling such as courtyard form, aspect ratio, orientation, wall enclosure and Natural elements present in the courtyard.

### **3.3 Data Analysis**

Data obtained from the case study was used to develop a base model which was used to test the various courtyard forms. The model was created using Revit architecture design software, after which it was simulated using ECOTECT energy software to ascertain the cooling effect of the various courtyard forms under consideration.

### **3.4 Data Presentation**

A descriptive, quantitative and qualitative analytical technique was applied in this study. However, the data obtained from each case study was analyzed and represented in different forms which included:

#### **3.4.1 Description**

This involved giving a summary account of the study variables investigated, it also entailed giving full description of the Hospitals studied by their history, architectural expression and spatial relationship between spaces.

#### **3.4.2 Plates and Figures**

Data collected during the case studies were presented in form of drawings sketches and images, this was done to give a graphical illustration of the issues under consideration, these illustrations were also tagged as plates and figures.

#### **3.4.3 Graphs**

Graphs were used to interpret quantitative data; this was done using computer aided software's. Initially, base case models were designed using Revit architectural software and were subsequently exported to Ecotect for energy simulations, the results were

exported to Microsoft excel, which was used to generate graphs to give a visual representation of the results.

#### 3.4.4 Charts

Data obtained from the study was also presented on a bar chart, to help show distribution and classification of results obtained, similar to the graphs, the charts were also used to show graphical expression of results obtained.

### 3.5 Conclusion

This chapter illustrates the step by step processes involved in carrying out this research. It employed both qualitative and quantitative methods of research, the qualitative method involved studying the courtyards of some selected Hospitals within the hot and dry climate of Kaduna State, as highlighted in the chapter. The Courtyards were studied using a visual survey, which was aided by a checklist that was adopted from literature review, the quantitative method involved developing base case models with varying courtyard ratios, ranging from 1:0.2 to 1:2, the models were designed using Autodesk revit architecture and was simulated using Ecotect software, the results were analysed using bar charts and graphs. The results from the study are further elaborated in the subsequent chapte

## **CHAPTER FOUR**

### **4.0 CASE STUDY REPORT**

#### **Introduction**

This chapter presents in detail how the data collected were analyzed in order to achieve the aim of the research which is enhancing energy efficiency in healthcare buildings through courtyard forms in the design of women and children Hospital in hot dry climate of Kaduna. The analysis was carried out in line with the research questions.

This section presents the results of the cases investigated. For the purpose of this research three case studies were conducted across selected hospitals within the hot dry climate zone of Kaduna state. This Hospitals include: The Ahmadu Bello University Teaching Hospital, Shika, as shown in plate I, Gwamna Awan General Hospital Kakuri and Barau dikko Teaching Hospital all located in Kaduna state. The study was focused on the variables outlined from literature as highlighted in the methodology of the research. These variables are the factors affecting courtyard design variants and its effect on energy efficiency in Hospitals.

#### **4.1 Case Study One: Ahmadu Bello University Teaching Hospital, Shika**



**Plate I:** Showing Main entrance of ABUTH Shika, Zaria

**Source:** Author (2017)

#### 4.1.1 Background Information

The Ahmadu Bello University Teaching Hospital as shown in plate I above which is formerly known as the institute of health was established in 1963 and opened in 1968. It was established by the former Northern Nigeria Government with the objective of providing facilities for training of Doctors, Nurses and other Medical personnel. The Hospital is presently run by a board established in 1985 and it comprises of the Chief executive (chief Medical director and other statutory officers, which is headed by Prof. Lawal Khalid. The Hospital comprises of two Major departments, the clinical department which includes Surgery, Medicine, clinical pathology, Pediatrics, Psychiatry, Med. Microbiology Maxillo facial surgery, Traumatic & Orthopedic, ophthalmology, Radiology, Community medicine, CHO Training, Anesthesia, Physiotherapy, O&G, Homology, H.I.M, Radiotherapy & oncology, Family medicine and pathology whilst the Non clinical department comprise of the Admin. Department, Finance department, Audit, HIM, works, security, laundry and med. social service. The study was focused on the pediatric and obstetric departments of the Hospital as stressed in the scope of study.

#### 4.1.2 Energy consumption in ABUTH Shika

The Hospital has two major sources of power supply, the supply from the Kaduna state electricity distribution cooperation (KAEDCO) and that from the generators. This is due to insufficiency of power supply from the state distribution cooperation. The KAEDCO supply is distributed by a central grid system via a 33kv metering unit as can be seen in Plate II below. This central unit is responsible for distribution of electric power to the various units of the Hospital, the Hospital consumes about 10036.6 kWh to 11488.6kWh monthly as at the time of the study. According to the Facility Engineer, the hospital receives an estimated average of 96hrs of electric supply in a week, these might seem satisfactory but the intensive nature of power demand in the Hospital makes this supply

insufficient.as such the Hospital has three standby generators with a combined output of 2500kv as shown in the plate III below. The hospital receives an average of 80hrs of power supply from the generators consuming an average of about 2,200 liters of diesel weekly.



**Plate III:** 2300KV Generator serving as power alternative



**Plate II:** 33KV Metering unit for ABUTH, Shika

**Source:** Author (2017)

#### 4.1.3 Accessibility

The Hospital can be accessed via the Zaria to Sokoto express road, the main building can also be accessed via two major entrances, the Main gate and the pedestrian gate as can be seen in plate IV below. The main entrance leads you to the parking and subsequently the outpatient unit, while the pedestrian entrance leads directly to the outpatient unit of the Hospital.



**Plate IV:** Showing pedestrian entrance to ABUTH, Shika

**Source:** Author (2017)

#### 4.1.4 Design characteristics of ABUTH Shika, Zaria

The main Building has an expression of modern Architecture, the pediatric department also shares the same design character, the first point of contact on getting to the pediatric unit is the records and reception that is incorporated with the patient waiting area as can be seen in plate V. The spatial organization is characterized by a double banking system with a narrow corridor that runs from the waiting area to the exit door as shown in the plate below. The corridor demarcates the spaces within the pediatric department. The major spaces within the pediatric unit consist of Records office, changing room, waiting area, consultant's office, weighing room, anthropometric room, examination rooms, matron's office and utility rooms.

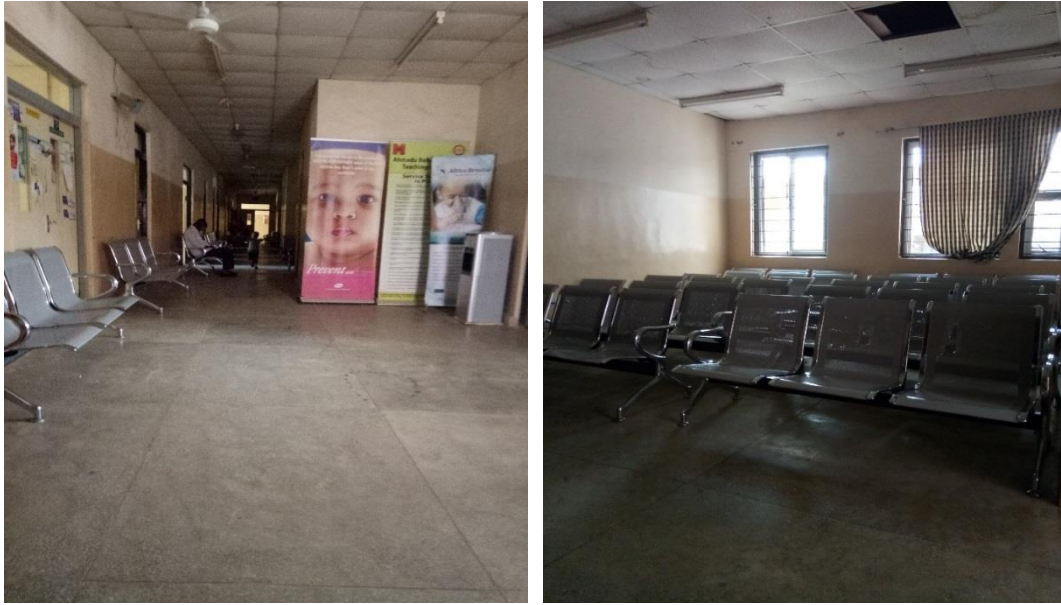


**Plate V:** Pediatric section waiting area ABUTH, Shika

**Source:** Author (2017)

#### 4.1.5 Courtyard design variants in the Hospital

The pediatric department is bounded by two rectangular courtyards both too the eastern and western axis of the Building. The courtyard has an approximate dimension of 30 x 7.5 m on both sides. The windows of the building are positioned on the eastern and western axis of the building which means they open to the courtyards on both sides of the Building. The courtyard is the major source of light and ventilation to the building. The courtyards design variants and its effect on the building shall be discussed in subsequent headings.

##### 4.1.5.1 *Courtyard form/Aspect ratio*

The courtyard has a semi enclosed form with a rectangular shape that is not accessible, it measures about 30 x 7.5m in dimension, which means it has an equivalent aspect ratio (W/L) of 1: 4.the courtyard is bounded by the Main building wall to the east and west axis and also bounded by a corridor to the North and south axis, it's also petitioned by a 1.5m dwarf wall to the North and south axis. The courtyard measures about 5m in height, which can be considered as shallow, which means that shading is minimal, as a result

produces less cooling, as observed by previous studies. Although its height has a positive significance on lighting because of its exposure to sunlight.

#### *4.1.5.2 Orientation*

Courtyard orientation simply refers to the position of the courtyard in reference to the solar and wind path. The courtyard has an east west orientation which implies that its longest axis is along the East and west direction. The shorter axis of the courtyard runs along the North and south direction. This pattern of orientation is considered inappropriate most especially in hot dry climates where the Hospital under investigation is located. The orientation pattern of the Hospital is considered inappropriate because courtyards with east west orientation produce the smallest portion of shade and subsequently not recommended for effective shading strategy for cooling as observed by past studies. Such negative effect was also noticeable in the existing building under study, air felt still and a bit hot at the time of the study, most especially in the absence of artificial source of cooling such as fans and AC's. Although past studies have not been able to prove the best orientation for effective courtyard designs, but it's been observed that courtyards with its longest axis along the North and south will produce better thermal performance.

#### *4.1.5.3 Shading devices*

Shading devices of the building facing the courtyard has significant influence on the level of cooling produced in the building, longer shading devices such as overhangs produce more shadow hence more cooling potentials while shorter overhangs will create more exposure of the building surface which in turn produces lesser cooling, the roof overhang in the hospital under study measures 600mm which is the standard for roof overhang or eaves projection. But however longer overhangs of up to 900mm are considered more effective for cooling than the conventional approach.

#### *4.1.5.4 Natural element within the courtyard*

Elements within the courtyard can greatly influence the energy behavior in the building, they help provide good ground cover and also assist in shading the building which in turn enhances cooling and comfort within the building. It has also been observed that natural elements such as plants and water bodies not only positively enhance the microclimate of the building, but also gives visual comfort as well. The courtyard under investigation has the presents of sparsely planted trees, grasses and flowers. The number of trees are insufficient, which results in less shading, the flowers are colorfully and orderly arranged to provide visual comfort as seen in plate VI below, while there is no provision for water bodies which according to research can help improve humidity as well as cooling.



**Plate VI:** Courtyard space of Pediatric section ABUTH, Shika

**Source:** Author (2017)

#### *4.1.5.5 Wall enclosure*

This refers to all elements or components surrounding the courtyard, these components are walls, doors, windows and corridors amongst others. It's been observed that openings such as windows when designed to open to the courtyard can greatly influence the level of ventilation and cooling experienced in the building, while a contrary approach will hamper the level of ventilation and cooling which ultimately results in discomfort and need for artificial means of cooling and ventilation. Wall type and finishing can also

impact level of cooling experienced in the building, light and absorbent materials will lead to more cooling. The Building under investigation has its windows opening to the courtyards which serves as the main source of lighting and ventilation to the building.

**Table 4.1:** Checklist for Accessing Courtyard of ABUTH, Shika

**Source:** Author (2017)

| <b>Scale factor:</b> 5= Very good, 4= good, 3= Moderate, 2= Weak, = Very weak |                                                                                                                              |           |                                                                                                                                                                                                                                                      |
|-------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Checklist of A.B.U.T.H Shika, Zaria</b>                                    |                                                                                                                              |           |                                                                                                                                                                                                                                                      |
| Courtyard form                                                                | The courtyard is rectangular and is enclosed in form                                                                         | <b>3</b>  | Rectangular courtyards are recommended for hot dry climates.                                                                                                                                                                                         |
| Aspect ratio                                                                  | The courtyard measures 7.5x30 in width and length respectively, it also measures 9m in height. it has an aspect ratio of 1:4 | <b>3</b>  | The courtyards' aspect ratio measures 1:4, which implies higher exposure to radiation due to elongated nature, however its 9m height is ideal for optimum shading, which in turn will improve cooling                                                |
| Orientation                                                                   | The courtyard has its longer axis oriented to the east west direction                                                        | <b>1</b>  | This sort of orientation is not considered appropriate for the said climatic zone, because it exposes a large surface of the building to solar radiation                                                                                             |
| Shading/overhang                                                              | It has a roof overhang of 600mm                                                                                              | <b>3</b>  | This falls within standard dimensions for overhang, although longer overhangs will give better shading hence better cooling                                                                                                                          |
| Elements within the courtyard                                                 | The courtyard has scanty trees with high concentration of flowers and shrubs, it is enclosed and inaccessible                | <b>3</b>  | The sparse nature of trees within the courtyard will lead to lesser shading, whilst the high concentration of flowers will enhance visual comfort. The enclosed nature of the courtyard also means that its therapeutic potentials has been limited. |
| <b>Total</b>                                                                  |                                                                                                                              | <b>13</b> |                                                                                                                                                                                                                                                      |

## 4.2 Case Study Two: Gwamna Awan General Hospital Kakuri, Kaduna State

### 4.2.1 Background Information

The Gwamna Awan general Hospital formerly known as Nassarawa General Hospital is situated at Kakuri, Kaduna south, Kaduna state. It was established in 1975 although it has witnessed several modifications to present date. The Hospital is managed by Dr Samson Dogo Nok, who serves as its medical director. The Hospital is made up of clinical and non-clinical departments amongst which include the pediatric and maternity departments. The Hospital can be accessed via the rehabilitation camp road, off Kakuri industrial layout as seen from Fig. 4.1. The major access leads to the parking area and subsequently to the outpatient unit of the Hospital, which comprise of the reception/records office, patients waiting area and the Nursing station.



**Figure 4.1:** Google image showing area view of Gwamna Awan Hospital Kaduna

**Source:** Google Earth (2016)

### 4.2.2 Design Characteristics

The Building has a modern architectural expression. The first point of contact on arrival is the major outpatient area, this area has an open plan and is made up of the record/reception, patient waiting, and consultants. From the outpatient ward, are corridors

which leads to the different units of the Hospital amongst which include the obstetrics and pediatric departments. The pediatric department has an outpatient unit which similarly has a reception/records, patient waiting area, and pharmacy and consultants' offices. A central lobby from the consultancy leads to the children ward, the children's ward has a rectangular plan with a central courtyard, the courtyard is enclosed by the children's ward as can be seen in Fig. 4.2. The Matrons office, utility, conveniences can all be found in the children's ward.



**Plate VII:** Perspective view of Gwamna Awan General Hospital, Kakuri, Kaduna

**Source:** Author (2017)

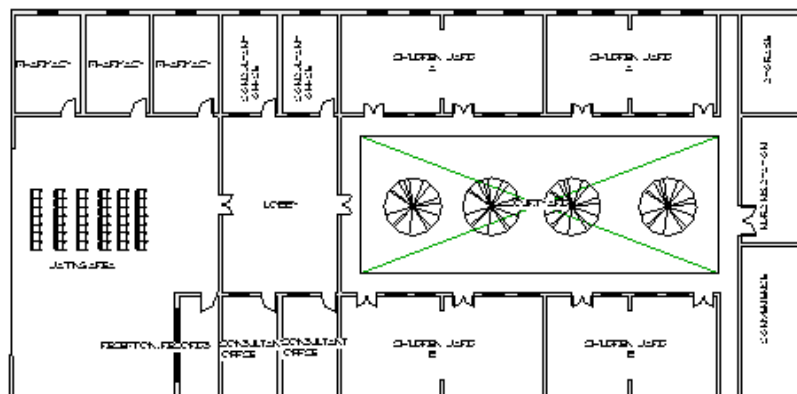


**Figure 4.2:** Showing floor plan of pediatric section of Gwamna Awan General Hospital, Kakuri, Kaduna

**Source:** Author (2017)

#### 4.2.3 Energy consumption in Dr Gwamna Awan General Hospital

Similar to the first case studied, the Hospital has two major sources of power supply, the supply from the state distribution board KAEDCO and a 500kv power generator. According to the Maintenance officer of the Hospital, they experience about 9Hrs of power supply daily and an increment of about 12 hours during the dry season. He further said that there is usually an improvement on power supply over the weekend as improvements can peak to 20 to 23Hrs. however he did stress that the power supply is insufficient because they require power for 24hrs and this leads to over dependence on the generators. He further lamented that the cost of powering the generator is too much for the Hospital management as a result the management had to provide 2.3kv generators to units that require prompt power such as Maternity and pediatrics, GOPD, theatre amongst others. This method reduces dependence on the 500kv generator as such cuts down its cost to a certain level.

#### 4.2.4 Courtyard design variants in the Hospital

The Hospital utilizes courtyards as a means of enhancing ventilation as well as lighting indoor spaces. It also provides good outdoor space for patients to relax and interact with nature. There are different courtyard systems adopted in the various departments of the Hospital as can be seen on the figure below. However, the study focused on the courtyard in the pediatric section of the Hospital which has been highlighted blue in Fig. 4.3 below.



**Figure 4.3:** Google image Showing Pediatric unit of Gwamna Awan Hospital Kaduna

**Source:** Google Earth (2016)

#### 4.2.4.1 Courtyard form/Aspect ratio

The courtyard under investigation has a rectangular form that is fully enclosed. It measures 8 meters (W) x 21.3 meters (L), which equates to a ratio of 1:2.6. The courtyard has a height of 3.5 meters which can be considered inadequate for proper shading due to the fact that it produces less shadows as a result of its small depth and According to literature lesser shading will result to lesser cooling will lead to increase in cooling energy loads.



**Plate VIII:** Courtyard space of Pediiatric section of Gwamana Awan Gneral Hospital, kakuri, Kaduna

**Source:** Author (2017)

#### 4.2.4.2 Orientation

The courtyard has a North South orientation as can be seen in plate x which means that its longer sides are facing the North and South axis respectively while its shorter sides are facing the East and West axis. This sort of orientation is considered ideal by scholars, most especially in the hot dry climate under consideration. This is because it limits the

longer surface of the building to solar radiation as well as protects it from harsh wind flows.

#### *4.2.4.3 Wall enclosure*

The courtyard is fully enclosed, which implies that it is bordered on all axis. It is enclosed by the Children's ward (A) to the north, this courtyard facing wall measures 3 meters, it also has most of its openings along this axis which means that the ward interior space is heavily dependent on the courtyard as a means of lighting and ventilation. The same can be said about the south facing wall, which has the children's ward (B) wall facing the courtyard, it shares similar description with the North facing wall. It is enclosed by the matron's office and conveniences to the east, with its walls also measuring 3 meters while it is bordered by the wards entrance lobby and consultant offices to the west. It was also observed that the courtyard was the major source of ventilation and lighting to the spaces enclosing it.

#### *4.2.4.4 Shading/overhang*

It has been observed that shading plays an important role on the cooling potentials of a building. One of such elements that also influences cooling as stressed by scholars are roof overhangs, this has been identified as one of the variables that can influence courtyard performance in the building. The building has an overhang of 1.2 meters over overlooking the courtyard as can be seen in the figure below. This length of overhang is considered adequate for better courtyard performance

#### 4.2.4.5 *Natural elements within the courtyard*

The elements within the courtyard are also crucial features that influence courtyard performance. It serves as good ground cover, shading element, wind breakers as well as aid both physical and visual comfort. The courtyard under study is characterized by presence of orderly planted trees, as shown in plate IX. This trees provide good shading for the building as observed at the time of the study, although there is no grasses or flowers which can also provide good ground cover as well as improve visual comfort r.



**Plate IX:** Courtyard enclosure of Pediatric unit of Gwamna Awan General Hospital

**Source:** Author (2017)

**Table 4.2:** Checklist for accessing courtyard design variant in Gwamna Awan General Hospital

**Source:** Author (2017)

| Scale factor: 5= very good, 4= Good, 3= Moderate, 2= Weak, 1= Very weak |                                                                                                 |       |                                                                                                                                                                                      |
|-------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Checklist for assessing Gwamna Awan General Hospital Courtyard          |                                                                                                 |       |                                                                                                                                                                                      |
| Variables                                                               | Features                                                                                        | Scale | Remarks                                                                                                                                                                              |
| Courtyard form                                                          | It is rectangular and enclosed in form                                                          | 4     | Rectangular courtyards are the most effective for cooling in Hot dry climates                                                                                                        |
| Aspect ratio                                                            | It has a dimension of 8x23, it has a ratio 1:2.6                                                | 3     | The ratio falls in range of acceptable courtyard ratios                                                                                                                              |
| Orientation                                                             | It is oriented with its longer sides facing the North and south respectively                    | 4     | This is considered an ideal orientation because it reduces heat gain most especially in the Hot dry climate                                                                          |
| Shading/Overhang                                                        | It has an overhang of 1200 meters                                                               | 4     | The roofs overhang provide efficient shading that enhances passive cooling                                                                                                           |
| Elements present in the courtyard                                       | It is characterized by sparsely planted trees.it also has little presence of shrubs and flowers | 3     | The presence of trees in the courtyard provides good shading and also enhances cooling in the building although it isn't designed to accommodate any therapeutic activity within it. |
| Total                                                                   |                                                                                                 | 16    |                                                                                                                                                                                      |

### 4.3 Conclusion from Case Studies

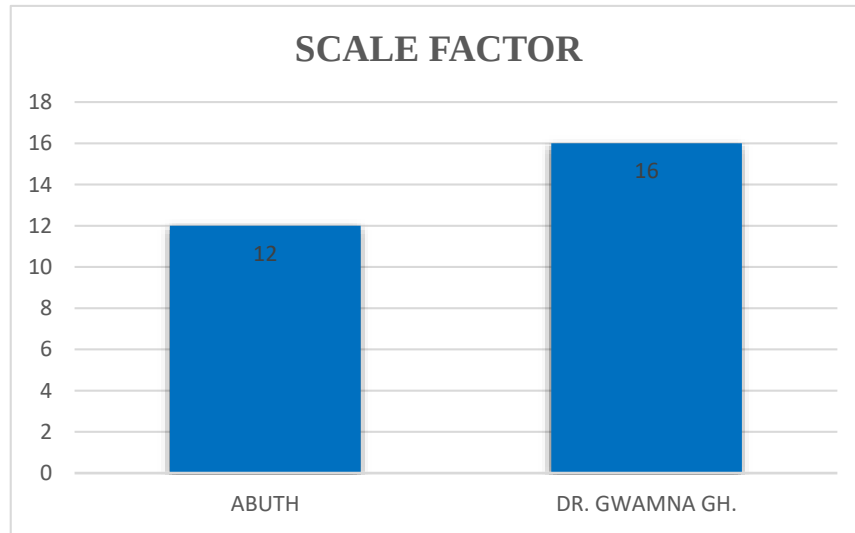


**Figure 4.4:** Chart showing cases studied

**Source:** Author (2017)

One of the objectives of the case study was to ascertain the level of application of the courtyards design variants as shown in the checklist in fig 4.2 above. The variants were accessed and graded in accordance to standards and recommendations from literature reviewed as seen from Table 4.1 and 4.2 respectively. Case study two (ii) was found to have better courtyard design variants with a scale factor of 16, whilst case study (i) had scale factor of 12. However, some major draw backs were observed in both cases.

- i. The courtyards were not utilized as a recreation/relaxation point for patients, most especially in case study one where the courtyard was fully enclosed and inaccessible. Such design approach is contrary to scholarly beliefs, where it has been observed that spaces such as courtyards should function not just as a climate modifier, but also as a place where patients can relax and interact with nature, a factor which has been observed to aid patient recovery.
- ii. The courtyards have high ratios, resulting in elongated forms which exposes courtyard surface area to higher radiation.

#### 4.4 Simulation of U-Shape and Centralized Forms with Different Orientations

The courtyards aspect ratio and orientation are the most effective variants that affects courtyard micro climatic performance. In order to ascertain the most effective form, a simulation was done on both courtyard forms under consideration to determine the most effective orientation for the courtyards. The forms were oriented at different angles of 0°, 45°, 90°, 180°, 225°, 270° and 315°. The results showed that the U- Shape rectangular courtyard with ratio 1:2 as shown in Fig. 4.5 has the least annual cooling load of 33724.31kWh when oriented at 0° North orientation

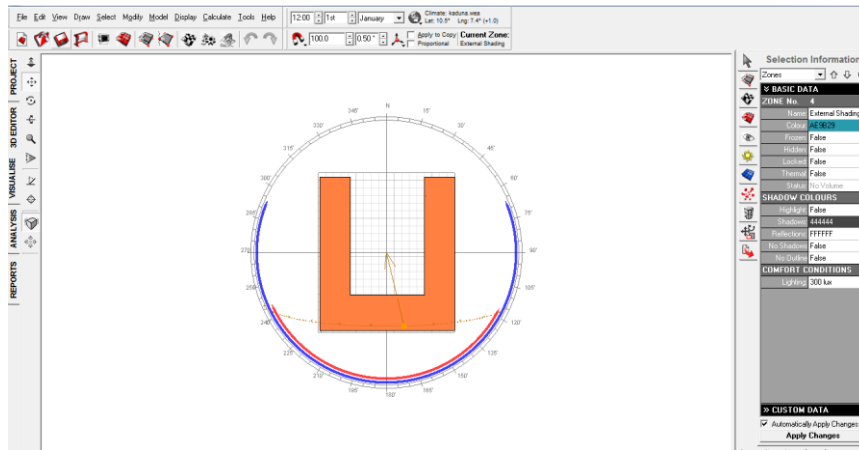


**Figure 4.3:** Chart showing annual cooling and heating load of U shape courtyard at different orientation

**Source:** Author (2017)

The highest cooling loads was observed at 180° south orientation, with cooling loads at 34133.5 kWh. However maximum cooling was recorded at 29.637 kWh on 13<sup>th</sup> April, at 15.00.

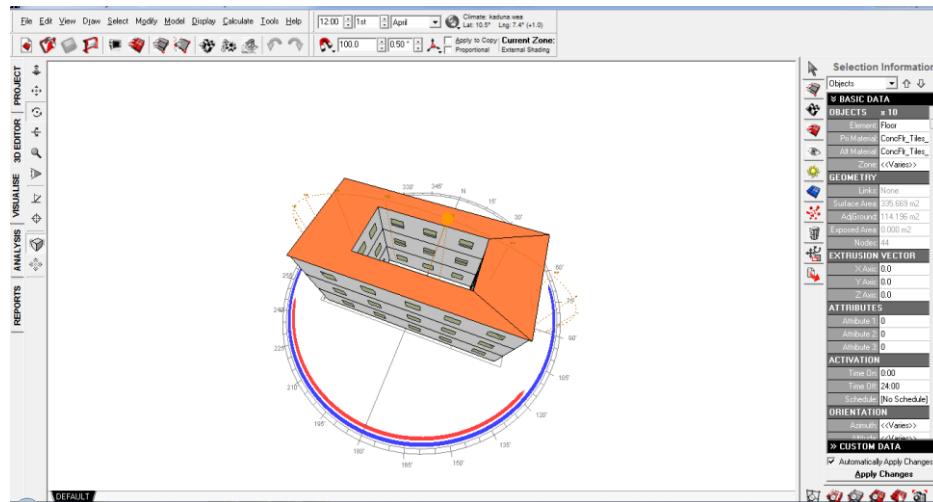


**Figure 4.4:** Simulation of centralised courtyard with different orientation

**Source:** Author (2017)

Contrary to the U-shape courtyard, the lowest cooling load of the centralized courtyard as seen in Fig. 4.4 was recorded at  $180^\circ$  at the rate of 45068.141 kWh on the other hand, the highest loads were recorded at 47029.78 kWh at angle  $90^\circ$  East orientation. However maximum cooling was recorded at 38.446 kW on 22<sup>nd</sup> February at 15:00. Below are charts showing energy cooling loads at different orientations for U-shape and centralized rectangular courtyards as shown in Figure 4.5 and 4.6 respectively

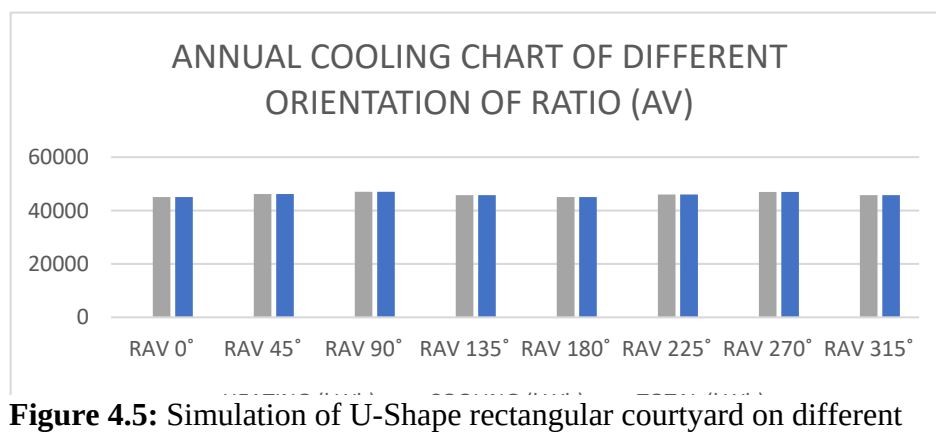


**Figure 4.5:** Simulation of U-Shape rectangular courtyard on different orientation

**Source:** Author (2017)

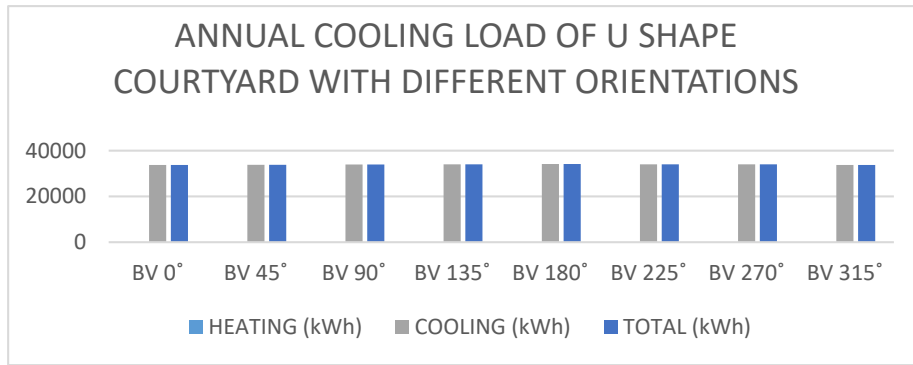


**Figure 4.6:** Chart showing annual cooling and heating loads of centralised courtyard on different orientation

**Source:** Author (2017)

#### 4.5 Simulation of Courtyard Forms with Different Aspect Ratios

A rectangular courtyard form was selected for the simulation, this is because the rectangular courtyard has been revealed to be the most effective and most applicable in the hot dry climatic zone under investigation, the courtyard was divided into two categories of enclosed and semi enclosed form, the enclosed form is depicted as a centralized courtyard whilst the semi enclosed was in U-shape form. Each of these forms were subsequently divided into five different ratios, ranging from 1:1.2 to 1:2 with an interval of 0.2 meters, the courtyard was assumed to have an area 48m<sup>2</sup>, which is 40% of a Building with assumed area of 120m<sup>2</sup>. The area of the courtyard was then designed according to the sample ratios of 1:1.2, 1:1.4, 1:1.6, 1:1.8, and 1:2. Each of this ratios was termed RI, RII, RIII, RIV and RV respectively. This lead to the design of ten (10) sample courtyard forms for simulation. The forms were designed using Revit Autodesk architecture 2014 and was later exported to Autodesk Ecotect for analysis, prior to analysis, the forms were all assumed to have the same floor area, an assumed constant height of 9m, and the same type of opening and finishing, this is in order to have a more comprehensive result. Below is a table showing details of the forms simulated.

**Table 4.3:** Details of courtyard forms simulated**Source:** Author (2017)

| RATIO | COURTYARD FORM | TYPE        | COURTYARD AREA   | FLOOR AREA             | BUILDING AREA     | HEIGHT          |
|-------|----------------|-------------|------------------|------------------------|-------------------|-----------------|
| 1:1.2 | Enclosed       | Centralized | 48m <sup>2</sup> | 316.058 m <sup>2</sup> | 120m <sup>2</sup> | 9m <sup>2</sup> |
| 1:1.4 | Enclosed       | Centralized | 48m <sup>2</sup> | 307.774 m <sup>2</sup> | 120m <sup>2</sup> | 9m <sup>2</sup> |
| 1:1.6 | Enclosed       | Centralized | 48m <sup>2</sup> | 307.489 m <sup>2</sup> | 120m <sup>2</sup> | 9m <sup>2</sup> |
| 1:1.8 | Enclosed       | Centralized | 48m <sup>2</sup> | 307.384 m <sup>2</sup> | 120m <sup>2</sup> | 9m <sup>2</sup> |
| 1:2   | Enclosed       | Centralized | 48m <sup>2</sup> | 335.669 m <sup>2</sup> | 120m <sup>2</sup> | 9m <sup>2</sup> |
| 1:1.2 | Semi enclosed  | U-Shape     | 48m <sup>2</sup> | 290.822 m <sup>2</sup> | 120m <sup>2</sup> | 9m <sup>2</sup> |
| 1:1.4 | Semi enclosed  | U-Shape     | 48m <sup>2</sup> | 279.038 m <sup>2</sup> | 120m <sup>2</sup> | 9m <sup>2</sup> |
| 1:1.6 | Semi enclosed  | U-Shape     | 48m <sup>2</sup> | 270.907 m <sup>2</sup> | 120m <sup>2</sup> | 9m <sup>2</sup> |
| 1:1.8 | Semi enclosed  | U-Shape     | 48m <sup>2</sup> | 264.206 m <sup>2</sup> | 120m <sup>2</sup> | 9m <sup>2</sup> |
| 1:2   | Semi enclosed  | U-Shape     | 48m <sup>2</sup> | 257.955 m <sup>2</sup> | 120m <sup>2</sup> | 9m <sup>2</sup> |

In order to achieve the aim of the simulation, certain assumptions were made. This includes

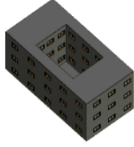
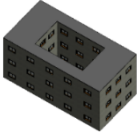
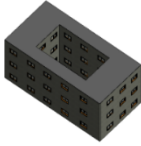
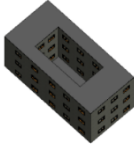
- i. The Building was assumed to be in the hot dry climate of Kaduna state, Nigeria.
- ii. The Building was assumed to be on a flat surface
- iii. The Building and courtyard were both assumed to be oriented with their longer axis facing the North and South direction respectively.
- iv. The building was assumed to be a two storey building with 9m height as a constant for all samples.
- v. All rooms facing the courtyard were assumed to have singled glazed windows measuring 1.2 x 0.9m
- vi. The building roof was assumed to have a flat roof
- vii. The courtyard's aspect ratio (W/L) are changed at intervals of 0.2 in order to compare the alternatives with different courtyard ratios.

viii. The occupancy hour of the building used is considered to be 24 hours every day including holyday this is due to nature of the hospital as observed from the cases studied. Occupant's activity rate was assumed to be 110w and 10m<sup>2</sup> per occupant.

**Table 4.4:** Simulated courtyard forms with different ratios

**Source:** Author (2017)

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|                                                                                     |                                                                                       |
|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
|    |    |
| Ratio (AI)                                                                          | Ratio (AII)                                                                           |
|    |    |
| Ratio (AIII)                                                                        | Ratio (AIV)                                                                           |
|  |  |
| Ratio (AV)                                                                          | Ratio (BI)                                                                            |
|  |  |
| Ratio (BII)                                                                         | Ratio (BIII)                                                                          |
|  |  |
| Ratio (BIV)                                                                         | Ratio (BV)                                                                            |

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#### 4.5.1 Ratio (AI) simulation results

The first ratio has a ratio of 1:1.2 and courtyard dimension of 6.3x7.6m, the simulation showed the total annual load consumption of 48571.867 kwh/m<sup>2</sup>/year. The highest load is shown to be in April at the rate of 7743.603kwh while the lowest load is experienced in August at the rate of 645.409 kWh. Maximum cooling can be achieved on 22<sup>nd</sup> February at about 15:00 with an expected energy consumption rate of 39. 311kwh.No heating load was experienced as shown in the Fig 4.7 below. Similarly,

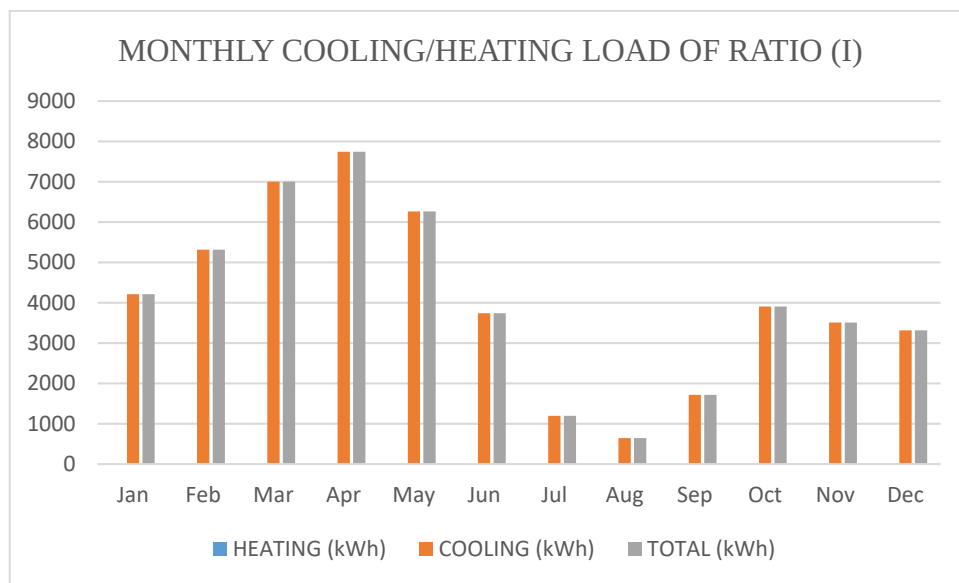


**Figure 4.7:** Chart showing annual cooling and heating loads for Ratio (A1)

**Source:** Author (2017)

#### 4.5.2 Ratio (AII) Simulation result

This has a ratio of 1:1.4 with a courtyard dimension of 5.9x8.2m, with this ratio, total annual consumption was found to be 47127.359 kwh/m<sup>2</sup>/year. The highest energy load is witnessed in April at 7617kwh, the lowest was shown to be in August at the rate of 555.937kwh. The cooling was shown to be in 22<sup>nd</sup> of February at about 15:00 at the rate of 38.624kwh, however similar to ratio (I) no heating was observed as shown the fig 4.8

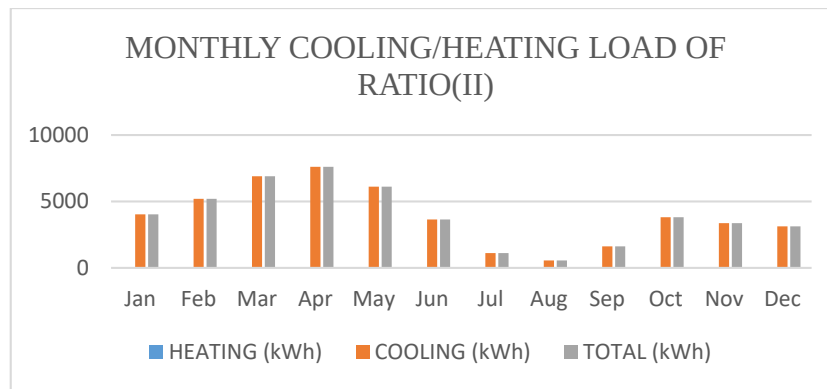


**Figure 4.8:** Chart showing annual cooling and heating loads for Ratio (AII)

**Source:** Author (2017)

#### 4.5.3 Ratio (AIII) Simulation results

This ratio has a courtyard dimension of 5.5x8.8m in the ratio of 1:1.6, it has an annual cooling load of 47139.09 kwh/m<sup>2</sup>/year. Its peak load was seen at April at the rate of 7509.324 kWh conversely its lowest loads was observed in August at 614.044 kWh. Maximum cooling is similarly observed in 22<sup>nd</sup> February at about 15:00.no heating was recorded as shown in the chart below in Fig. 4.9.

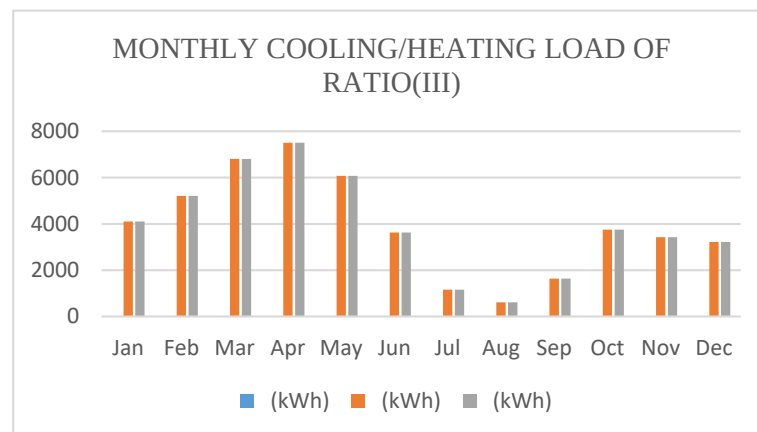


**Figure 4.9:** Chart showing annual cooling and heating loads for Ratio (AIII)

**Source:** Author (2017)

#### 4.5.4 Ratio (AIV) simulation result

This sample has a ratio of 1:1:8 with courtyard dimension of 5.2x9.3m, the simulation showed the total annual load consumption of 45338.621 kwh/m<sup>2</sup>/year. The highest load is shown to be in April at the rate of 7381.638kwh while the lowest load is recorded in

August at the rate of 511.504 kWh. Maximum cooling can be achieved on 22<sup>nd</sup> February at about 15:00 with an expected energy consumption rate of 37.904 kWh. No heating load was recorded as seen in Fig. 4.10.

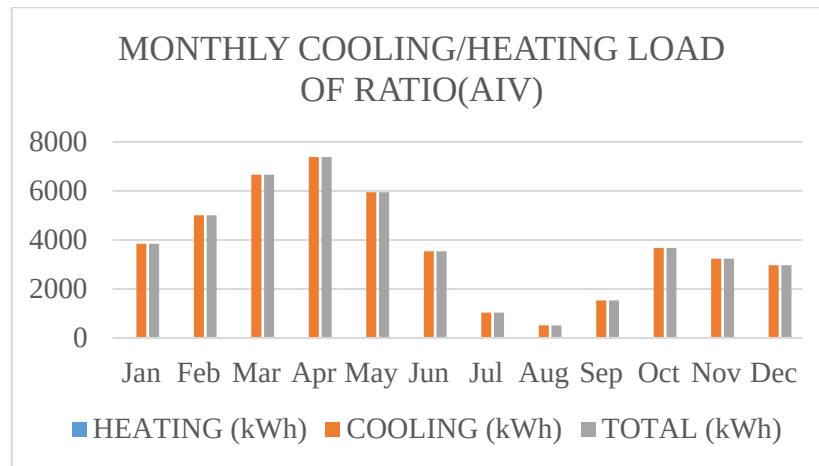


**Figure 4:10** Chart showing annual cooling and heating loads for Ratio (AIV)

**Source:** Author (2017)

#### 4.5.5 Ratio (AV) simulation result

This sample has a ratio of 1:2 with courtyard dimension of 4.9x9.8m, the simulation showed the total annual cooling load of 45084.121 kwh/m<sup>2</sup>/year. The highest load is shown to be in April at the rate of 7479.978 kWh while the lowest load is recorded in August at the rate of 477.833kWh. Maximum cooling can be achieved on 22<sup>nd</sup> February at about 15:00 with an expected energy consumption rate of 38.445 kWh. No heating load was recorded as shown in Fig. 4. 11 below

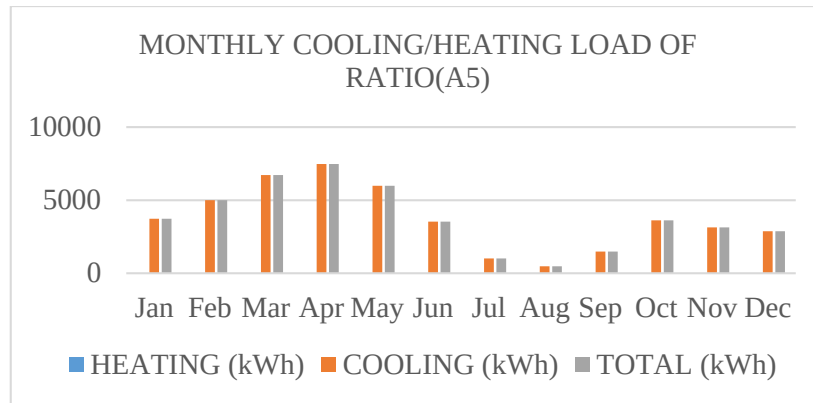


**Figure 4.11:** Chart showing annual cooling and heating loads for Ratio (AV)

**Source:** Author (2017)

#### 4.5.6 Ratio (BI) simulation results

This phase of simulation takes into focus the U-shape courtyard. Similarly, to the centralized form, the first ratio 1:1.2 with courtyard dimension of 6.3x7.6m, the simulation showed the total annual cooling load of 41242.703 kwh/m<sup>2</sup>/year. The highest load is shown to be in April at the rate of 6757.648 kWh while the lowest load is experienced in August at the rate of 559.688kWh. Maximum cooling can be achieved on 22<sup>nd</sup> February at about 15:00 with an expected energy consumption rate of 33.072 kWh. No heating load was experienced as shown in the Fig 4.12 below

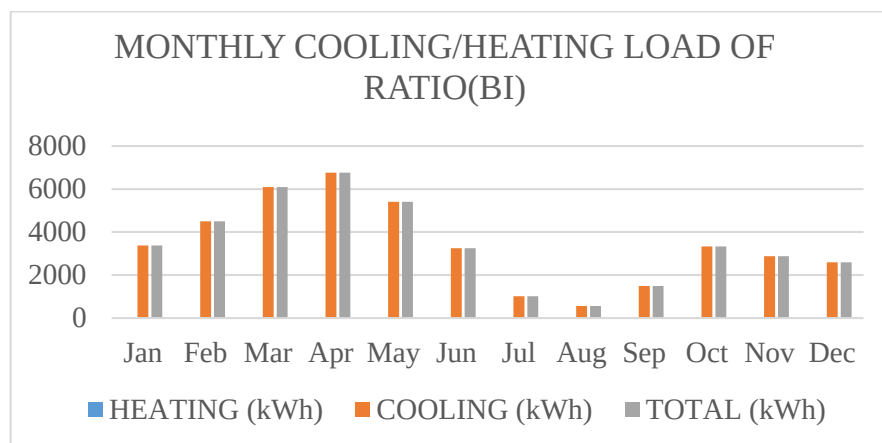


**Figure 4.12:** Chart showing annual cooling and heating loads for Ratio (B1)

#### 4.5.7 Ratio (BII) simulation results

This has a ratio of 1:1.4 with a courtyard dimension of 5.9x8.2m, with this ratio, total annual cooling load was found to be 40809.043kwh/m<sup>2</sup>/year. The highest energy load is witnessed in April at 6686.648kwh, the lowest was shown to be in August at the rate of 555.558 kWh. The maximum cooling was shown to be in 22<sup>nd</sup> of February at about 15:00 at the rate of 32.745kwh, however no heating was observed as shown the Fig. 4.13

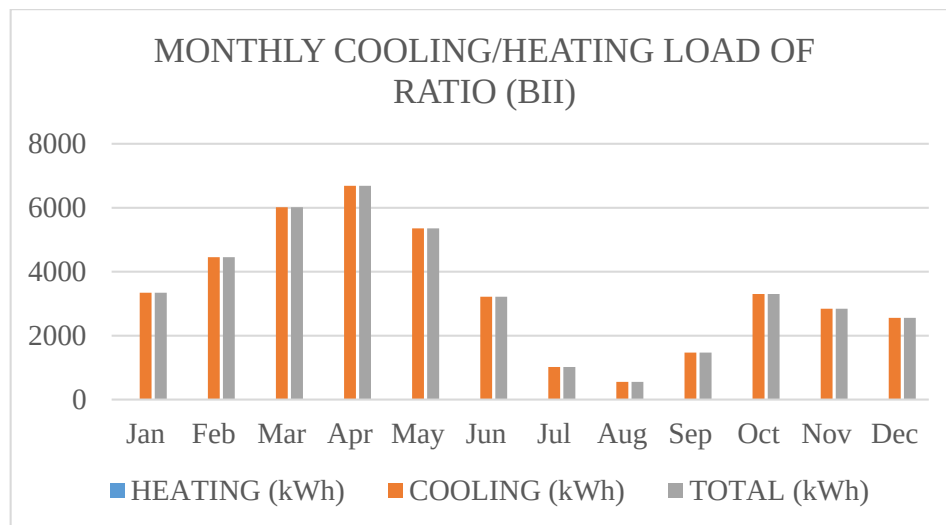


**Figure 4:13** Chart showing annual cooling and heating loads for Ratio (BI1)

**Source:** Author (2017)

#### 4.5.8 Ratio (BIII) simulation results

This ratio has a courtyard dimension of 5.5x8.8m in the ratio of 1:1.6, it has an annual cooling load of 42124.438 kwh/m<sup>2</sup>/year. Its peak load was seen at April at the rate of 6987.025 kWh conversely its lowest loads was observed in August at 554.734 kWh. Maximum cooling is similarly observed in 22<sup>nd</sup> February at about 15:00 at the rate of 33.833kw .no heating was recorded as shown in the Fig. 4.14 below.

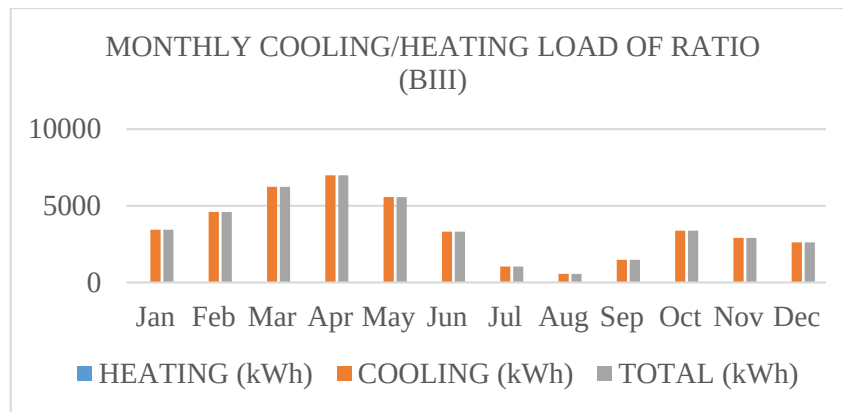


**Figure 4.14:** Chart showing annual cooling and heating loads for Ratio (BIII)

**Source:** Author (2017)

#### 4.5.9 Ratio (BIV) simulation results

This sample has a ratio of 1:1:8 with courtyard dimension of 5.2x9.3m, the simulation showed the total annual load consumption of 41610.574 kwh/m<sup>2</sup>/year. The highest load is shown to be in April at the rate of 6716.586 kWh while the lowest load is recorded in August at the rate of 584.987 kWh. Maximum cooling can be achieved on 22<sup>nd</sup> February at about 15:00 with an expected energy consumption rate of 32.785 kWh. No heating load was recorded as can be seen in Fig. 4.15

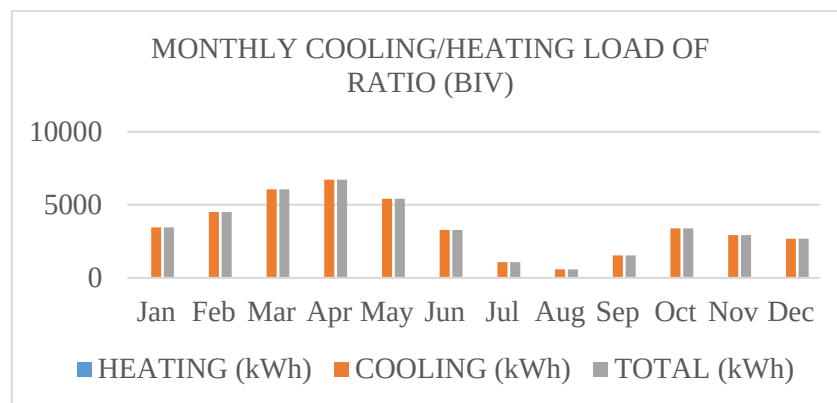


**Figure 4.15:** Chart showing annual cooling and heating loads for Ratio (BIV)

#### 4.5.10 Ratio (BV) simulation results

This sample has a ratio of 1:2 with courtyard dimension of 4.9x9.8m, the simulation showed the total annual cooling load of 33724.309 kwh/m<sup>2</sup>/year. The highest load is

shown to be in April at the rate of 5705.731kWh while the lowest load is recorded in August at the rate of 415.186 kWh. Maximum cooling is achieved on 22<sup>nd</sup> February at about 15:00 with an expected energy consumption rate of 28.904 kWh. No heating load was recorded as seen in Fig. 4.16

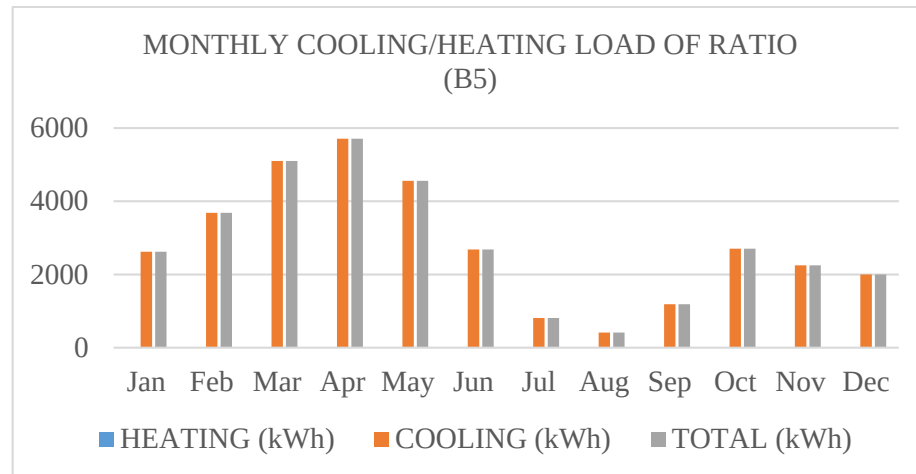


**Figure 4.16:** Chart showing annual cooling and heating loads for Ratio (BV)

**Source:** Author (2017)

#### 4.6 Findings from Courtyard Forms Simulated

The simulation of the different courtyard forms and ratios show that, ratio R (BV) representing the semi closed U shape courtyard with ratio 1:2 has the least annual cooling load of 33724.309 kWh compared to other forms and ratios as shown in the Fig. 17 below. It was also observed that little or no heating is required all through the year, this is majorly due to the climatic characteristic of the region under consideration. The study also revealed that the lowest annual cooling loads is experienced in August ranging from 415.186 kWh to 645.409 kWh, while the highest annual cooling load will be experienced in April with consumption ranging from 5705.731kWh to 7743.603kwh. Lastly, the findings have revealed that

- i. In a Hot dry climate of Kaduna state, Nigeria, a U shape courtyard with ratio of 1:2 with north orientation will save more energy and resultant cost, compared

to enclosed centralized courtyards with ratios 1:1.2, 1:1.4, 1:1.6, 1:1.8, 1:2. It will also save more than U shape courtyards with similar ratios

- ii. The U shape courtyard R(BV) with ratio 1:2 will save 23.38% of total annual energy consumption compared to R (BIV) with ratio 1:1.8
- iii. The U shape courtyard R(BV) with ratio 1:2 will save 24.91% of total annual energy consumption compared to R (BIII) with ratio 1:1.6
- iv. The U shape courtyard R(BV) with ratio 1:2 will save 21.01% of total annual energy consumption compared to R (BII) with ratio 1:1.4
- v. The U shape courtyard R (BV) with ratio 1:2 will save 22.29% of total annual energy consumption compared to R (BI) with ratio 1:1.2
- vi. The U shape courtyard R(BV) with ratio 1:2 will save 33.68% of total annual energy consumption compared to R (AV) with ratio 1:1.2
- vii. The U shape courtyard R(BV) with ratio 1:2 will save 34.44% of total annual energy consumption compared to R (AIV) with ratio 1:1.8
- viii. The U shape courtyard R(BV) with ratio 1:2 will save 39.78% of total annual energy consumption compared to R (AIII) with ratio 1:1.6
- ix. The U shape courtyard R(BV) with ratio 1:2 will save 39.75% of total annual energy consumption compared to R (AII) with ratio 1:1.4
- x. The U shape courtyard R(BV) with ratio 1:2 will save 44.03% of total annual energy consumption compared to R (AI) with ratio 1:1.2

Figure 4.15 shows the annual cooling and heating loads of all the ratios tested.

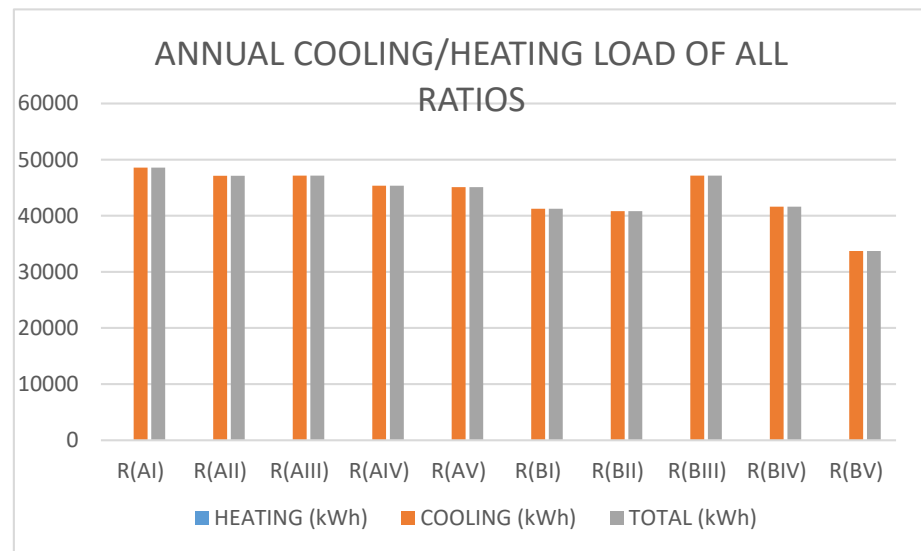


**Figure 4.17:** Chart showing annual cooling and heating loads for all Ratios

**Source:** Author (2017)

#### 4.7 Conclusions from Findings

The findings above for cooling/heating consumption of different courtyard forms, shows that under the Hot dry climatic conditions of Kaduna state Nigeria, under 24hrs operational time of a typical Hospital, with occupancy rate of 45w per 10 occupants, under mixed ventilation mode of Natural and (HVAC) system of comfort band between 18°C to 26°C, it has shown that a U shape rectangular courtyard with ratio 1:2 on a North-South orientation, will save more energy of up to 39.68% annually when compared to a Centralized rectangular courtyard with similar features. The study also revealed that a U Shape Rectangular courtyard of ratio 1:2 will save energy of up to 44.03% annually as compared to other forms and ratios that were considered in the study. It was also observed that the difference in monthly energy loads between the different courtyard forms is negligible as shown in the various energy charts. Although the little variations noticed could add up to large savings over time. Consequently, the study further revealed that Courtyard design variants most especially those considered in the study such as aspect ratio, orientation, shading/overhangs and wall enclosures all play a significant role in the

courtyards performance as a microclimatic modifier, as also observed by several literatures reviewed. Hence it's therefore very important that Architects and other allied Building professionals give keen details to courtyard design at the inception stage, in other not to come up with not only functional and aesthetic Buildings but Buildings that will also help save cost and conserve resources for the future generation.

## CHAPTER FIVE

### 5.0 DESIGN PRELIMINARIES

#### Introduction

This chapter shall discuss the application of the research findings in the design of a proposed Pediatric Hospital in hot dry climate of Kaduna state, Nigeria, as highlighted in objective number four (IV) in the first chapter. However, the chapter shall focus on the site documentation which shall be discussed in the following sequence, Site location, site selection and site analysis

#### 5.1 Site Location

Kaduna is located on latitude 9°03'N and 11°32'N. It can be found in the North Western part of Nigeria as seen in Fig. 5.1. Kaduna is one of the most cosmopolitan states of Northern Nigeria. It is bordered by Zamfara, Katsina and Kano states to the north, Niger and the FCT to the east, Bauchi and Plateau states to the west and Nassarawa state to the south.



**Figure 5.1:** Kaduna State geographical location and map on the Nigerian map

**Source:** TVC News, (2017)



**Figure 5.2:** Google image of proposed site location

**Source:** Google Earth (2017)

However, the site is located around Kaduna new millennium city. It's also North off Kaduna third bridge which leads to Kaduna new Millennium city. The site is bordered by a residential estate with large expanse of land to the North and west, while it's bordered by river Kaduna to the East and south respectively as can be seen in Fig. 5.2 above.

## 5.2 Site Selection Criteria

For a site to be selected, it has to possess some intrinsic characteristics that has the potentials to enhance and improve the design goals. In the case of siting a Hospital, the location and environmental features plays a paramount role in creating the conduciveness needed for fast patient's recovery as well as staff's productivity. Hence the site selected for the proposed design was chosen based on the following criteria as shown in Fig. 5.3 below



### 5.2.2 Accessibility

The site can be easily accessed via Gobarao road which links to other major roads linking to Kaduna main city. It also has close links to Kaduna third bridge. These connections mean that the site can be easily accessed from any part of Kaduna metropolis.

### 5.2.3 Topography

Site topography has a great influence on draining site water. As such it becomes a pivotal criterion in selecting a site. The site under consideration has a gentle slope which slopes to the eastern part of the site towards the river Kaduna bank. The site has a contour value ranging from 593-583 from west to east respectively. This implies that the site water can be easily drained from the west axis to the east axis of the site towards the river bank as shown in fig. 5.4 below.



**Figure 5.4:** Google image showing the location of the Site selected

**Source:** Google Earth (2017)

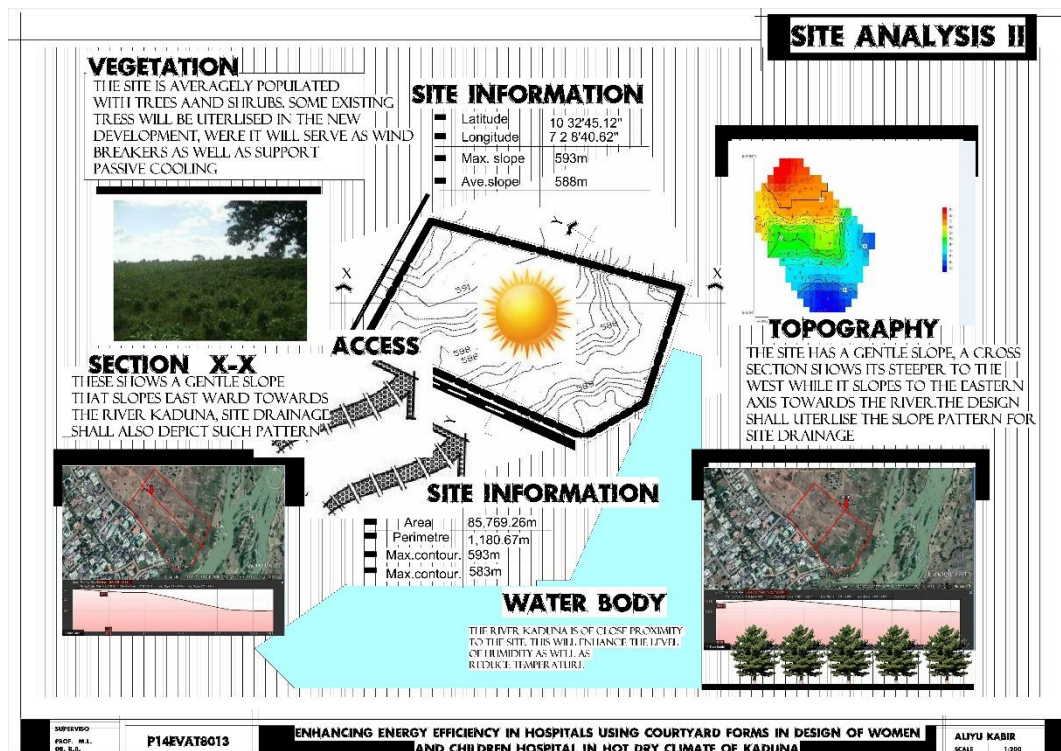


**Figure 5.5: Topographical Analysis sheet**

**Source:** Author (2017)

#### 5.2.4 Land Mass

The site selected has sufficient land area as shown in Fig. 5.5 to accommodate the design as well as other necessary auxiliary facilities. The site is more spacious to the north as such future expansion will be planned towards that axis.

#### 5.2.5 Presence of water body

The site also shares border with river Kaduna towards the western and southern axis, this factor is of immense benefit to the proposed Hospital, this is because water bodies are recommended to be around Hospital environment as this can improve both visual and thermal comfort.

### 5.3 Climatic Analysis

The climate is the average weather condition of a place over a long period of time. The climate analysis can easily be understood by measuring the climatic factors of that particular location. These factors include the Temperature, Relative humidity, Rainfall, wind as well as sun shine hours. Analyzing these climatic factors play a key role in determining the type of material, orientation, drainage pattern, shading devices, types of opening as well as landscape to be adopted for the proposed design as shown in Fig. 5.6.

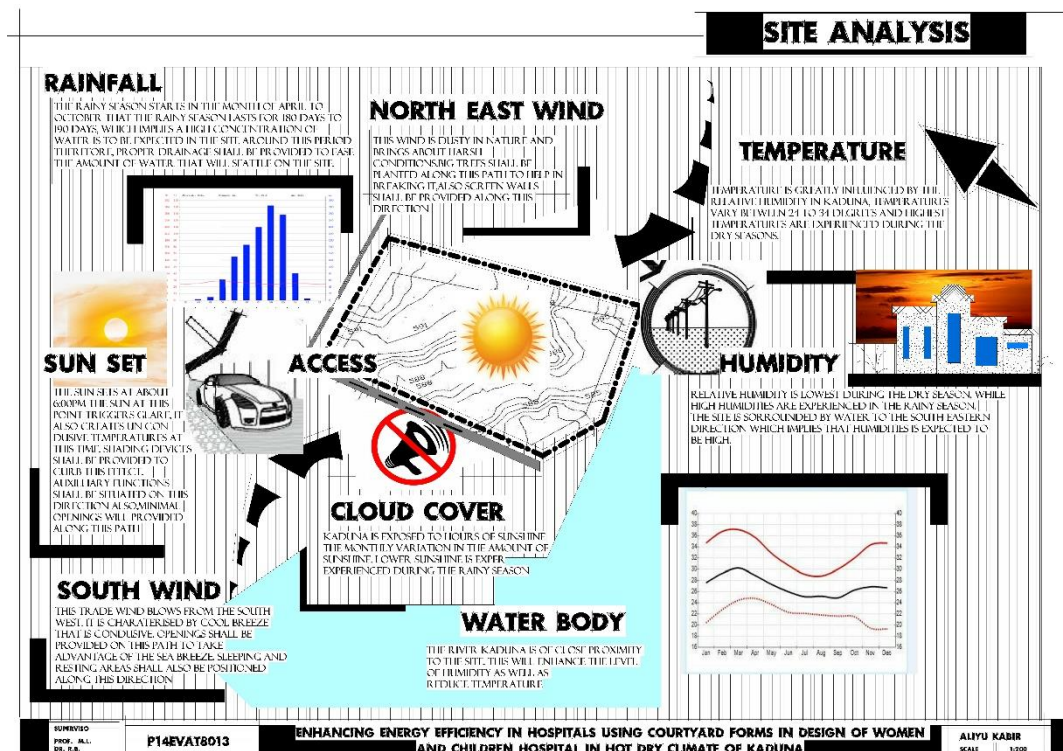


**Figure 5.6:** Climatic Site Analysis sheet

**Source:** Author (2017)

#### 5.3.1 Temperature and Humidity

Temperature refers to the degree of hotness or coldness of a place at a particular period of time whilst humidity refers to the amount of moisture content or water vapor in the sky. Temperature is greatly influenced by humidity. In Kaduna state temperatures peak during the dry season due to clearer skies while low humidity is recorded during the same period. Conversely lower temperatures are observed during the rainy season due to high

humidity levels. This will aid in determining types of opening to be used as well as vegetation.

### 5.3.2 Rainfall

Rainfall in this location is annually experienced between the months of April- October with peak periods recorded around August and September. This rainfall pattern indicates high concentration of water within the said period. This implies that proper drainage systems should be employed to drain the large volume of water to be expected.

### 5.3.3 Wind

The source of wind is majorly from the prevalent wind masses, that is the North east trade wind and the south west trade wind. The North east trade wind brings about the harsh Hamatan conditions that is usually uncomfortable for Building users and is usually dusty in Nature. It is therefore recommended to provide wind breakers along this path. It is also essential to make provision for screen walls along this axis. On the other hand, cooler breeze with milder wind is experienced along the south west axis. The breeze is beneficial to occupants as such should be properly utilized by creating openings along this path. It is also recommended to have sleeping and resting areas towards this direction.

## CHAPTER SIX

### 6.0 DESIGN BRIEF

Provision of an adequate and functioning healthcare service is paramount to human survival, most especially women and children whom are considered most vulnerable in society. In an attempt to address some of the problems plaguing women and children healthcare in hot dry climatic region of Nigeria, the proposed Hospital is designed to meet the women and children healthcare needs as well as provide a therapeutic environment that promotes comfort by passive means without expending too much energy and resources. The Hospital complex comprise of a Pediatric and Maternity section which both share the same auxiliary facilities that make up the whole complex.

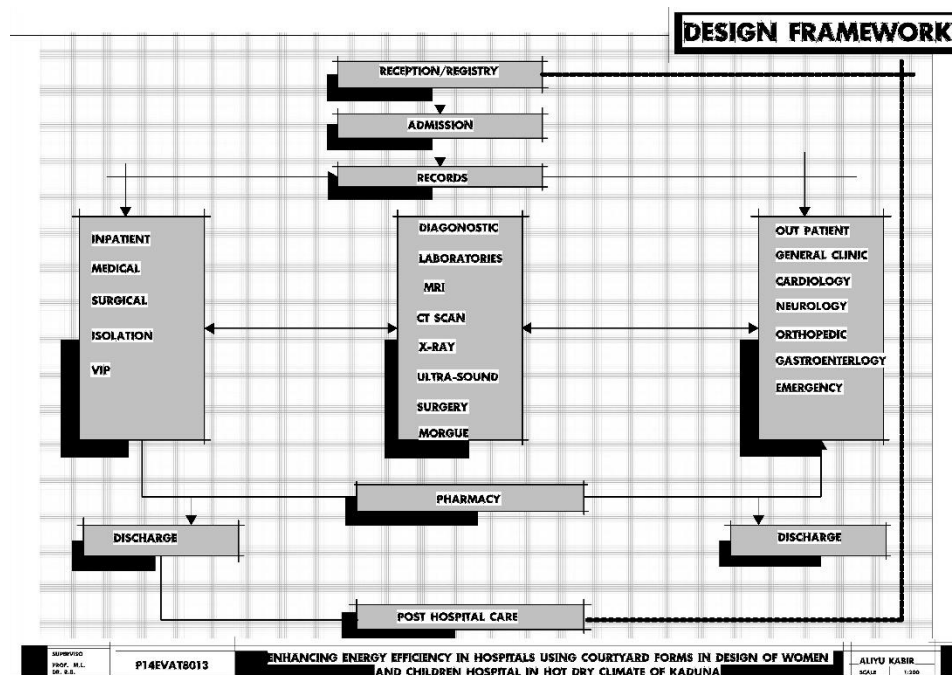


**Figure 6.1:** Hospital Design Framework

**Source:** Author (2017)

#### 6.1.1 Conceptual development

In order to provide a functional design, it is paramount to ensure that related spaces with common function are closely linked, as this will make for a more efficient design, the Hospital and health care facilities whole building design guide provided a design

framework as shown in the Fig. 6.1 above that aids the overall organization of Hospital function. The proposed design was also able to adopt a similar framework in order to achieve optimum efficiency, as shown in the figure below,

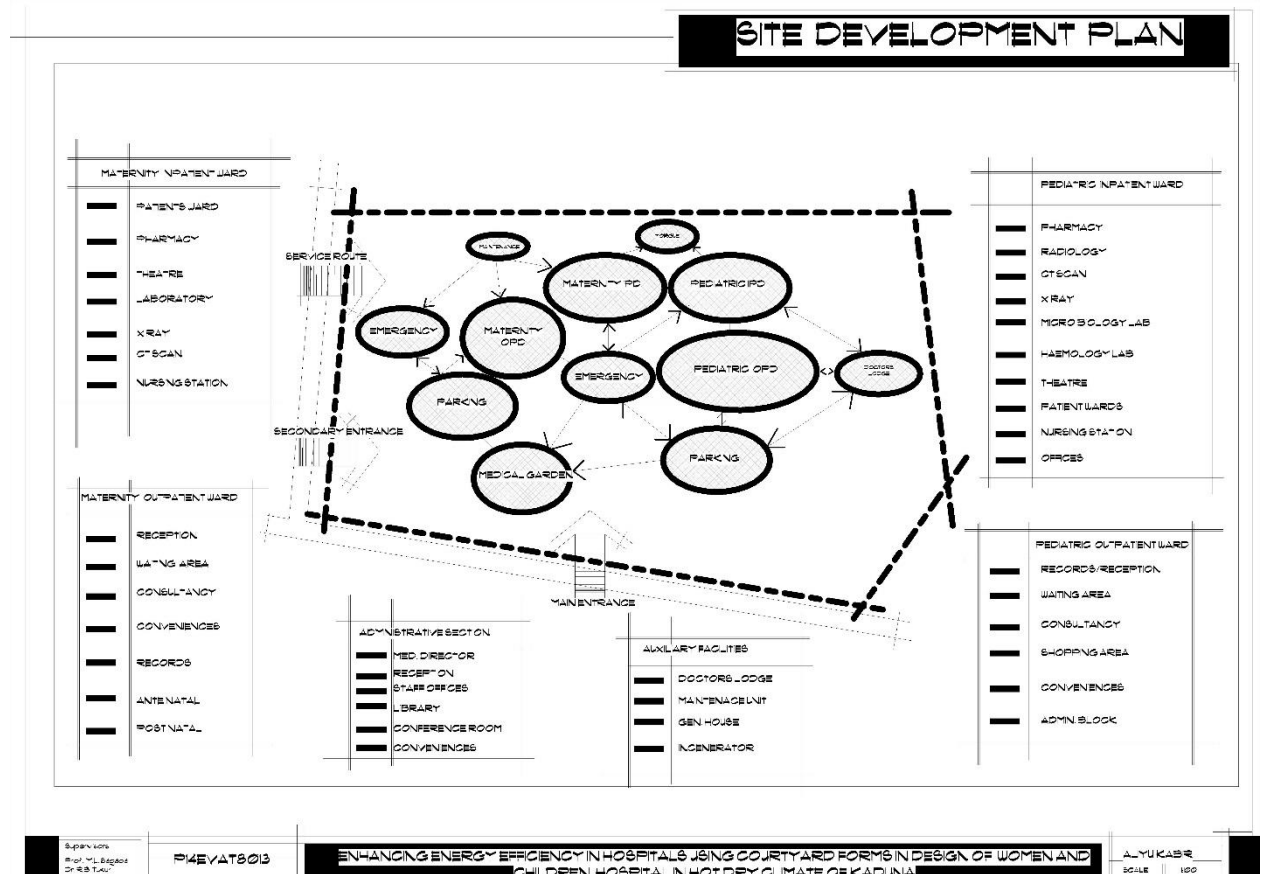


**Figure 6.2:** Concept development plan

**Source:** Author (2017)

The site development plan was developed according to the hospital design framework highlighted earlier. It guides the spatial arrangements of the proposed hospital; it also shows the link between all the major functions in the hospital complex as well as the access routes leading to them. This was done in order to achieve optimum functionality as well as efficiency.

## 6.2 Schedule of Accommodation

The schedule of accommodation was developed by adhering to space anthropometry and ergonomic guiding Hospital designs, most especially women and children health. Guidelines were retracted from studied literature. Table 6.1 shows the Schedule of Accommodation of the Administrative block, Table 6.2 shows that of the Outpatient section, Table 6.3 shows that of the Inpatient section and Table 6.4 to 6.7 shows the schedule of accommodation of auxiliary facilities comprising of Restaurants, Laundry, Storage and morgue respectively as shown below.

**Table 6.1:** Schedule of Accommodation for Administrative Block

**Source:** Author (2017)

| ADMINISTRATIVE BLOCK |                           |      |                  |
|----------------------|---------------------------|------|------------------|
| S/N                  | SPACE FUNCTION            | UNIT | AREA             |
| 1                    | Reception                 | 1    | 12m <sup>2</sup> |
| 2                    | Security                  | 1    | 8m <sup>2</sup>  |
| 3                    | Medical directors' office | 1    | 14m <sup>2</sup> |
| 4                    | Asst. M.D Office          | 1    | 10m <sup>2</sup> |
| 5                    | General offices           | 7    | 12m <sup>2</sup> |
| 6                    | Conference room           | 1    | 32m <sup>2</sup> |
| 7                    | Medical Library           | 1    | 72m <sup>2</sup> |
| 8                    | Relaxation room           | 1    | 34m <sup>2</sup> |
| 9                    | Utility room              | 1    | 10m <sup>2</sup> |
| 10                   | Storage                   | 1    | 8m <sup>2</sup>  |
| 11                   | Conveniences              | 7    | 5m <sup>2</sup>  |

**Table 6.2:** Schedule of Accommodation for Outpatient Section**Source:** Author (2017)

| <b>OUTPATIENT SECTION</b> |                       |             |                   |
|---------------------------|-----------------------|-------------|-------------------|
| <b>S/N</b>                | <b>SPACE FUNCTION</b> | <b>UNIT</b> | <b>AREA</b>       |
| 1                         | Entrance              | 1           | 80m <sup>2</sup>  |
| 2                         | Reception             | 1           | 56m <sup>2</sup>  |
| 3                         | Patients waiting      | 1           | 120m <sup>2</sup> |
| 4                         | Consultancy waiting   | 1           | 82m <sup>2</sup>  |
| 5                         | Consultancy Office    | 4           | 15m <sup>2</sup>  |
| 6                         | Nursing station       | 1           | 20m <sup>2</sup>  |
| 7                         | Pharmacy              | 1           | 40m <sup>2</sup>  |
| 8                         | Dispensary            | 1           | 25m <sup>2</sup>  |
| 9                         | Common room           | 1           | 24m <sup>2</sup>  |
| 10                        | Lift                  | 2           | 12m <sup>2</sup>  |
| 11                        | Storage               | 3           | 15m               |
| 12                        | Call room             | 2           | 12m <sup>2</sup>  |
| 13                        | Laboratories          | 3           | 60m <sup>2</sup>  |
| 14                        | Convenience           | 9           | 4m <sup>2</sup>   |
| 15                        | Security point        | 2           | 12m <sup>2</sup>  |

**Table 6.3a:** Schedule of Accommodation for Inpatient Section**Source:** Author (2017)

| <b>INPATIENT SECTION</b> |                       |             |                   |
|--------------------------|-----------------------|-------------|-------------------|
| <b>S/N</b>               | <b>SPACE FUNCTION</b> | <b>UNIT</b> | <b>AREA</b>       |
| 1                        | General patient ward  | 4           | 144m <sup>2</sup> |
| 2                        | Private ward          | 6           | 52m <sup>2</sup>  |
| 3                        | Ante natal ward       | 1           | 228m <sup>2</sup> |
| 4                        | Post-natal ward       | 1           | 227m <sup>2</sup> |
| 5                        | Delivery              | 2           | 48m <sup>2</sup>  |
| 6                        | Theatre               | 2           | 50m <sup>2</sup>  |
| 7                        | Doctors Changing      | 2           | 8m <sup>2</sup>   |
| 8                        | Scrub                 | 2           | 10m <sup>2</sup>  |
| 9                        | Intensive care        | 1           | 62m <sup>2</sup>  |
| 10                       | Nursing station       | 6           | 16m <sup>2</sup>  |
| 11                       | Anesthesia            | 2           | 20m <sup>2</sup>  |
| 12                       | Radiology             | 1           | 80m <sup>2</sup>  |
| 13                       | Radiology waiting     | 1           | 30m <sup>2</sup>  |
| 14                       | CT Scan               | 1           | 23m <sup>2</sup>  |
| 15                       | Pharmacy              | 1           | 112m <sup>2</sup> |
| 16                       | Pharmacy waiting      | 1           | 73m <sup>2</sup>  |
| 17                       | Pharmaceutical office | 2           | 12m <sup>2</sup>  |
| 18                       | Utility               | 5           | 11m <sup>2</sup>  |
| 19                       | Triage                | 2           | 10m <sup>2</sup>  |
| 20                       | Hematology lab        | 1           | 52m <sup>2</sup>  |

|    |                  |   |                   |
|----|------------------|---|-------------------|
| 21 | Microbiology lab | 1 | 56m <sup>2</sup>  |
| 22 | Gymnasium        | 1 | 114m <sup>2</sup> |

**Table 6.4b:** Schedule of accommodation for inpatient section

**Source:** Author (2017)

**Table 6.5:** Schedule accommodation for Restaurant

**Source:** Author (2017)

| RESTAURANT |          |      |                  |
|------------|----------|------|------------------|
| S/N        | FUNCTION | UNIT | AREA             |
| 1          | Dinning  | 1    | 62m <sup>2</sup> |
| 2          | Kitchen  | 1    | 22m <sup>2</sup> |
| 3          | Store    | 2    | 14m <sup>2</sup> |
| 4          | Servery  | 1    | 8m <sup>2</sup>  |

**Table 6.6:** Schedule of accommodation for Laundry

**Source:** Author (2017)

| LAUNDRY |                    |      |                  |
|---------|--------------------|------|------------------|
| S/N     | FUNCTION           | UNIT | AREA             |
| 1       | Collection/Sorting | 1    | 15m <sup>2</sup> |
| 2       | Washing area       | 1    | 30m <sup>2</sup> |
| 3       | Ironing            | 1    | 14m <sup>2</sup> |
| 4       | Clean Storage      | 1    | 20m <sup>2</sup> |
| 5       | Dirty storage      | 1    | 16m              |
| 2       |                    |      |                  |

**Table 6.7:** Schedule of accommodation for General store**Source:** Author (2017)

| <b>GENERAL STORE</b> |                    |             |                  |
|----------------------|--------------------|-------------|------------------|
| <b>S/N</b>           | <b>FUNCTION</b>    | <b>UNIT</b> | <b>AREA</b>      |
| 1                    | Main store         | 1           | 32m <sup>2</sup> |
| 2                    | Delivery           | 1           | 22m <sup>2</sup> |
| 3                    | Sterile goods room | 1           | 26m <sup>2</sup> |
| 4                    | Office             | 1           | 9m <sup>2</sup>  |
| 5                    | Utility            | 1           | 12m <sup>2</sup> |
| 6                    | Sorting            | 1           | 24m <sup>2</sup> |

| <b>MORGUE</b> |                 |             |                  |
|---------------|-----------------|-------------|------------------|
| <b>S/N</b>    | <b>FUNCTION</b> | <b>UNIT</b> | <b>AREA</b>      |
| 1             | Waiting area    | 1           | 18m <sup>2</sup> |
| 2             | Cold store      | 1           | 32m <sup>2</sup> |
| 3             | Specimen room   | 1           | 17m <sup>2</sup> |
| 4             | Loading Bay     | 1           | 28m <sup>2</sup> |
| 5             | Caskets/Locker  | 1           | 32m <sup>2</sup> |
| 6             | Storage         | 1           | 14m <sup>2</sup> |
| 7             | Records         | 1           | 21m <sup>2</sup> |
| 8             | Entrance        | 1           | 9m <sup>2</sup>  |

**Table 6.8:** Schedule of accommodation for Morgue**Source:** Author (2017)

### **6.3 Functional Analysis**

There are three major entrances to the site, the first which is the primary access leads to the pediatric ward, the second which is the secondary access leads to the maternity ward while the third provides access to services such as maintenance, the mortuary and power installations. Although pathways were created around the complex to aid circulation to all spaces within the Hospital complex. The general outpatient ward is the first point of contact on arrival, it has a clear route that can be easily accessible from the parking area as well as the pedestrian walk way, this is characterized in both the pediatric and maternity department of the Hospital, similarly the Emergency unit was designed to be as accessible as possible from both the primary and secondary entrances, there is also a bold signage that clearly celebrates the emergency wards for ease of location. The pediatric and maternity units are two storey high, the ground floor comprise of majorly the outpatient functions such as reception/records, general waiting area, consultation rooms, pharmacy, laboratories, radiology and theatre. While the general wards, private wards and exclusive wards occupy the first and second floor respectively, this was done to provide privacy as well as conduciveness for the patients in the wards. The overall view of the Hospital complex can be seen in Fig. 6.3 below.

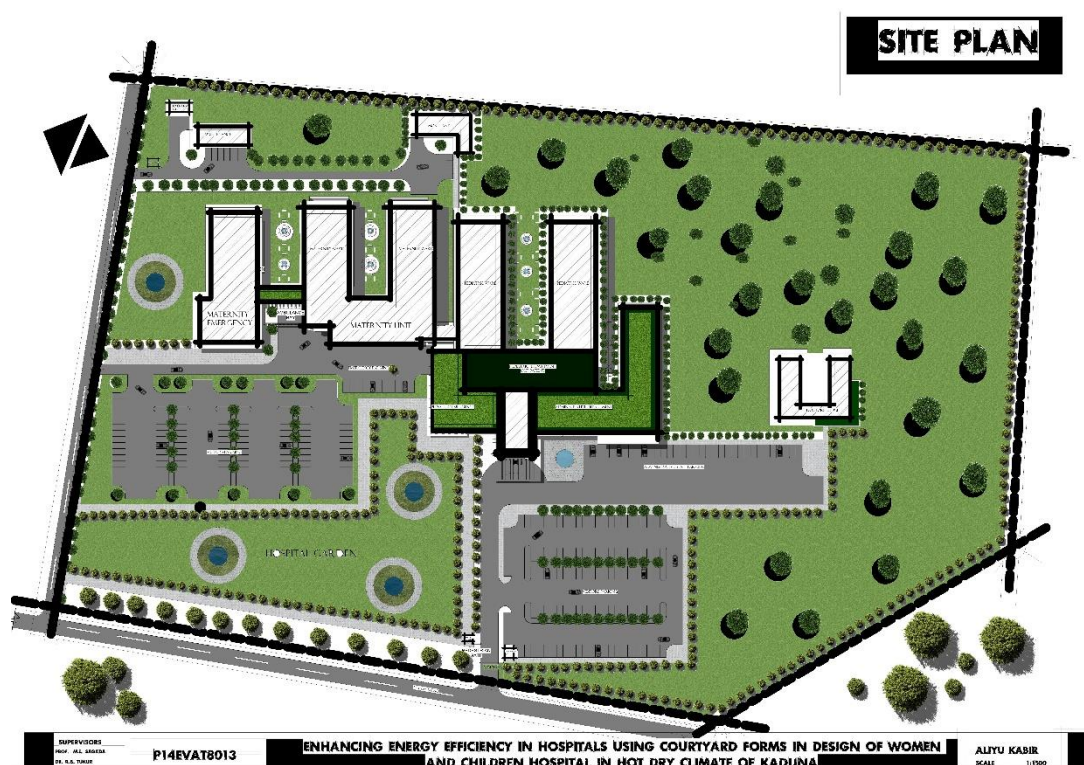


**Figure 6.3:** Site Plan sheet

Source: Author (2017)

## 6.4 Departments/Units

The Hospital complex comprise of majorly the pediatric and maternity units and these units are made up of other sub units and departments that makes up the hospital complex, some of the major units of the hospital shall be discussed in the section below and they include:

### 6.4.1 GOPD (General outpatient department)

This is the first point of contact on getting to the Hospital, this is where patients register and book their appointments with a consultant, it is done on arrival in the records/reception of the Hospital, this was made as open as possible so as visitors can have easy access to it, a spacious waiting area was created so as to accommodate large traffic, the pediatric waiting area was made more spacious so as to accommodate the

playful nature of children, it was also ensured that the area was well lighted and properly ventilated to aid patients comfort, indoor plants were also provided to help make the waiting area more conducive, it was also ensured that the courtyard was visible from the waiting area to aid scenery while patients wait their turns. The consultant's offices were provided just adjacent to the waiting area for swift transition from the waiting. The administrative section is also accessible from the outpatient ward, the admin has a distinct entrance which leads to staffs' offices, the Directors office, conference office, medical library and staff room. The administrative section was separated from the major outpatient zone but made very accessible to ensure the administrators keep track of the Hospital operations.

#### 6.4.2 Emergency department

The Emergency department caters for critical and urgent cases that need quick attention, the emergency has a clear access from all entrances to the Hospital, an ambulance bay and parking was provided specially for the emergency units, the pediatric and maternity emergencies were separated due to differences in their operation. Both have waiting areas on arrival, a ward, doctor's office, minor theatre room, Anastasia room, a recovery room, intensives care, neo natal room, changing room, Nursing station and a delivery for the maternity emergency.

#### 6.4.3 Laboratories

This is where test is carried out as well as other clinical investigations. The laboratory is very accessible and has a clear path so that patients could easily reach it after consultation. There are three main laboratories provided this includes the Microbiology lab, the Haemology lab and the general laboratory. There are also other micro spaces within the laboratory which includes blood bank general office, sterilization room, storage and utility spaces as well as conveniences.

#### 6.4.4 Radiology

This is where medical imaging, diagnosis and treatment is carried out, it was ensured that natural lighting was controlled to allow for better working environment for imaging. It was ensured that the radiology department was as accessible as possible most especially from the consultation area, it was also situated close to the laboratory to aid way finding around the Hospital. The radiology department comprise of the X-ray unit, CT- scan, imaging room, staff office, utility/storage spaces, conveniences.

#### 6.4.5 The surgical department

The Surgical unit is where surgeries and acute operations are performed, it was ensured that it was strategically positioned to enable swift entrance and exit, the surgical unit was situated very close to the emergency, pharmacy and inpatient wards. It was further ensured that natural lighting and ventilation was controlled to a minimal level, it was also positioned to avoid traffic that may impede circulation to and from the surgical unit. Spaces within the surgical department includes: Main theater room, anesthesia room, sterilization room, changing room, scrub, clean and dirty utility, recovery room.

#### 6.4.6 Pharmaceutical unit

the pharmaceutical unit was centrally placed, so it could be accessible from all points of the hospital, a clear path was created to this unit, most especially from the consultancy, surgery and waiting areas, the pharmaceutical unit comprise of a waiting area, general office, chief pharmacist office, a dispensary, a cash office, drug storage, patients waiting area, conveniences

#### 6.4.7 Patients ward

The patients ward constitute the major part of the inpatient ward, the patients ward was carefully designed since its comfort level could determine how fast patients recover, a lot

of emphasis was placed on cooling this spaces as passively as possible with the aid of the courtyard which was the main focus of the research. The general wards were situated at the first floor, while the private wards were located at the second floor. It was ensured that the windows of the wards were open able to the courtyard to enhance natural ventilation and lighting. The general pediatric ward was designed with special consideration for the children needs, it was ensured that the enough circulation space was provided as kids like to run around, a play area was also provided with an entertainment area where they can watch their favorite programs, a nursing station was also provided in the ward to oversee the children. The private pediatric wards were designed to accommodate four patients, with each patient having their own private space, Provision was also made for patient's caregivers, to give the patients all the comfort they need. The same approach was used in the design of the private ward of the maternity unit, similarly it was ensured that caregiver's space was provided. A gymnasium was also provided adjacent to the maternity ward, to help them keep fit hence aid faster recovery. An exclusive ward was also provided in the pediatric section to cater for patients whom would need a more comfortable ward, this ward accommodates one patient per room, it has provision of an extra room to accommodate patients' family, children may need all the support they can get when ill, and the families presence could aid the Childs recovery.

#### 6.4.8 Auxiliary Facilities

This are facilities provided to support the overall function of the Hospital complex, these units include the restaurant, the restaurant was provided to cater for the feeding needs of patients, staffs and visitors, a gallery with gift shops was also provided in the pediatric unit to give a more refreshing environment for the children. A laundry was also provided to ensure washing services is prompt. Further a maintenance department was also

designed to make sure that the Architectural mechanical, electrical, water services are functioning efficiently.

## **6.5 Special Design Consideration**

In order to provide a design that will serve its purpose and be sustainable for a long period of time, it is necessary to make sure certain conditions are given paramount consideration to ensure that the design goals are met. This factors include;

### **6.5.1 Passive cooling approach**

The design was set to identify the most efficient courtyard form for cooling in the hot and dry climate of kaduna state, Nigeria. The study found the semi enclosed U shape courtyard to be the most efficient for cooling and it was adopted in the proposed design to aid passive cooling. Egg crate shading devices were also adopted to reduce solar impact through the windows which in turn will improve cooling. Green roofs were also adopted to provide sufficient cover against harsh radiations, as well as provide extra cooling to the building large vegetation was also used, comprising of trees, shrubs and grasses. These provides necessary cover against harsh wind, whilst also aiding cool breeze which will enhance cooling experience in the building. Light materials were also used for exterior finishes which will serve as solar reflectors, because the more intense solar radiation is prevented from hitting the Building, the cooler it becomes.

### **6.5.2 User focused design**

For a design to be considered functional it must be able to meet the users' needs and in this case the patients, staffs and visitors constitute the users of the proposed Hospital design. An open plan system was adopted to ensure that patients are able to access the different units of the Hospital without difficulty, enough circulation space was created to ensure ease of movement around the Hospital complex. It was also made possible for in

house occupants to have good views of the outside environment so as to aid visual comfort. Pavements were designed to accommodate patients on wheel chairs as well as other those walking on foot, ramps and lifts were also provided to ease vertical movement for those with physical challenges. The courtyard space was utilized not only as a microclimate modifier, but as a usable space where patients can interact fully with their outdoor environment.

#### 6.5.3 Future expansion

For a design to be sustainable it should not only meet the present needs of the users but also take the future needs into cognizance, for this purpose a grid system with expansion joints was provided to enable ease of future modifications, decking was also on the top floors to allow for vertical extension since urbanization can limit horizontal expansion in the nearest future.

#### 6.5.4 Drainage

Site drainage is very important in utilizing or getting rid of surface water. Rainfall is the main source of surface water hence it becomes necessary to plan how to evacuate the excess down pours to be expected. From the site analysis it was observed that the site slopes gently to the eastern part of the site. 900mm deep Gutters were provided along the path ways to drain surface water, the courtyards are areas that are susceptible to water logging, to avoid excess surface water in the courtyards, and gutters were provided on both sides of the courtyard to help collect surface water. Hospitals make use of a lot of water for its daily operation's, to meet these needs, a central collection point was created at the lowest point of the site, and this was done to recycle the collected water for future usage.

#### 6.5.5 Construction system

As highlighted earlier a frame structure with a grid of 4m x 6m was adopted for the design, such dimensions were adopted to suit the open nature of the hospital design. Expansion joints were also provided at strategic points to aid future modifications. External columns were also projected to provide support for the roof slabs.

##### 6.5.5.1 *Foundation*

A strip foundation was adopted for the design based on the soil analysis of the site, deep rooted foundation columns were also used to cater for possibilities of additional floors in the future

##### 6.5.5.2 *Exterior wall*

The exterior wall was designed with 230mm concrete wall laid in stretcher bond all around the Building. Lead cladding was also anchored to exterior areas most especially areas that are prone to high solar exposure.

##### 6.5.5.3 *Interior petition*

Dwarf demountable aluminum walls measuring 2000mm height with 100mm thickness was used for interior partitions most especially in the patients ward and offices. This was adopted to enable easy interior modifications when necessary, the complex nature of hospitals sometimes makes it difficult to administer light and ventilation evenly across all the spaces, the use of dwarf moveable wall partitions coupled with high level windows makes for a better light and air distribution across all spaces. Dwarf demountable walls also makes it easier for the healthcare professionals and administrators to keep tabs with ongoing activities in the Hospital environment.

#### 6.5.5.4 *Materials*

Special care was given in selecting material and finishes due to the sensitive nature of the Hospital environment, terrazzo floor finish was used in the outpatient ward, this is due to the heavy traffic usually experienced in the OPD, and terrazzo has the qualities to withstand heavy usage and has durable properties that makes it suitable for the OPD. Similarly, vinyl floor finish was used in the inpatient wards such as theatre, pharmacy and patients' wards, this is because vinyl sheets are laid as a monolithic floor that is joint less, this quality makes it difficult for dirt's to be trapped in the joints, it also makes it easier to clean. Additionally, vinyl gives an appealing appearance.

#### 6.5.5.5 *Colour*

Colour plays an important role in healthcare buildings. Its relevance goes beyond decorations but can be used as an element to greatly influence patient's recovery. According to Olesen (2017) healing colors are the colors that influence mood, as it calms the nervous system and makes the environments less provoking and peace inducing. According to the colour healing therapy as cited by Olesen (2017) orange colour is one of the best colours most especially in children rooms, its associated with warmth, joy and happiness. Yellow, green, blue, pink and purple are all recommended colours, while colours like red should be used minimally.

## **CHAPTER SEVEN**

### **7.0 SUMMARY, CONCLUSION AND RECOMMENDATION**

#### **7.1 Summary**

The study was set out to find a way, in which passive cooling can be improved using courtyard forms which will in turn improve energy efficiency in Hospitals. It has been discovered that Health care facilities use up large amount of energy due to the need to provide optimum comfort and conduciveness for patients, visitors and staffs. However, it has also been found that the situation is more derelict in third world countries like Nigeria, where there is insufficient power supply. In an attempt to improve the situation, several passive methods such as courtyards have been studied, these studies have looked at how the courtyard design variants such as courtyard form, shape, aspect ratio and orientation can influence the cooling potentials of a building. However, it was noticed that a study that attempts to find out the impact of the courtyard forms on passive cooling has not been recorded in the hot dry climatic region of Kaduna State Nigeria. This gap prompted the researcher to conduct this study in order to address the problem. The research was set out to find the most suitable courtyard form and aspect ratio that will provide the best cooling potentials which will hence improve energy efficiency in Healthcare buildings in the focus area. To achieve this, some objectives were outlined and followed through. First, the research was set to ascertain the level of application of courtyard design variants in existing Hospital design, this was done by identifying the courtyard design variables with their effects on buildings. Furthermore, a checklist was adopted from literature which was used in assessing the courtyard design of the existing cases. Secondly, the research was also able to determine the most effective courtyard form for cooling in hot dry climate of Kaduna state, by developing base case models using Revit Autodesk software with different courtyard aspect ratios, under assumed conditions that reflected the

characteristics of the area of study. Thirdly, the extent to which the most effective courtyard form improves energy efficiency was also recorded. This was achieved by simulating the base case models using ECOTECT software. In addition, a case study of some selected hospitals was also carried out in order to meet the objectives of the research as well as identify design credits and short comings. Consequently, all the research findings and results were used in coming up with a proposed Women and Children Hospital in Hot dry climate of Kaduna State Nigeria.

## **7.2 Conclusion**

This study was conducted to see how courtyards can be used as a passive strategy to improve cooling in healthcare buildings in hot dry climate of Kaduna State, which in turn will reduce energy consumption. The study considered the rectangular courtyard with enclosed and semi enclosed forms been established as the most applicable forms in the study area. The courtyards were designed with different ratios ranging from 1:1.2 to 1:2 with an assumed area of 48sqm and a building of 128sqm for both forms. Also, certain conditions were assumed to ensure the simulation depicts real case scenario of the study area, such as, the annual climatic data of Kaduna State was used, the base case models were all assumed to be 9m high, the models were also assumed to have a North and South orientation. The simulations were done using Autodesk ecotect simulation software. The results showed that a two storey building of North and South orientation with a semi enclosed U shape courtyard with ratio 1:2 has an annual cooling load of 33724.309 kwh/m<sup>2</sup>/year which is the least annual consumption compared to the other considered ratios. Conversely, the U shape semi enclosed courtyard with ratio 1:6 has the highest annual energy load of 42124.438 kwh/m<sup>2</sup>/year. The centralised courtyard with ratio 1:2 was also found to have the least energy consumption compared to other centralized ratios with an annual consumption of 45084.121 kwh/m<sup>2</sup>/year while the highest centralized ratio

was recorded to be ratio 1:1.2 with an annual consumption load of 48571.867 kwh/m<sup>2</sup>/year. It was also recorded that the u shape courtyard with ratio 1:2 has a lesser energy load of up to 33.68% compared to a similarly designed centralized courtyard of the same ratio and area. Further, the study uterlised the U shape semi enclosed courtyard with ratio 1:2 being the most efficient form in the design of a proposed women and children Hospital in Hot dry climate of Kaduna.

### **7.3 Recommendations**

After successfully carrying out the research the study was able to point out certain factors which might aid future designs:

- i. Hospitals should endeavor to make use of courtyards in its design as it has been established that courtyards can greatly improve passive cooling which will reduce dependence on HVAC systems for cooling
- ii. The study also recommends that all courtyard design variables such as form, aspect ratio and orientation should be considered in the design phase so that the courtyard can perform optimally.
- iii. The study also recommends that U shape courtyards with ratio 1:2 should be adopted, most especially for two storey buildings in the hot dry climate of Kaduna state, Nigeria.
- iv. It is also recommended that Hospitals should uterlise the courtyard space as a therapeutic environment were patients can interact with nature, a factor which has been acknowledged to aid patients' recovery.

#### **7.4 Contributions to knowledge**

The major contributions of this research are;

- i. A U shape semi enclosed courtyard of ratio 1:2 in a two storey building, will have the least annual energy consumption compared to other ratios considered in the study ranging from 1:1.2 to 1:2 in hot and dry climate of Kaduna State, Nigeria.
- ii. The U shape semi enclosed courtyard with ratio 1:2 will reduce annual energy consumption of up to 33.68% compared to a centralized courtyard with the same dimension.

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## APPENDICES

  
**MINISTRY OF HEALTH AND HUMAN SERVICES**  
KADUNA STATE, NIGERIA

MOH/ADM/744/VOL.1/523 24<sup>th</sup> April, 2017

NOTICE OF APPROVAL AFTER FULL COMMITTEE REVIEW

**ENHANCING ENERGY EFFICIENCY IN HOSPITALS USING COURTYARD FORMS FOR THE DESIGN OF WOMEN AND CHILDREN'S HOSPITAL IN HOT DRY CLIMATE KADUNA**

Name of Principal Investigator: ALIYU KABIR

Address of principal Investigator: DEPARTMENT OF ARCHITECTURE,  
FACULTY OF ENVIRONMENTAL  
DESIGN,  
AHMADU BELLO UNIVERSITY,  
ZARIA

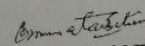
Date of receipt of application: 30<sup>TH</sup> MARCH, 2017

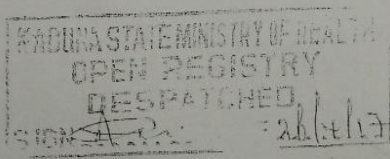
Date of Ethical Approval: 24<sup>TH</sup> APRIL, 2017

This is to inform you that the research described in the submitted protocol, the consent forms, advertisements and other participant information materials have been reviewed and given full approval by Health Research Ethics Committee (HREC).

If there is delay in starting the research or any change, inform the HREC so that the dates of approval can be adjusted accordingly.

However, Researcher is kindly requested to submit a copy of his/her findings to the State Ministry of Health, please.

  
**DR. B.M. JATAU**  
Chairman



Independence Way, P.M.B 2014, Kaduna, Kaduna State-Nigeria  
Tel: + 234 (0) 818 407 8693 | Website: [www.kdsg.gov.ng](http://www.kdsg.gov.ng) | Email: [health@kdsg.gov.ng](mailto:health@kdsg.gov.ng)

**Appendix I:** Letter of approval from the Kaduna state Ministry of Health for conducting case studies in selected Healthcare facilities in Kaduna

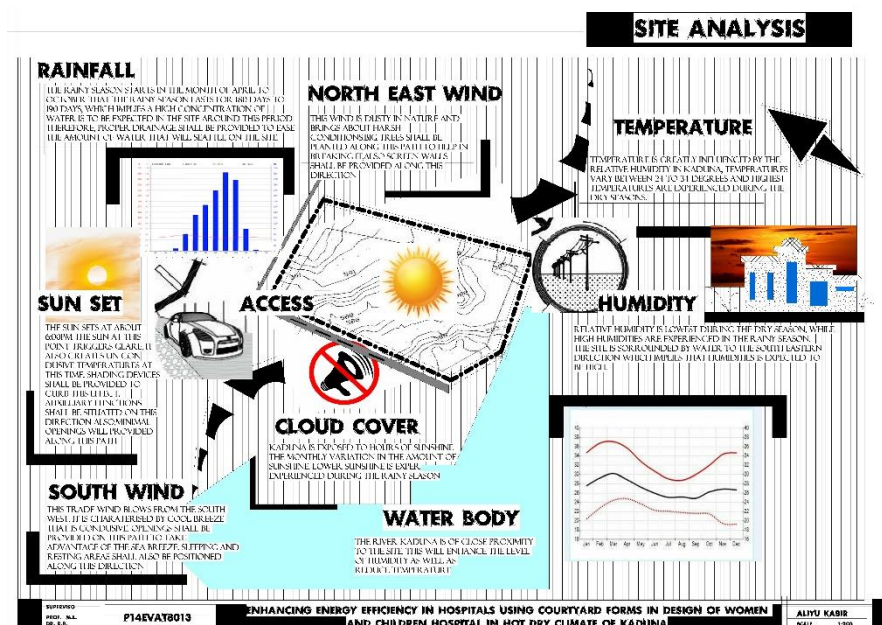
| DESIGN VARIANTS OF THE COURTYARD   |                |               |
|------------------------------------|----------------|---------------|
| <b>FORM</b>                        |                |               |
|                                    |                | Square        |
|                                    |                | Rectangle     |
|                                    |                | Circle        |
|                                    |                | Others        |
| <b>SHAPE</b>                       |                |               |
|                                    | Fully enclosed | O- Shape      |
|                                    | Semi enclosed  | U-Shape       |
|                                    |                | L-Shape       |
|                                    |                | I-Shape       |
| <b>AREA</b>                        |                |               |
| <b>NOs OF FLOORS</b>               |                |               |
| <b>ORIENTATION</b>                 |                |               |
|                                    |                | North         |
|                                    |                | South         |
|                                    |                | West          |
|                                    |                | East          |
| <b>SHADING DEVICES</b>             |                |               |
|                                    |                | Roof overhang |
| <b>WATER GROUND RATIO</b>          |                |               |
| <b>VEGETATION GROUND RATIO</b>     |                |               |
| <b>HEALING PROPERTIES</b>          |                |               |
| <b>COURTYARD PLAN ASPECT RATIO</b> |                |               |
| <b>FUNCTIONS</b>                   |                |               |

## Appendix II: Checklist for accessing courtyard performance

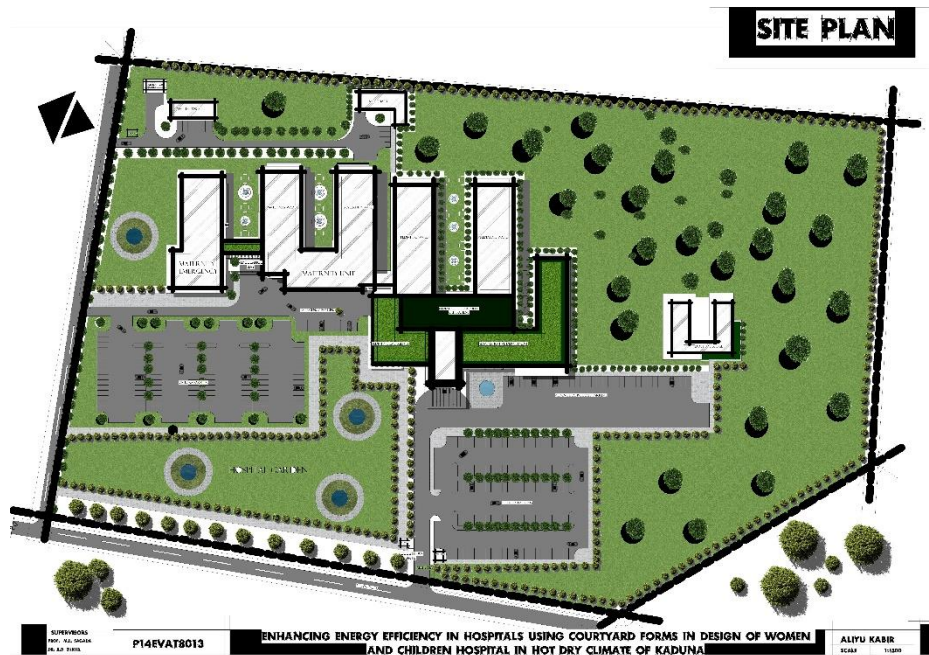
Source: (Almhafdy *et al*, 2013)

| SITE SELECTION CRITERIA                                        |                                                                                   |                                                                                                                                         |                                                                                    |                                                                                     |
|----------------------------------------------------------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| S/N                                                            | CRITERIA                                                                          | SITE A                                                                                                                                  | SITE B                                                                             | SITE C                                                                              |
|                                                                |  |                                                        |  |  |
|                                                                | KADUNA METROPOLIS                                                                 | NEW MILINIUM CITY                                                                                                                       | KADUNA CENTRAL                                                                     | KADUNA SOUTH                                                                        |
| 1                                                              | ACCESSIBILITY                                                                     | 4                                                                                                                                       | 2                                                                                  | 2                                                                                   |
| 2                                                              | LOCATION                                                                          | 4                                                                                                                                       | 4                                                                                  | 3                                                                                   |
| 3                                                              | VEGETATION                                                                        | 3                                                                                                                                       | 2                                                                                  | 3                                                                                   |
| 4                                                              | WATER BODY                                                                        | 5                                                                                                                                       | 4                                                                                  | 2                                                                                   |
| 5                                                              | TOPOGRAPHY                                                                        | 3                                                                                                                                       | 3                                                                                  | 4                                                                                   |
| 6                                                              | LAND AREA                                                                         | 4                                                                                                                                       | 3                                                                                  | 3                                                                                   |
|                                                                | TOTAL                                                                             | 23                                                                                                                                      | 18                                                                                 | 17                                                                                  |
| <small>NUMBERED<br/>DRAWING<br/>NO. 4.5</small><br>P14EVAT8013 |                                                                                   | ENHANCING ENERGY EFFICIENCY IN HOSPITALS USING COURTYARD FORMS IN DESIGN OF WOMEN<br>AND CHILDREN HOSPITAL IN HOT DRY CLIMATE OF KADUNA |                                                                                    | <small>ALYU KASIR<br/>SCALE<br/>1:500</small>                                       |

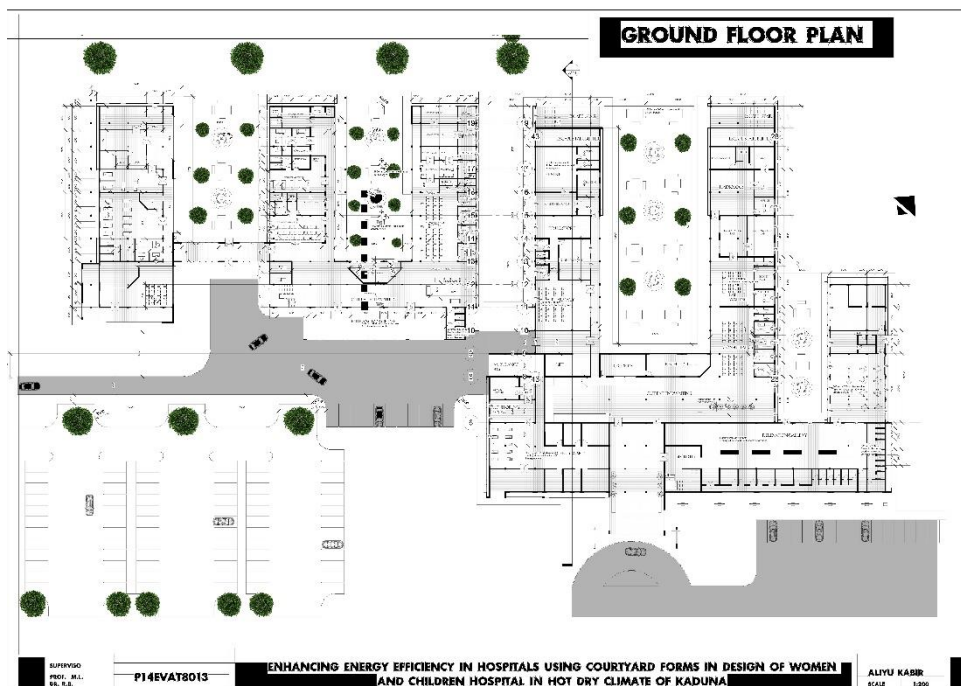
### Appendix III: Site selection criteria



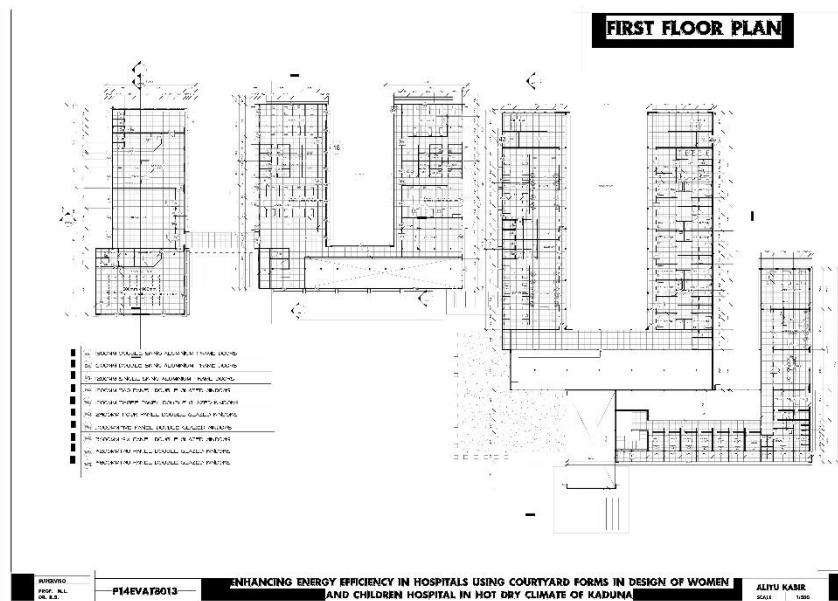
### Appendix IV: Site Analysis II



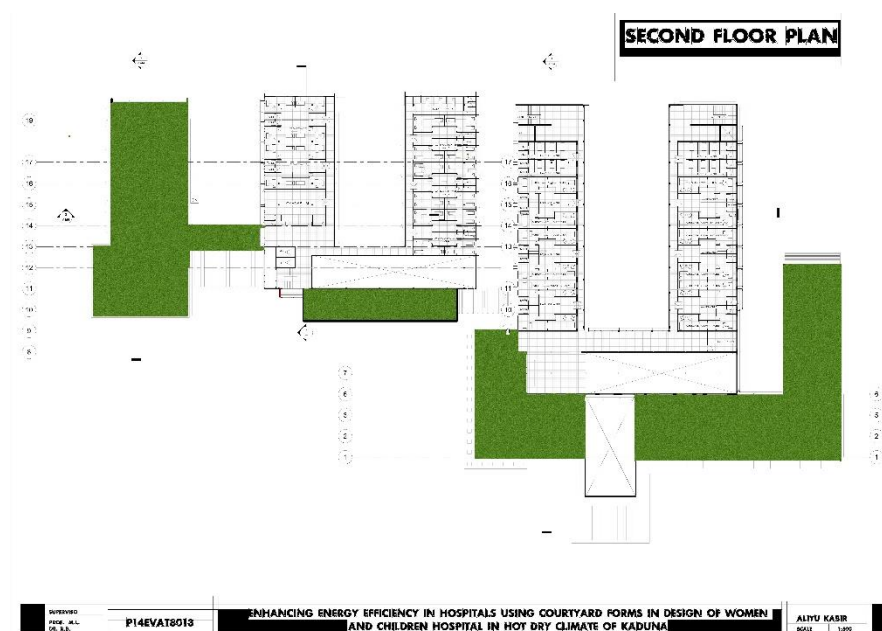
Appendix V: Site plan



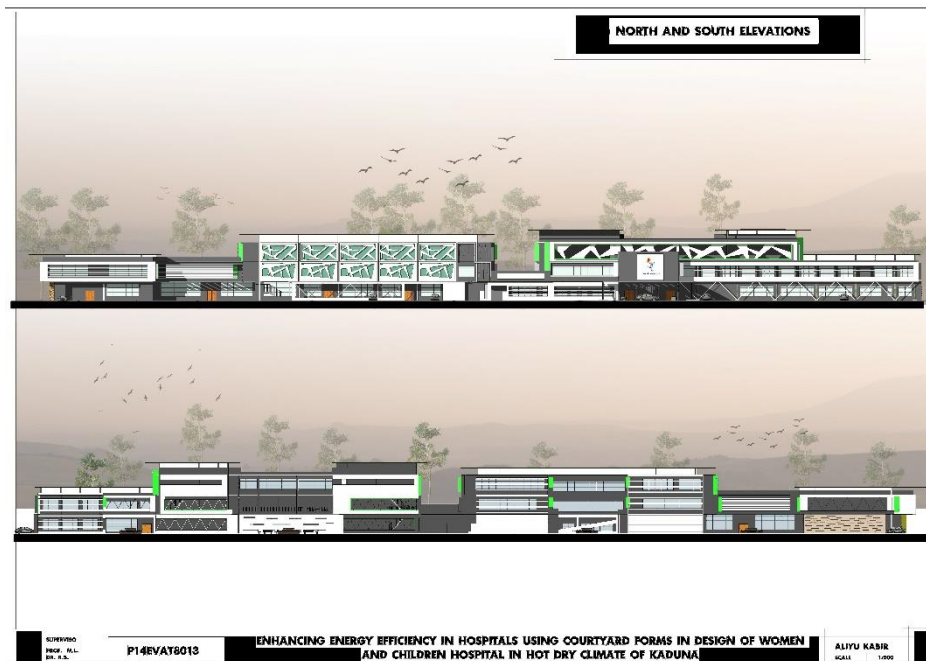
Appendix VI: Ground floor plan



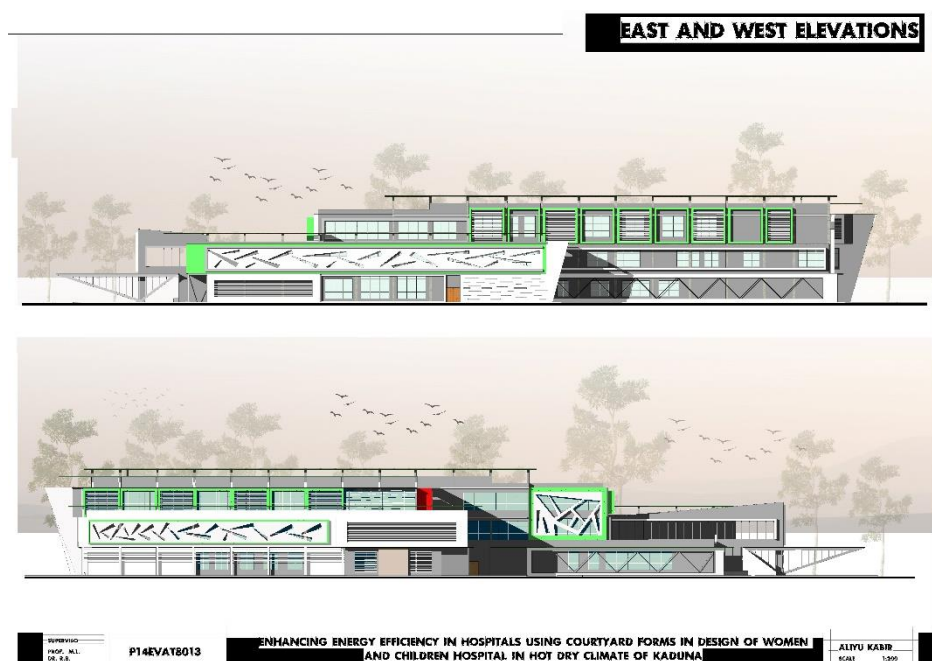
Appendix VII: First floor plan



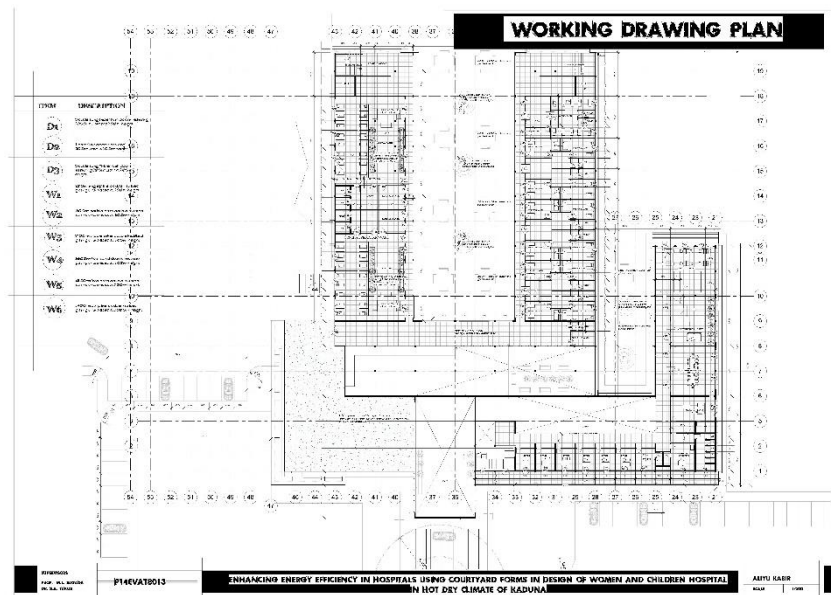
Appendix VIII: Second floor plan



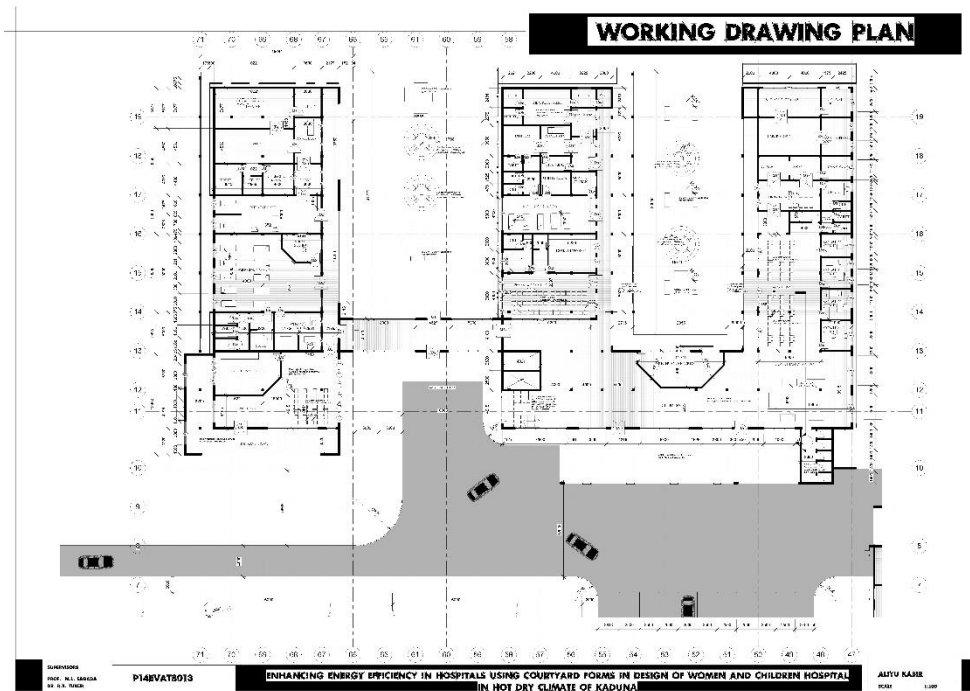
**Appendix IX: North and South Elevations**



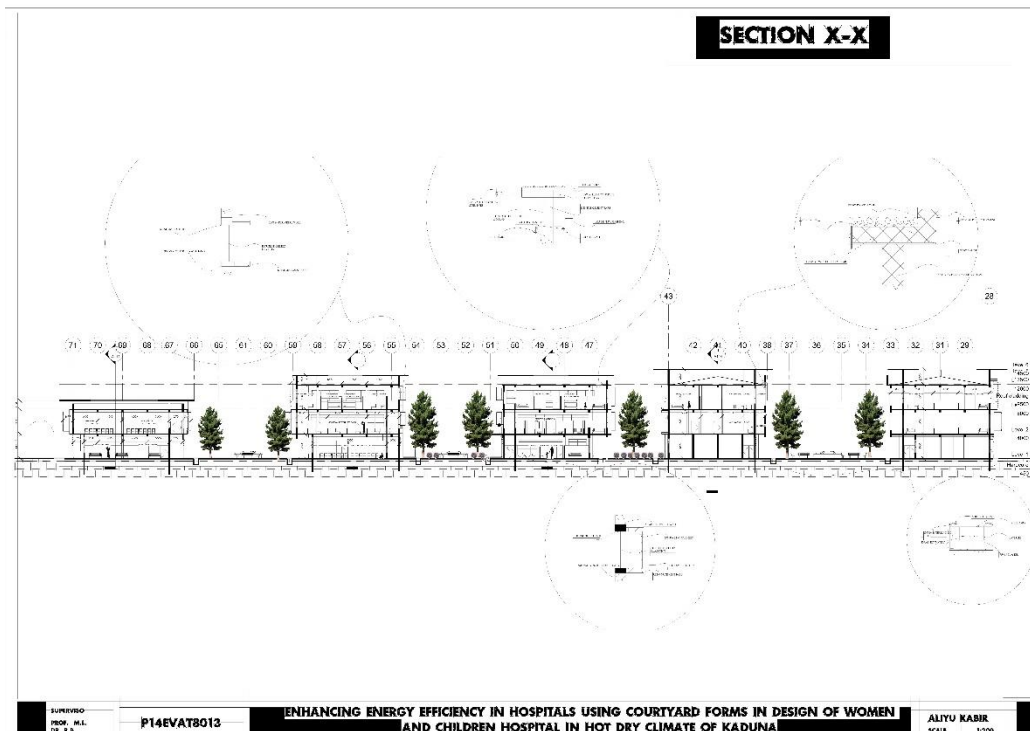
**Appendix X: East and West Elevations**



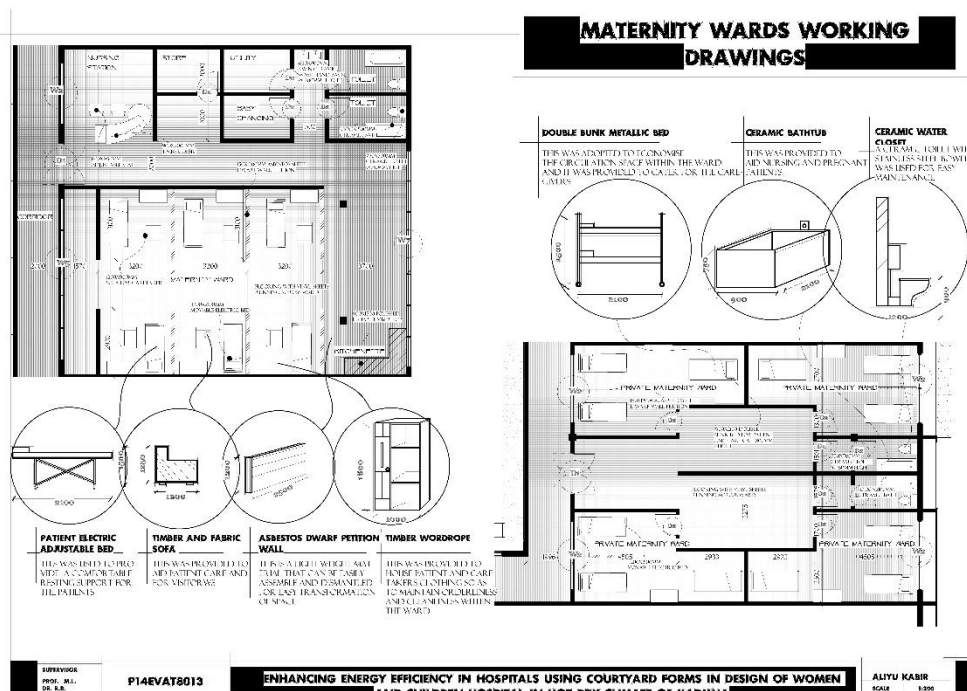
**Appendix XI: Second floor working drawing**



**Appendix XII: Working drawing of ground floor of maternity section**



Appendix XIII: Cross sectional view of Hospital complex



Appendix XIV: Maternity wards working drawing



[illegible]

## Appendix XVII: Design details

| DETAILS                  |          |          |          |
|--------------------------|----------|----------|----------|
| <b>DOORS AND WINDOWS</b> | <b>1</b> | <b>1</b> | <b>1</b> |
|                          | <b>1</b> | <b>1</b> | <b>1</b> |
|                          | <b>1</b> | <b>1</b> | <b>1</b> |
|                          | <b>1</b> | <b>1</b> | <b>1</b> |

## Appendix XVIII: Doors and windows schedule



**Appendix XIX: Approach 3D View**



**Appendix XX:Rear 3d view**



**Appendix XXII:** Arial view



**Appendix XXI:** Arial view