THERMAL ZONING PRINCIPLE FOR ENERGY EFFICIENCY IN THE DESIGN OF INDOOR FITNESS AND SPORT CENTRE, WARRI NIGERIA

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DECLARATION

I declare that the work in this thesis entitled " Thermal Zoning Principle for Energy Efficiency in the Design of Indoor Fitness and Sport Complex Warri, Nigeria'' has been carried out by me in the department of Architecture, A.B.U Zaria under the supervision of Dr. A.M Batagarawa and Dr. S.N Oluigbo.

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

Bello Fatima Jumai	----------	_____
Name of student	Signature	Date

CERTIFICATION

This project thesis entitled "THERMAL ZONING PRINCIPLE FOR ENERGY EFFICIENCY IN THE DESIGN OF INDOOR FITNESS AND SPORT COMPLEX WARRI, NIGERIA'' by BELLO FATIMA JUMAI meets the regulations governing the award of the degree of Master of Science of the Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

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Dr. S. N. Oluigbo Member, Supervisory Committee	Date
Dr. S. A. Salisu Head of Department	Date
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ABSTRACT

The four major building orientations, North, South, East, and West, receive different heat gains causing different indoor temperature and cooling demand within spaces. In fitness and sport centres, the different spaces have differing thermal requirements for occupants' comfort, where fitness activities require low air temperature, and sauna/spa/pool activities require higher temperatures. Air conditioning and ventilation account for highest amount (42%) of energy usage within fitness and sport centres and this significant energy usage can be reduced by thermally zoning the different spaces within the centres. Thermal zoning involves coordinating and placing spaces based on a buildings natural susceptibility to heat gain and thermal requirements of spaces. The aim of this study is to evaluate the effect of thermal zoning on cooling energy consumption within fitness and sport centres in warm humid region of Nigeria. Three different fitness and sport complexes namely University of Benin Indoor Sport Centre, Samuel Ogbemudia Stadium Indoor Sport Centre, and Mayfair Fitness centres were assessed for this study. Field measurements of indoor air temperature of different spaces within the four orientations in the three different indoor fitness and sport complexes are recorded using dry and wet bulb thermometers in the hottest season of the year at 8am, 1pm and 5pm for five consecutive days in 2016 and the result is validated using the Autodesk Ecotect computer simulation software. Also, primary data from the three case studies are collected to model and simulate the predicted cooling energy demand using Autodesk Revit and Autodesk Ecotect simulation software respectively. The air temperature recorded for the four orientations of University of Benin Sport centre, Samuel Ogbemudia Sport Centre, and Mayfair fitness centre are compared and the result from the analysis shows that the North orientation for all cases experiences the lowest internal average temperature of 26.75^0C throughout the day, the east 28.18^0C,

south 29.75^{0}C and the west 31^{0}C. The cooling demand predicted for the four orientations were also compared and the result from the analysis shows that the spaces within the North orientation for the three cases demands about 255KWhm^{-2}, 244KWhm^{-2} and 228KWhm^{-2}, the South 234KWhm^{-2}, 236KWhm^{-2}and 200KWhm^{-2}, East 245KWhm^{-2}, 230KWhm^{-2} and 252KWhm^{-2}, West 278KWhm^{-2}, 281KWhm^{-2}, and 252KWhm^{-2}. This result shows that there is a heat gain difference of about 2^{0}C to 3^{0}C between all orientations and also there can be a significant energy savings of about 18% between the North orientation which has the lowest energy demand and the West orientation which has the highest energy demand. Therefore, spaces with low temperature requirements such as sport halls, fitness gym should be placed within orientation or zones with lower cooling energy demand while spaces with high temperature requirements such as sauna/pool/spa, should be located within orientation with higher temperature and higher cooling demand.

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LIST OF ABBREVIATIONS

AFSFDG	Air Force Services Facilities Design Guide
ARPA	Alberta Recreation and Parks Association
ASHRAE	American Association of Heating, Refrigeration and Air conditioning Engineers
CIBSE	Chartered Institution of Building Services Engineers
CN-SBS	Carbon Neutral Steel Building Systems
DOE	Department of Energy
EPA	Environmental Protection Agency
Ff	First floor
IEA	International Energy Agency
HVAC	Heating Ventilation and Air Conditioning
WBDG	Whole Building Design Guide
WHO	World Health Organization

1.0 INTRODUCTION

1.1 Background to the study

The concept of energy efficiency has become an important consideration in the construction industry, and this is due to its benefits in money saving, reduction of fuel, poverty and reduction in environmental degradation (US Environmental Protection Agency, 2010). Energy is the major component of a building which is about 50% of the building resource consumed and this figure is fast rising as construction increases (Zhang, 2012).

A fitness and sport centre is a health, recreational, and social facility which is geared towards exercise, sports, and other physical activities which may be a for-profit commercial facility, a community or institutionally supported centre (Mion, 2014). Statistics have shown that at least 55% of Nigerians are overweight due to lack of physical activities and also poor nutritional habit, 30-35% are hypertensive out of which 20% is due to overweight (World Health Organisation WHO, 2008). Dalleck and Kravitz (2002) stated that physically inactive people tend to suffer from diseases like diabetes, obesity, depression, heart related problems, hypertension and related diseases. The benefits of fitness and sport activities in a community includes; health improvement, eliminating discrimination and improving community cohesion, strengthening community identity and pride, tackling youth crime and anti-social behaviour, reducing fear of crime, neighbourhood renewal, local economic development, improving the quality of the built and natural environment, and encouraging sustainable travel (Atkins, 2000).

According to the Licence Criteria for Fitness Centre (2009), fitness and sport centres are high energy consuming buildings that have an impact on the environment in a number of ways and this is usually as a result of the number and type of activities that go on

inside and outside the facility. The areas where energy is commonly wasted in a fitness centre are; heating, ventilation and air conditioning, lighting, swimming pools, electrical equipment such as gym apparatus and vending machines, water use for showers and cleaning and types of building materials used in the fit out of fitness centres (Licence Criteria for fitness centre, 2009). Carbon Trust (2006) shows that in warm climates; air conditioning and ventilation account for 42% energy usage, heating and hot water 17%, lighting 4%, pumps 5% while other activities account for 32% energy usage in a fitness and sport centre.

In warm humid climates where the climate is characterised by high humidity and high temperature for ten or eleven months in a year, it is always necessary to avoid sensible and latent heat gains in every possible way and to achieve comfort conditions while minimizing energy consumption (Attia and De Herde, 2010). Cooling and ventilation is very essential for occupants' comfort in hot climates and most fitness and sport centres depend on mechanical means of meeting these requirements (Fergus, 2004). Different spaces within fitness and sport centres have different temperature requirements for occupants' comfort (Carbon Trust, 2006).

Attia and De Herde, (2010), defined thermal zoning as a bioclimatic design strategy which involves the positioning of building spaces with regard to the path of the sun, prevailing winds, and openings locations in order to improve thermal comfort in relation to the functions and thermal requirements of such spaces. Bleil and Alssadani (2012) also defined thermal zoning as a system of coordinating and placing spaces based on the buildings natural susceptibility to heat gain. According to the US Department of energy (2002), zoning a building can reduce the heating and cooling energy demands by as much as 20 percent.

1.2 Problem Statement

In an attempt to increase thermal comfort of indoor spaces, excess energy is consumed and due to the constant power disruption in Nigeria, this energy demand has pushed the various building sectors to invest in non-renewable means of energy supply therefore the inability to adopt energy-efficient practices and leading to the increase of environmental degradation (Abiodun, 2014).

Despite the effort of many researchers to incorporate sustainable design approaches into building design, there is still minimal consideration of energy conservation and efficient approaches such as thermal zoning especially in the design stage of buildings where the main design solutions are usually identified (Brien, Athienitis, and Kesik, 2011).

1.3 Aim and Objectives

The aim of this study is to evaluate the effect of thermal zoning on cooling energy consumption in fitness and sport centres. This will be achieved by the following objectives:

i) Conduct a review on the principle of thermal zoning and its various strategies.
ii) Assess the relationship between thermal zoning and internal air temperature.
iii) Assess the cooling energy demand in existing fitness and sport centres.
iv) Demonstrate the use of thermal zoning for the enhancement of energy efficiency in the design of fitness and sport centres.

1.4 Research Questions

The research questions are:

i) What is the thermal condition of indoor fitness and sport centres in warm humid regions of Nigeria?

ii) How can the principle of thermal zoning be applied in the design of a fitness and sport centre?

iii) What percentage of cooling energy can be saved from applying the principle of thermal zoning?

1.5 Scope and Delimitation

The study is delimited to indoor fitness and sport centres in warm humid regions of Nigeria in order to carry out a more detailed study and enhance the reliability of findings and observations. Data was collected through the case study approach with the help of visual survey and real time field measurements of cases in the warm humid climate area of Nigeria.

The facilities to be provided in the proposed design were based on studies of existing fitness and sport centres both within and outside Nigeria. This is essential in order to achieve the standard services provided in an indoor fitness and sport centre and possible additions to improve existing services. However, because some of the information were based on studies carried out in foreign developments, adjustment were required in order to suit the locality of the proposed project.

1.6 Justification

The study area which is located in the warm humid region of Nigeria is characterised by high temperature and humidity in addition to a fitness and sport centre which consumes a significant amount of energy in providing comfort and services users and visitors can add to the cost of running the building.

The application of thermal zoning in the design of building in a region with such weather condition and also a country with lack of standard energy sources reduces the

need for alternative power supply, saves on energy costs and enhances thermal comfort and services provided to the users.

The different spaces within a fitness and sport centre have different thermal requirements to provide comfort for occupants and once these requirements can be met, there would be less need for artificially cooling and ventilating the spaces thereby increasing energy efficiency and reducing energy consumption.

Thermal zoning principle used in the project helped to meet these various thermal requirements therefore leading to a sustainable and energy efficient fitness and sport centre.

2.0 LITERATURE REVIEW

2.1 Thermal Zoning

A zone is particularly that area of the building that is continuously subjected to variation in thermal load, for example the areas near a window which is under continuous change in temperature due to variation of heat from the sun (Raunekk, 2012).

Attia and De Herde, (2010), defined thermal zoning as a bioclimatic design strategy which involves the positioning of building spaces with regard to the path of the sun, prevailing winds, and openings locations in order to improve thermal comfort in relation to the functions and climatic requirements of such spaces.

Also, Bleil and Alssadani (2012) stated that thermal zoning refers to how space layouts affect the predicted heating and cooling energy demands in buildings, it involves coordinating and placing spaces based on the buildings natural susceptibility to heat gain.There might be transfer of energy from one zone to another if there are differences in the indoor temperatures. Thermal zoning can be needed for passive solar conditions, for building ultra-low energy consumption and for complex buildings that have multiple functions, to ensure that suitable indoor climatic conditions are obtained in different parts of the building. In hot climates, the concept of thermal zoning or heat buffering entails creating intermediate semi-controlled outdoor zones that serve as an active double skin (Brien *et al.,* 2011). These outdoor zones serve to block the heat in the mass of spaces and include courtyards, deep veranda, porches and earth sheltered partitions of buildings. A combination of shade and natural ventilation also plays a key role in the process of thermal zoning aiming to improve the internal temperatures thus improving thermal comfort within that building (Attia and De Herde, 2010).

Thermal comfort can be defined as the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation (ANSI/ASHRAE Standard 55, 2013). The main factors that influence thermal comfort are those that determine heat gain and loss, namely metabolic rate, clothing insulation, air temperature, mean radiant temperature, air speed, and relative humidity (ANSI/ASHRAE Standard 55, 2013). Psychological parameters such as individual expectations also affect thermal comfort, the combination of high temperature and high relative humidity serves to reduce thermal comfort and indoor air quality (Fang, Wyon, Clausen, and Fanger, 2004).

The American Society of Heating, Refrigerating and Air-conditioning (ANSI/ASHRAE, 2013) defined a comfort range for indoor climate: 20-23.5^{o}C during the winter and 23-26^{o}C during the summer. Indoor air temperature which is the main dominant factor that influence the human thermal comfort is affected by a number of parameters. Such parameters include roof, wall, window-to-wall ratio, external colour, shading devices as well as 'orientation' as the most important parameter (Bakhlah & Hassan, 2015).

According to the U.S. Department of Energy (2002), zoning can reduce heating and cooling bills by as much as 30 percent. The principle is mainly concerned with working with the climate of a particular region.

2.2 Classification of Thermal Zoning

We like different temperatures in different zones or rooms; an efficient ecological building recognizes these differences and creates different thermal zones for different spaces (Marshall, 2014). Table 2.1 below shows the different classification of thermal zones.

Table 2.1: Classification of Thermal Zones

ZONES	TEMPERATURE
Cold Zone	14-18°c
Cool Zone	18-22°c
Warm Zone	23-28°c
Hot Zone	29-34°c

Source: Adapted from Almusaed *et al.* (2006)
Marshall (2014)

From our knowledge of thermal comfort, it is well know that to maintain these temperatures for different zones will be a challenge but nevertheless, if the range given in the plate 2.1 above can be achieved then the building occupants can attain a level of thermal comfort.

Thermal zoning tries to ensure the best match possible between the distribution of spaces and the distribution of available heat. The ideal thermal zoning is;

2.2.1 Cold Zone

These are spaces located around the colder dark north side. They only need to be heated occasionally and have temperatures between 14-18°c.

2.2.2 Cool Zone

This zone includes principal function in the building. They have a temperature range of 18 to 22°c. The best orientation option is with a south, east, southeast facing window in buildings from cold and temperate climate and north, east, and northeast in buildings from warm climates.

2.2.3 Warm Zone

These are zones where constant warmth and light are needed. Best placed on the south side of the building with large windows and good thermal capacity to hold any thermal gain through the evening, they have a temperature range of 23 to 28°c.

2.2.4 Hot Zone

Suitable where natural lighting and good ventilation are desirable. They are usually between 29 and 34°c.

After understanding the various temperature range for the different zones within a building, it is important to note the different temperature range for indoor fitness and sport centres according to Carbon Trust (2006) as seen in Table 2.2.

Table 2.2: Recommended Space Temperatures for fitness and sport centres

SPACES	RECOMMENDED TEMPERATURE (°C)
Multi-purpose	12-18 for sports activities and 18-21 for sedentary activities
Pool hall	See table 2.3
Fitness gym	16-18
Weight training	14-16
Squash courts	16-18 for courts and 18 for spectators
Ancillary halls	18 for sports and 21 for non-sports
Studios (dance and martial art)	18
Yoga	18
Changing areas	20-25
Reception, offices and circulation	20
Crèche	21-23
Refreshment and bar areas	18
Massage	32-34

Source: Adapted from Carbon Trust (2006)

Table 2.3 below shows the different temperatures as related to the types of pool halls.

Table 2.3: Recommended Pool Temperatures and zones

Pool Type	Temperature (°C)
Training and competition	25-27
Conventional	28
Diving	28
Leisure	29
Teaching	29
Hydrotherapy	32-40
Spa	40

Source: Carbon Trust (2006)

2.3 Thermal Zoning Strategies

According to Bleil and Alssadani (2012), there are different strategies on how to zone a building:

i. Zoning based on different spatial activities
ii. Zoning based on different HVAC requirements and/or control
iii. Zoning based on different solar gains(orientation)
iv. Zoning based on temperature stratification

The first two strategies have building usage and operation highly imbedded in them whereas the third and fourth ones are more building design dependant (Bleil and Alssadani, 2012). For the sake of this study, zoning based on spatial activities and solar gains were adopted.

2.3.1 Zoning based on Different Spatial Activities

According to Tonuk and Kayihan (2006), a rational and ecological space organization has the benefit of reduction of the energy consumption at occupation phase of the building. After the determination of the heating and cooling requirements of the spaces

according to their function, the location of these spaces on the plans must also be determined. Space organization must be made for both cold and hot months with planning that facilitate the cooling. Also, the location and direction of spaces must be determined in a manner which takes advantage of the prevailing winds (space organization which creates a natural ventilation must be considered).

An application of this strategy (Arch Daily, 2011), can be seen in Figure 2.1. The purpose of the study is to have an outer skin to create a heat buffer, reducing temperature fluctuations in cold periods and protecting technical equipment. The house is divided into zones based on temperature requirements: rooms that require the highest internal temperature (i.e. bathrooms) are placed in the centre. The buffer located in the northern part of the house conceals a storage space. The building has a compact shape (its Area/Volume ratio being at 0.83) and no glazing at the north façade. Buffer zones in buildings perform the same function as thermostat (used to regulate temperature)

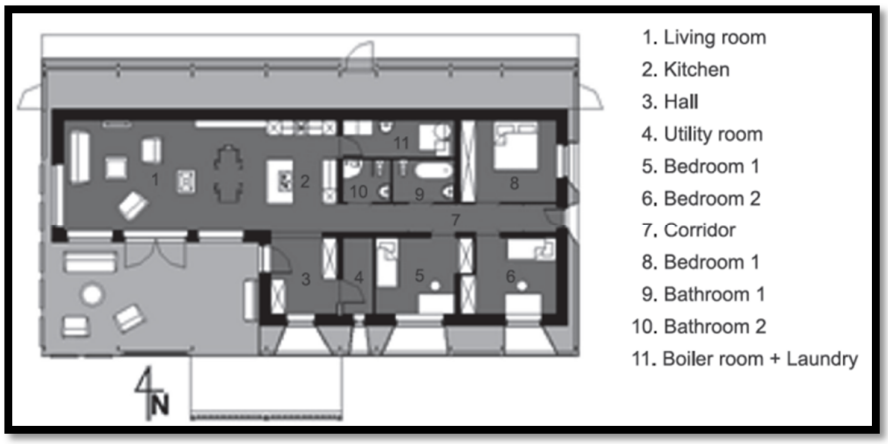


Figure 2.1: Double Skin House – building plan and room layout: dark grey – residential area, light grey – buffer zones
Source: Arch Daily (2011)

Another application can be seen in Figure 2.2: university campus of Baruch College, in Manhattan, New York, in 2001. It is a multipurpose building that occupies an entire block. It represents the hub of the college. It is 72m high and it has 14 floors and three

basement floors. In the basement floors, there are athletics and recreation spaces such as the Marvin Antonowsky Performing Arts Complex, the Rose Nagelberg Theatre and Engelman Recital Hall, gym and auxiliary gym areas, a swimming pool, racquet-ball courts, movies rooms, and some offices.

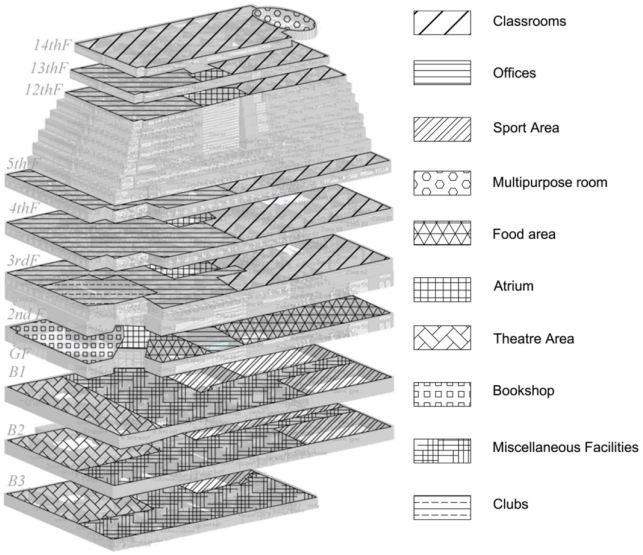


Figure 2.2: Internal spaces layout of the building
Source: Pisello *et al.* (2012)

The primary energy requirement of each floor, for each month, corresponds to the overall electricity need and this is the main objective of the design (Pisello *et al.,* 2012). Thus cooling, heating, hot water generation, ventilation, lighting, and auxiliary equipment (pumps, *etc.*) are considered. The main results of the research show that placing the sport areas at the basements lead to savings of up to 16% and 10% for basement 3 and 1, respectively (Pisello *et al.,* 2012)

2.3.2 Zoning based on Different HVAC Requirements and/or Control

In the design of heating ventilation and air conditioning systems (HVAC), a 'zone' is an area of a building in which temperature is controlled by one thermostat. This is not the same as a single space or room. For example, a small house, in which thermal demand is relatively constant throughout, might be controlled by a single thermostat and so

considered a single zone. In a more complex, larger building where there may be significant differences in thermal demand, there may be multiple zones (Designing Buildings Wiki, 2015).

In simple buildings, a single zone might be supplied by a single boiler, or air handling unit. In more complex buildings with varying demands, multiple zones might be supplied by a single central HVAC system, but each zone might correspond to a single terminal unit that provides local thermostatic control. Carefully designed zoning can help rationalize different thermal demands and so reduce the number of HVAC subsystems required. This can reduce capital and operational costs. It is important that this is considered as an integral part of the concept design stage and that HVAC is not simply added on at the end of the design process .

2.3.3 Zoning based on Different Solar Gains (orientation)

The heating and cooling of a building depends on the heat from the sun and the change in thermal loads due to changes in the position of the sun is what is known as solar gain (Raunekk, 2012).

Effective orientation in buildings help to reduce the need for mechanical means of cooling within a building. Orientation together with spatial organization affect the ability of a building to ventilate and receive solar radiation (Torwong, 2007). Warm/warm humid climates usually experience constant high temperatures and relative humidity and low air movement throughout the year (Abiodun, 2014) with a diurnal temperature range of minimum 23–27°C and maximum 30– 34°C, mean annual RH value of 84% and thus buildings experience a great level of thermal discomfort (Abiodun, 2014). To minimize solar gain and maximize ventilation, traditional buildings in hot and warm humid climates usually employ spread-out plans and permeable internal organization. By orientating the longer sides of the buildings to

intercept prevailing winds and the shorter sides to face the direction of the strongest solar radiation, thermal impact from solar radiation will be minimized (Torwong, 2007). An example of the effect of orientation on building design is seen in Figure 2.3 below;

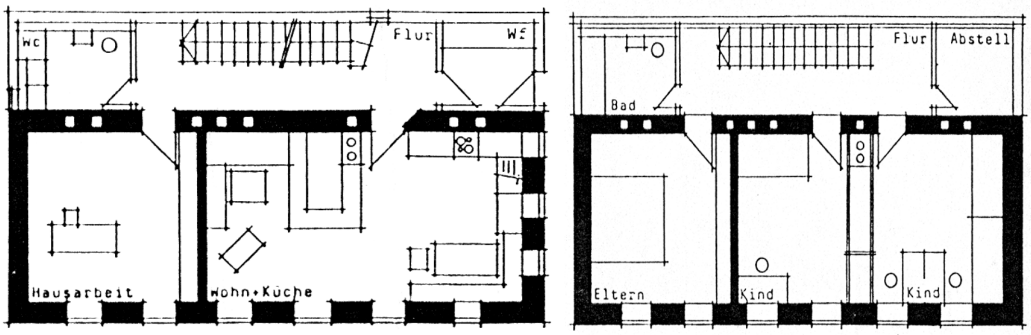


Figure 2.3: Building Zoning influenced by orientation
Source: Tönük and Kayýhan, (2006)

In Figure 2.3, the objective of the design is to minimize solar gain into living spaces by appropriate orientation. The design principles adopted here includes: South orientation on the site plan, thermal zone on the northern facade including all sanitary facilities, storage and stairs, enclosed northern, eastern and western facade, living rooms on the southern facade, Open - glazed southern facade and cross ventilation (Tönük and Kayýhan, 2006).

2.3.4 Zoning based on Temperature Stratification

Because hot air rises, the upper levels of the building are usually warmer than the lower levels. This temperature stratification can be used to zone uses or activities by temperature requirements (DeKay and Brown 2014). This phenomenon was recognized by the Inuit Igloo builders of the Canadian north as seen in Figure 2.4 and Figure 2.5, who used the lower level of the entrance as a cold air trap and for storage and the upper levels for living.

Ralph Erskine followed the same principle for his design of a Ski Lodge at Borgfjall, in Sweden. The circulation spaces with the least strict temperature requirements are lowest

in the section. The living/cooking quarters are on an intermediate level and the sleeping quarters which needs to be the warmest, are on the uppermost level.

In hot climates, the same principle may be exploited in the opposite direction, placing day time used rooms on lower levels where it is cooler, using high ceilings to allow heat to collect above the heads of occupants where it can be vented out of high windows while maintaining privacy at the view level.

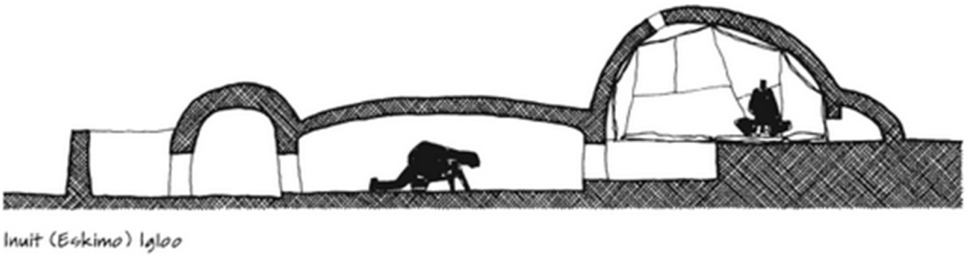


Figure 2.4: The Inuit (Eskimo) Igloo
Source: DeKay and Brown (2014)

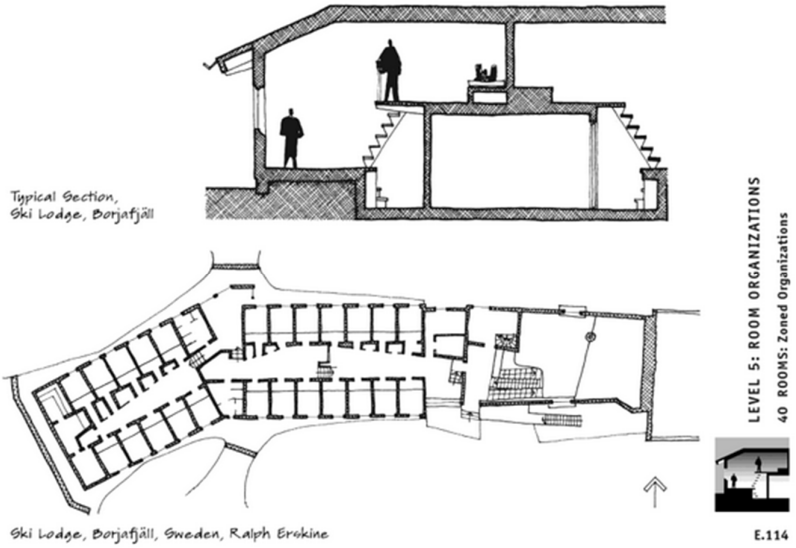


Figure 2.5: Section and Plan of Ski Lodge, Borjafjall, Sweden
Source: DeKay and Brown (2014)

From the above examples, it is seen that there is a need for appropriate zoning in sport centres as there is a reasonable amount of energy saved from the practice. The zoning

strategy to be investigated in this study is zoning based on orientation since orientation has been recognized as the most important parameter that affects indoor air temperature.

2.4 Energy Efficiency in Fitness and Sport Centres

Energy is fundamental to all human activities (Uyigue *et al.,* 2007). Efficient energy which is simply known as energy efficiency is using less energy to provide the same level of energy service (U.S DOE, 2002). It is a way of managing and restraining the growth in energy consumption, a building is more energy efficient if it delivers more services for the same energy input, or the same services for less energy input. For example, insulating a home allows a building to use less heating and cooling energy to achieve and maintain a comfortable temperature (International Energy Agency (IEA), 2014).

An energy efficient design aims to provide thermal comfort and acceptable indoor air quality with the minimum use of energy. Mechanical ventilation is a primary energy intensive process, and air conditioning is even more so, therefore, an energy efficient fitness and sport centre will provide the desired internal conditions by relying on natural means of cooling and ventilation where possible (Chartered Institution of Building Services Engineers, 2007).

The goal of energy efficient building is to use resources more efficiently and reduce buildings negative impact on the environment (EPA, 2010). Its benefits include;

i. Reduced cost
ii. Enhancing comfort condition within buildings thereby improving health and productivity
iii. Improved building design and operation
iv. Life-cycle cost savings
v. Added market value of buildings

vi. Reduced carbon-dioxide emissions and consumption of finite fossil fuels

vii. Reduced capital cost by better integration of building fabric and systems

viii. Reducing demand on non-renewable fuels

ix. Energy buildings achieve one key green-building goal of completely or very significantly reducing energy use and greenhouse gas emissions for the life of the building (Hui, 2007).

2.4.1 Energy Consumption in Fitness and Sport Centres

Energy is the major component of a building which is about 50% of the building resource consumed and this figure is rising fast as construction increases (US Environmental Protection Agency, 2010). There are three main ways through which buildings consume energy; Operating energy, induced energy and production energy

2.4.1.1 Operating Energy

This refers to the energy necessary for maintaining required level of comfort and operating conditions in the building (such as lighting, ventilation, etc.) (EPA, 2010). It also refers to the amount of energy that is consumed by a building to satisfy the demand for heating, cooling, ventilation, lighting, equipment, and appliances (Carbon Neutral Steel Building Systems (CN-SBS), 2013).

According to Carbon Trust (2006), in a typical sports centre, energy costs are second only to labour costs accounting for as much as 30% of total operating costs which is a higher figure than in most other sectors. Energy is supplied in two forms; fossil fuel (gas, oil, coal or LPG) and electricity. Carbon trust has set guidelines for the use of energy in fitness and sport centres.

Table 2.4: Energy used by activity zone (related to zone area or number of items, not total building area)

Zone	Electricity KW/h/m²		Heating/cooling fuel KW/h/m²		Cost £/m²		Cost £/year	
	GP	TYP	GP	TYP	GP	TYP	GP	TYP
Leisure Pool Hall	208.1	318.4	999.6	2325.6	21.4	40.8	12 435	23 647
Conventional pool hall	208.1	318.4	824.9	1936.7	19..7	36.9	11 422	21 391
Sport hall	39.4	69.0	102.6	224.3	3.2	6.0	2779	5254
Bowls hall	31.8	51.9	67.6	130.5	2.4	4.2	1626	2786
Ice rink hall	204.8	307.7	73.8	158.8	12.0	18.5	30 005	46 286
Fitness/health suites	78.4	130.0	209.3	482.3	6.4	12.0	1025	1916
Internal courts	52.4	86.2	86.3	190.5	3.7	6.6	2247	3987
Wet changing and shower	93.4	167.1	529.7	1267.0	10.4	21.9	2296	4809
Dry changing and shower	92.4	149.6	299.4	676.0	8.1	15.0	1131	2098
Spectator	62.3	102.4	168.4	354.8	5.1	9.2	409	734
Common areas (mechanical vent)	74.1	117.7	168.4	354.8	5.8	10.0	1325	2305
Common areas (natural ventilation)	52.7	80.9	109.5	185.3	4.0	6.3	798	1261
Plant rooms	74.1	117.7	168.4	354.8	5.8	10.0	921	1604
Stores	52.7	80.9	109.5	185.3	4.0	6.3	359	567

Source: Carbon Trust (2006)

Table 2.4 above shows the energy consumed in different zones within a fitness centre. GP (good practice) is a combination of different eco-architecture and sustainable design principles and strategies which includes: appropriate and monitored thermal zones, natural ventilation, natural lighting, building fabrics, operation and scheduling of HVAC systems (Energy Efficiency Best Practice Programme, 2001)

Also, according the Alberta Recreation and Parks Association (ARPA) (2004), energy costs for recreation facilities are an important component of facility operating costs. Facilities are more impacted by electricity price increases as typically electricity represents about 80% in sport facilities. They concluded that energy costs in sport centres represented 35% of total operating cost and this is enough reason to focus on measures to minimize operating energy cost in fitness and sport centres. The distribution of operating energy in sport centres is shown in Figure 2.6

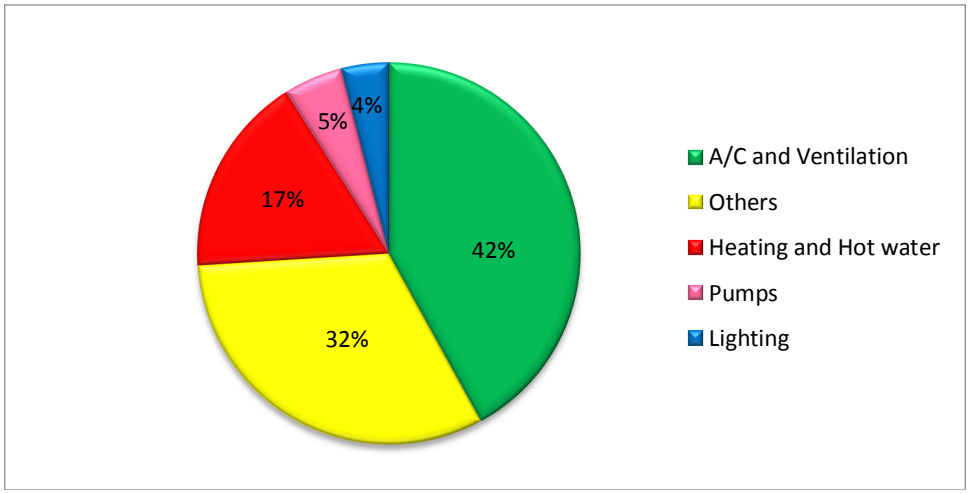


Figure 2.6: Operational Energy in Sport and Leisure centres
Source: Carbon Trust (2006)

2.4.1.2 Induced Energy

Energy consumed indirectly through construction (EPA, 2010)

2.4.1.3 Production Energy

This refers to embedded or embodied energy that is energy invested in the building material through the process of production, assembly, maintenance, alteration and demolition, and of recycling components of materials (Roy, 2008).

2.4.2 Energy Efficiency Assessment Methods

The assessment of building energy efficiency is one of the most effective measures in reducing building energy consumption (Yao *et al.,* 2012). There are different methods for assessing or calculating building energy efficiency. Existing methods to assess building energy efficiency according to Yao *et al.* (2012) are:

i. Methods based on building energy consumption calculations or computer simulation
ii. Life Cycle Assessment (LCA) approaches
iii. Features based approaches

iv. Those based on multi-attribute criteria

2.4.2.1 Computer Simulation

Simulations in buildings are used to predict energy flows in internal temperature profiles, envelope losses, system performance, and electrical loads (Ibarra and Reinhart, 2009). Computer simulations also involves the use of software programs to predict building energy performance. The building in question may be an existing structure, a retrofit of an existing structure, or a new design. Building energy flows are complex, hence the need for a complete simulation of the thermal behaviour of the designed space in the conditions of use established beforehand (Ibáñez *et al.,* 2005). According to Ibarra and Reinhart (2009), due to the complexity of a building model, computer simulation can analyze the effect of different energy conservation measures and their complex interactions more efficiently, comprehensively, and accurately than any other available method of calculating buildings energy efficiency

2.4.3 Assessing the Performance of Thermal Zoning using Simulation

Different simulation tools have been used to assess the performance of thermal zoning in commercial buildings (U.S DOE, 2014). These tools include;

i. ECOTECT
ii. Energy Plus
iii. DesignBuilder
iv. TRNSYS
v. EQuest

2.4.4 Using ECOTECT to assess the performance of Thermal Zones and Energy Efficiency

Ecotect program is a building design and environmental analysis tool that covers a broad range of simulation and analysis functions required to understand how a building

design will operate and perform (Ecotect, 2009). It is an environmental design tool which includes an intuitive 3-dimensional modeling interface with extensive performance analysis functions covering shading, thermal, lighting, acoustic, energy, resource use and cost aspects. Ecotect provides performance analysis which is simple, accurate, interactive and visually responsive (Crawley, 2008). Ecotect is one of the few tools in which performance analysis is simple, accurate and most importantly, visually responsive (Bjekic *et al.,* 2003).

Ecotect has been successfully used by the following researchers to simulate the heating and cooling energy consumption of different thermal zones and predict indoor temperature within buildings as seen in Table 2.5.

Table 2.5: Studies Reviewed

Authors/Year	Project Title
Al-Tamimi and Fadzilb (2010)	Experimental and simulation study for thermal performance analysis in residential buildings in warm humid climate(comparative study)
Taylor (2002)	Energy Efficiency for everyone: Analysis of development of an energy efficient project home
Shebl (2007)	Effect of window to wall ratio and different climate conditions on energy consumption for residential and commercial buildings in Egypt

2.5 Design Considerations for Fitness and Sport Centres

The design considerations for fitness and sport centres can be divided into; location and site planning, accommodation, materials and construction, safety requirement and services (Air Force Services Facilities Design Guide, (AFSFDG) 2005).

2.5.1 Location and Site Planning

Prior to designing a fitness and sport facility, the proposed site location and development should be assessed in terms of catchment area, potential market and target

user demographics (Air Force Services Facilities Design Guide, 2005). A well designed facility should take into account the following:

i. Organization: Develop a sense of order, arrival, orientation and community in planning the site. Allowance for possible future expansion to cater for new activities and trends.

ii. Climatic consideration: fitness Centers design and building orientation must take advantage of local climatic conditions. Where practical, use passive solar construction techniques to reduce energy consumption. Consider local climate conditions when creating outdoor spaces for fitness activities.

iii. Circulation: Plan organized, easily recognizable pedestrian, vehicular, bicycle, service, handicap, and fire emergency access. Make pedestrian pathways leading to the fitness facility obvious and consider linking the pathways to other fitness trails and sports fields.

iv. Building orientation: Building Orientation. Allow for the building to capture natural lighting in accordance with Sustainable Development recommendations. Ensure natural lighting does not cause glare or interfere with activities, especially in the gymnasium.

v. Site accessibility, including proximity to roads and links to public transport. A traffic analysis may be required to ascertain impact on the site and surrounding infrastructure.

vi. Vehicular access: vehicular circulation and parking provision for cars, bicycles, motorcycles and staff parking. Any need for an overspill parking area and adequate provision for accessibility in respect of both parking and building access (consider site gradients, and avoid stepped or ramped approaches).

Consider passenger loading and/or "U" shaped drop off areas near the fitness facility entrances, providing convenience to guests.

vii. Service vehicles: Provide paved access drives and parking areas designed to accommodate service vehicles. Avoid interior court areas.

viii. Pedestrian access: walkways to building entrances will be 2.4m wide. All other sidewalks will be 1.8m wide. Design and grade sidewalks to provide barrier-free access to the first floor of all fitness facilities and to any associated outdoor use areas.

ix. All facilities providing services to the public need to be accessible to people with a wide range of disabilities.

2.5.2 Accommodation

The following are the considerations to note when designing the interior spaces of a fitness and sport centre (Sport England, 2008)

i. The interior of the facility should be open and flexible.

ii. Avoid creating an institutional appearance when designing the interior environment.

iii. Consider a "main-street" circulation system, which creates a dynamic flow of movement through the facility.

iv. Create visual connections between the entrance and activity spaces, thereby creating a "visual menu" for users.

v. Allow natural light into the facility, keeping in mind user protection, glare in critical activity spaces, and energy conservation issues.

vi. Directional signage should be clear and visible.

vii. Design for flexibility and expansion.

viii. Make spaces multifunctional.

ix. Locate the activity spaces that receive the greatest number of users near the main entrance.

x. Locker rooms should be directly accessible to and from the pool, if applicable.

xi. Minimize the number of corridors where practical.

2.5.3 Materials and Construction

The following criteria are to be considered when choosing materials and construction techniques for fitness and sport centres. These include;

i. Use a structural system that allows for flexibility and expansion. Minimize the number of load bearing walls to allow for reconfiguration. Use a structural system that allows for large, column-free areas.

ii. Consider using suitable local materials and construction methods. Use new materials and techniques only where it can be shown in actual practice that there is an economic or functional advantage.

iii. Consider grouping high bay spaces together. The massing of the building should relate to the surrounding structures. The high bay areas should not be too dominant.

iv. Use materials and finishes that accommodate many different uses.

v. Use finishes that limit unwanted noise within the building.

vi. Sharp edges and wall projections should be avoided.

vii. The design of the youth zones should appeal to the teenage and youth market, using lighting, sound and visual effects to create a unique experience.

2.5.4 Safety

Safety design considerations are as follows;

i. Establish independent egress points from each of the functional areas that have different operating hours from the fitness center.

ii. Provide electronic alarms and clear labels on doors that cannot be viewed directly from the control point.

iii. For enclosed structures like sport halls, openings should be provided at rooftop to discourage spread of fire and allow smoke to escape.

iv. The crowd should be separated by providing gang ways in between seatings and stands

v. Fire outbreak and spread can be minimized by the application of non-combustible fire resistant materials

2.5.5 Services

The following considerations should be given to service areas;

i. Allow easy access to building services located above the ceiling. Gyms are generally highly serviced areas.

ii. Provide floor drains in the drying area.

iii. Provide appropriate floor drains for all showers. Ensure the floor is sloped to the drain to prevent standing water

iv. Locate irrigation controls in the maintenance area.

v. Use electrical systems and equipment that are energy efficient, reliable, flexible, easy to maintain, and of sufficient capacity.

2.6 Spaces in a Fitness and Sport Centre

According to Whole Building Design Guide (2014), the various spaces in a fitness and sport centre includes:

i. Fitness spaces

ii. Gymnasium

iii. Group exercise room/classroom

iv. Structured activities

v. Locker rooms and associated functions

vi. Administrative and support spaces

vii. Enhanced spaces

viii. Pools

ix. Outdoor spaces

2.6.1 Fitness Spaces

Activities carried out in these spaces include; cardiovascular equipments, free and plate loaded weight lifting, selectorized weights (such as cable-operated weight machines, stretching/warm up/cool down spaces, indoor running track. See Figure 2.7

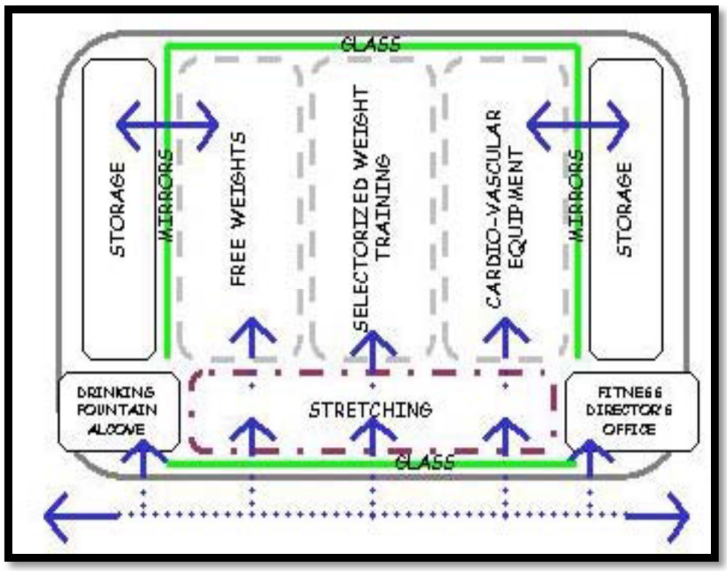


Figure 2.7: Fitness Equipment Functional Diagram
Source: Air Force Service Facility Design Guide (2005)

2.6.2 Gymnasium

Accommodates indoor sport activities such as volley ball, basketball, tennis courts, squash courts, etc. See Figure 2.8

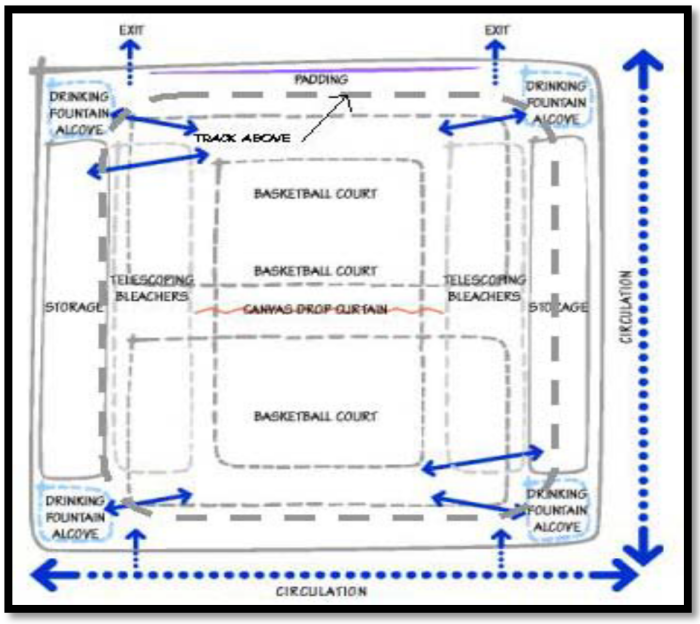


Figure 2.8: Gymnasium Functional Diagram
Source: Air Force Service Facility Design Guide (2005)

2.6.3 Group exercise room/ classroom

These spaces accommodate organized fitness class activities. See Figure 2.9

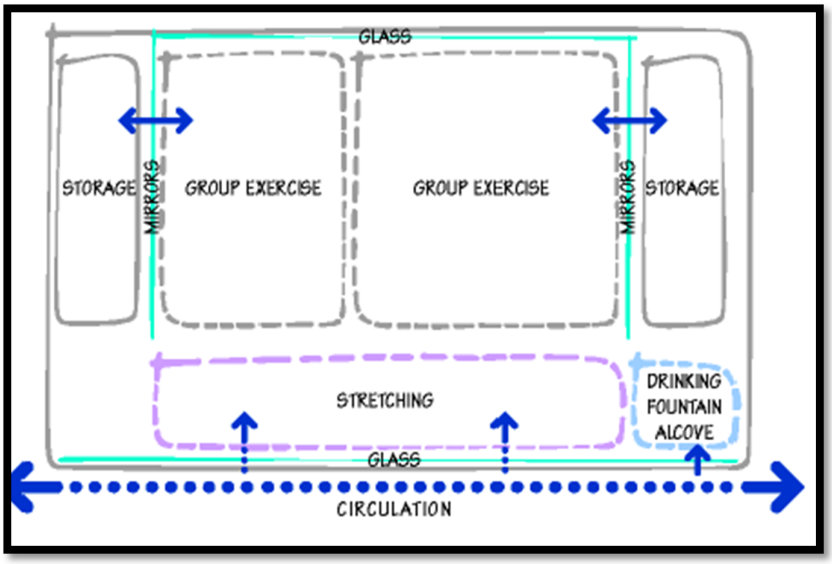


Figure 2.9: Group Exercise Functional Diagram
Source: Air Force Service Facility Design Guide (2005)

2.6.4 Structured activities

These include a variety of well-defined activities such as; racquet ball, climbing wall, spinning classes, etc. See Figure 2.10

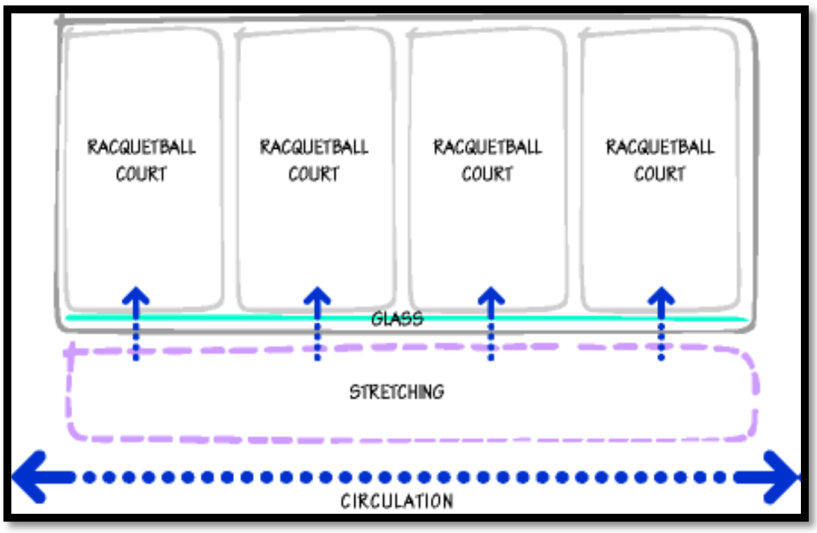


Figure 2.10: Racquet Ball Functional Diagram
Source: Air Force Service Facility Design Guide (2005)

2.6.5 Locker rooms and associated functions

These spaces are typically separated by gender and accommodate the basic functions of changing, storing clothes, patron showers, and toilets. Other additional optional spaces here include sauna, steam room, and hot tub. See Figure 2.11

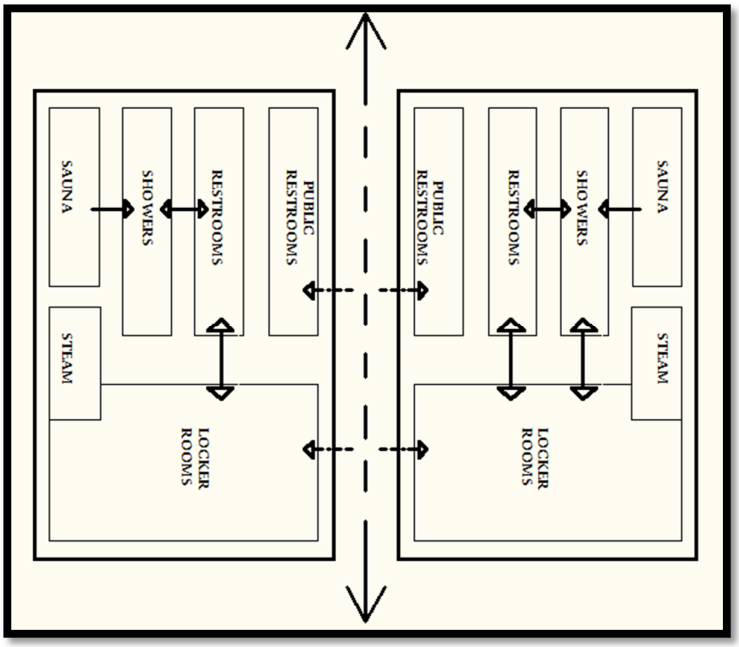


Figure 2.11: Locker Room Functional Diagram
Source: Air Force Service Facility Design Guide (2005)

2.6.6 Administrative and support spaces

These staff spaces accommodate the operation and administration of the facility and include the following; reception/control counter and equipment issues, offices, storage, receiving and equipment repair, and staff support. See Figure 2.12

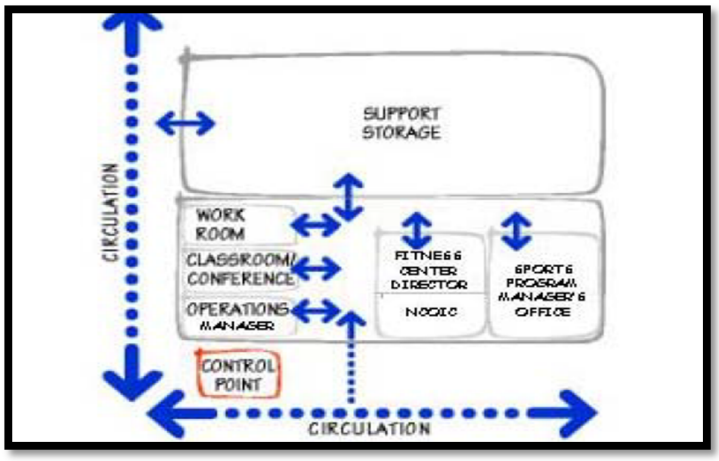


Figure 2.12: Fitness Spaces Functional Diagram
Source: Air Force Service Facility Design Guide (2005)

2.6.7 Enhanced spaces

These optional spaces can enhance the patrons social and/or overall experience and may provide additional revenue resources; vending, juice bar or other food services, retail sales of athletic clothing and equipment, spectators seating for the gymnasium or structured activities, child care, fitness assessment spaces, massage or physical therapy spaces, tanning and gender specific work out spaces.

2.6.8 Pools/Spa/Health suites

Pools may be indoor or outdoor and may include multiple components such as dedicated lap pool (without a shallow side), diving pool, family pool, and hot tub. See Figure 2.13.

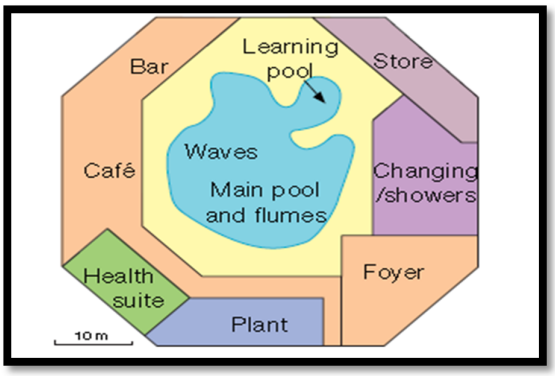


Figure 2.13: Swimming pool Functional Diagram
Source: Sports England (2000)

2.6.9 Outdoor spaces

Outdoor spaces such as sport playing fields and outdoor running or bicycling tracks.

2.7 Conclusion

The findings from this chapter can be summarised as follows;

i. The space layout of a building can affect the heating and cooling energy demands.
ii. The spaces within fitness and sport centres can be grouped into different zones based on their temperature requirements
iii. The different zoning strategies can be combined together for a building design
iv. Thermal zoning works along with different factors (shading, natural ventilation, etc.) for it to be effective in reducing energy consumption
v. Air conditioning and Ventilation accounts for 42% operating energy in fitness and sport centres.
vi. Most studies carried out on thermal zoning focused on the application of mechanical means of controlling energy consumption in buildings.

The next chapter describes the research methodology. How the research is carried out is explained in details and also the research approach is discussed.

3.0 RESEARCH METHODOLOGY

The research is an evaluative research (due to the nature of data acquisition and analysis). Evaluative research aims at testing effectiveness of projects, policies or programs to determine how they have failed against stipulated standards or targets in order to suggest modifications and alternatives (Veal, 2006).

Tools for data collection and analysis include visual survey, interview, site measurements which is incorporated into case studies in order to provide firsthand information on indoor fitness and sport centres, and secondary data from the case visited. This is necessary in order to deduce the appropriate methods in the design of energy efficient thermally zoned fitness and sport centre.

3.1 The Case Study Approach

Case study is a dominant approach in architectural research (Johansson, 2010). It may be referred to as a research method or a unit of analysis which involves the study of an example or a case of the phenomenon been researched (Veal, 2006).

According to Yin (2004), a case study can be seen as an empirical inquiry that investigates a contemporary phenomenon within its real life context using multiple source of evidence. Case study should include detailed documentation of information on the history and environment of study (Oluigbo, 2010).

Three cases were studied;

i. University of Benin Sport Complex, Ugbowo Campus, Benin Edo state
ii. Samuel Ogbemudia Stadium indoor fitness and sport centre, Ekenwan road, Edo state
iii. Mayfair Fitness centre, Ayoyaya, Lagos state

3.1.1 Case Study Selection

Oluigbo (2010) stated that for case studies to be identified or selected, they have to possess some intrinsic virtues which are in relation with the phenomenon under consideration. Therefore, to properly select case studies best suited for this research, the following criteria were considered:

i. Function

ii. Location

iii. Climatic zone

iv. Scope of the facility: Size and equipment

The selected cases were analyzed based on the listed criteria below as seen in Table 3.1

Table 3.1: Criteria for case study selection

Cases	Function	Location	Climatic Zone	Scope of facility
UniBen Sports Complex	Fitness and sport centre	Benin, Edo state, Nigeria	Warm humid	Indoor and outdoor sports
Samuel Ogbemudia Stadium	Fitness and sports centre	Warri, Delta state, Nigeria	Warm humid	Indoor and outdoor sports
Mayfair Fitness centre	Fitness and recreation centre	Ayoyaya, Lagos state, Nigeria	Warm humid	Indoor fitness area.

To effectively analyze these case studies, a number of data collection instruments are used.

3.2 Method of Data Collection

Data was obtained from

i. Primary source

ii. Secondary source

3.2.1 Primary Source

The primary sources used for data collection are;

i. Visual survey

ii. Interview

3.2.1.1 Visual survey

This is a method of data collection in which the eyes was used to study and observe. This survey must be guided by critical literature review guidelines. It can be documented through tabulation, sketches, pictures, written reports.

3.2.1.2 Interview

This is a method of data collection which involves preparing a list of interview schedule and laid down questions to ask the interviewee. It is grouped into three main types namely; structured, semi-structured and unstructured (Neville, 2007). The purpose of the interview is to get relevant information concerning the history of the facility, occupancy and operational schedules. The interviewee in this case is the management of the selected facility because they have substantial information concerning the facility. The list of interview schedule is seen in Appendix A.

3.2.2 Secondary Source

The secondary source used for data collection are;

i. Literature review through journals, books, articles, etc.

3.2.2.2 Literature Review

This method involves documenting information got from journals, articles, and books.

3.3 Instrument of Data Collection

For the purpose of this study, the instruments used for the collection and documentation of data are; photographs, sketches, written reports, and thermometer.

3.3.1 Photographs

Photographs are taken of relevant case studies to identify the different variables used to check the extent to which the principle of thermal zoning was applied in the cases.

3.3.2 Sketches

Sketches are made of some elements of the selected case studies. These sketches show the properties of the various variables.

3.3.3 Written reports

Notes are taken on the fieldwork to outline the account and the extent of the dependent variable of the case studies.

3.3.4 Thermometer

A dry and wet bulb thermometer was used during the site measurement to record daily temperature of the different orientation.

3.4 Variable of Study

Variables are parameters that scholars investigate in order to give full assessment of the selected case studies in a research. They are analysed based on the research questions or proposed design problem. The variables considered in this research are design dependent variables which points out how the objectives of the case studies are carried out. They are;

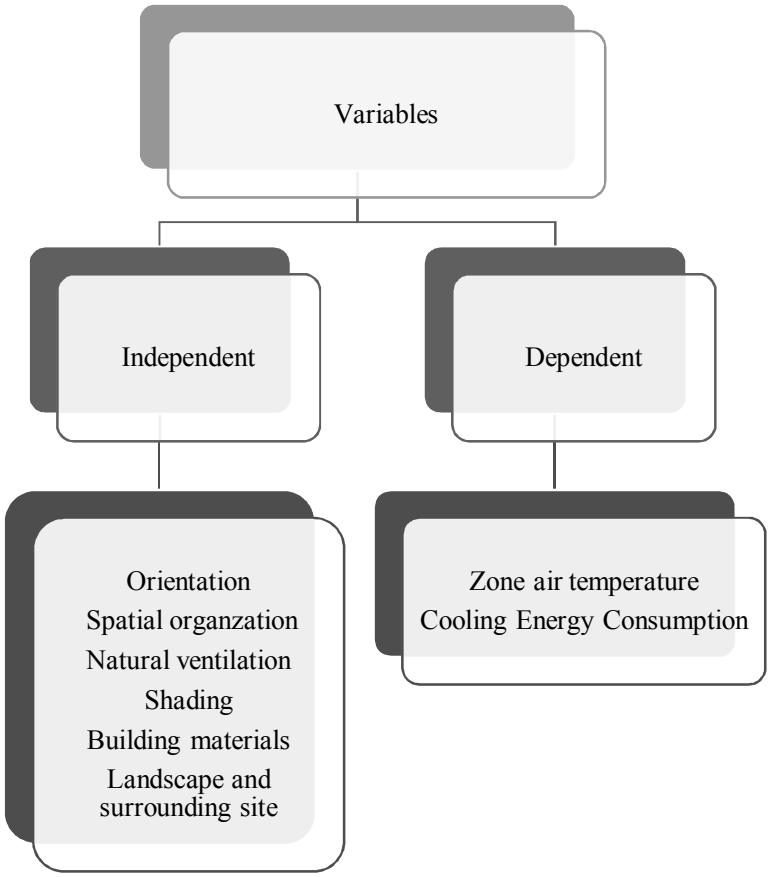


Figure 3.1: Case study variables
Source: Attia and De Herde (2010)

3.5 Procedure for Data Collection

To achieve the aim of this study, the cases selected were visited to record visual analysis of their architectural features, and site measurement of indoor temperature of the cases were carried out to investigate the real condition of the existing building under real climate. The survey was conducted late in January and beginning of February 2016 three times a day at 8am, 1pm and 5pm for 5 days consecutively. Late January to beginning of February is the hottest period in the year for warm humid region of Nigeria according to the average of 30 years meteorological data from the nearest weather station (Emaziye *et al.,* 2012) Field measurements from University of Benin Sport centre, Benin City was recorded from 26th January to 30th January, 2016 In Samuel Ogbemudia Stadium, Warri, Delta state it is recorded from 31st February to 4th February,

2016 and in Mayfair Fitness Centre, Lagos state, it is recorded from 7th February to 11th February respectively. Selecting the hottest period to indicate the real worst condition as a method has been used by many researches (Hamdani et al., 2012; Hassan and Ramli, 2010; Rodrigues and Landin, 2011). The device used is a dry and wet bulb thermometer.

3.6 Data Analysis

The sport centres are divided into four orientations; North, South, East, and West zones. Indoor air temperature recorded in each orientation is compared between the three cases to assess the relationship between thermal zoning and internal air temperature. The results are analysed based on the average across all orientations. The result from real time measurements were validated using the computer simulation software; Ecotect. Also the cooling energy consumption of the cases were calculated by the same simulation software tool to take record of cooling energy demand of the existing cases. This helped calculate the energy savings at the end of the proposed indoor fitness and sport complex design for.

4.0 CASE STUDY FINDINGS AND RESULTS

This chapter presents and discusses the data obtained from the case studies at University of Benin Sport Complex, Samuel Ogbemudia Stadium Indoor sport complex and Mayfair fitness Centre.

4.1 University of Benin Indoor Sports Centre, Benin City, Edo State Nigeria

Overview

Location: Ugbowo Campus Benin City, Edo state

Construction date: 2010

Regional climate: Warm humid climate

The University Sports Complex provides modern sporting facilities including Olympic size swimming pools, indoor sports hall for about 3,000 people, synthetic track, standard size football fields, roofed grand stand for about 3,000 spectators, etc. for use by both staff and students. The university has one of the best university Stadia in the country and it serves as alternative for some state and national sporting activities. The sport complex is used for local, national and international competitions and it hosted the West African University Games in 1985. The complex has a spread out plan that consists of three basic sections; the main bowl, the swimming area and the indoor sport hall. The surrounding facilities include outdoor courts such as; hockey court, lawn tennis court, and basketball courts, and also retail space plus parking lots at the immediate entrance of the site with little landscaped areas. Plate 4.1 below shows the Façade of the indoor sport centre.



Plate 4.1. : University of Benin sports centre, indoor sports hall
Source: Field Work (2016)

4.1.1 Variables of Study

The variables considered for this study are:

4.1.1.1 Building orientation

University of Benin indoor sports hall is rectangular in shape with a total square area of about 340m^2 and 10m high with its longer sides facing the east-west direction and as such the better part of the building is exposed to direct solar radiation. See Figure 4.1

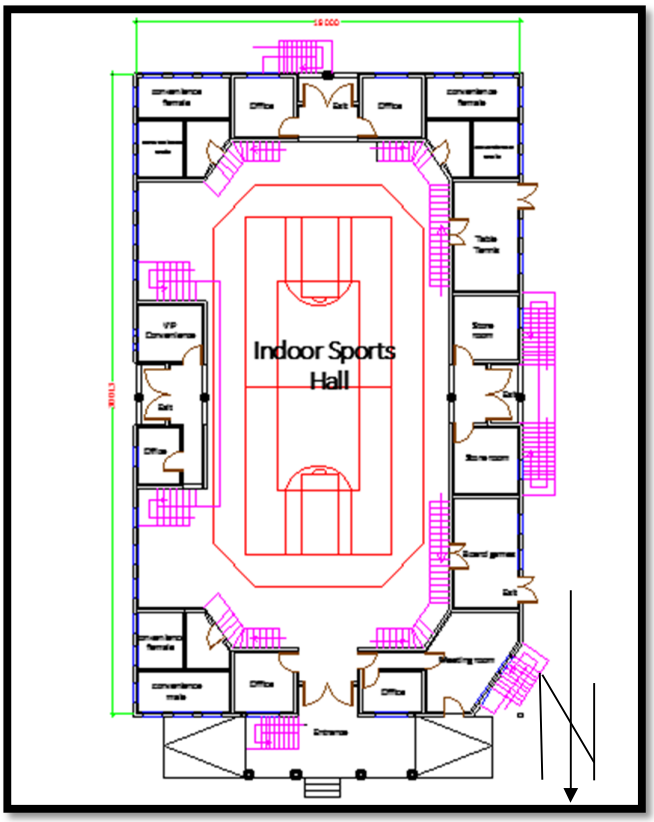


Figure 4.1. : Indoor sports hall rectangular form and orientation
Source: Field Work (2016)

4.1.1.2 Spatial Organization

The spatial arrangement of the indoor sports hall is simple and conventional. The hall has a variety of spaces ranging from offices, multipurpose hall, meeting rooms, board game room, store rooms and convenience spaces. The hall is divided into two floors where the multipurpose hall is a double volume hall and the spectators' area is on the first floor together with other offices. The changing rooms and offices are located on the perimeter of the building while the multipurpose hall is situated right in the middle of the building. All activities are concentrated on the North, South and West zone of the building.

4.1.1.3 Natural ventilation

The building has a cross flow and stack ventilation system with openings on all four sides to admit air for indoor environment comfort as seen in Plate 4.4. However it was not adequate hence the functional spaces within the sports hall made use of hair conditioning system. Projection windows were used for ventilation and lighting. There is absence of trees or vegetation around the building to aid further ventilation.



Plate 4.4. : Indoor sports hall showing cross ventilation of main hall
Source: Field Work (2016)

4.1.1.4 Building materials

The building is made of concrete block wall and finished with a cream/maroon colour. The hall is finished with a non-slippery carpet tiles while the other spaces are finely finished with ceramic tiles. Doors are metal doors of 1.5m wide. The roof has a steel structural system covered with aluminium roofing sheet on the exterior and Polyvinyl chloride boards on the interior as shown in Plate 4.2.



Plate 4.2. : Indoor sports hall showing metal door, block wall, and aluminum roofing
Source: Field Work (2016)

4.1.1.5 Shading Techniques

Thermal protection was considered according to the survey carried out, the building façade and other exit points have a deep recess in order to protect the indoor environment from the glaring sun and to provide a buffer between the indoor spaces and the outdoor environment as shown in plate 4.3. All window areas are exposed to glaring sun and as such increases the heat gain to interior space



Plate 4.3. : Indoor sports hall showing recessed entrance and projected windows
Source: Field Work (2016)

4.1.1.6 Landscape features

The building environment is surrounded by hard and soft landscape as seen in Plate 4.5. Despite the shading technique introduced in the design, there are no trees located near the building which is a demerit to the Sport hall because large tress can provide shading against the elements of weather and also reduce indoor air temperature.



Plate 4.5. : Indoor sports hall showing the few trees around
Source: Field Work (2016)

4.1.2 Discussion and findings

This section elucidates results from the field measurements and findings from visual surveys, and contains the key findings of the study in relation to the Research questions and existing body of knowledge.

Measurements were taken physically using a dry and wet bulb thermometer to find out the actual indoor air temperature of the different orientations within the indoor sports area. The thermometer was placed on the wall about 1.5m high. The said measurements were taken at three different times of the day for five consecutive days and the average temperature for each time was used to plot the charts in Figure 4.2 and 4.3 below.

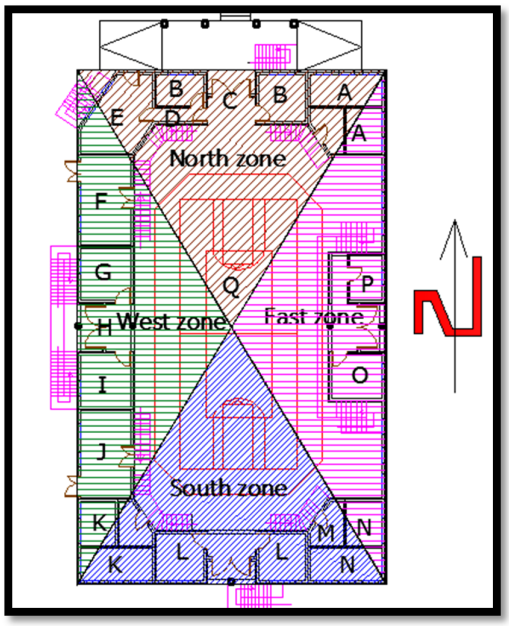


Figure 4.2: Ground floor plan

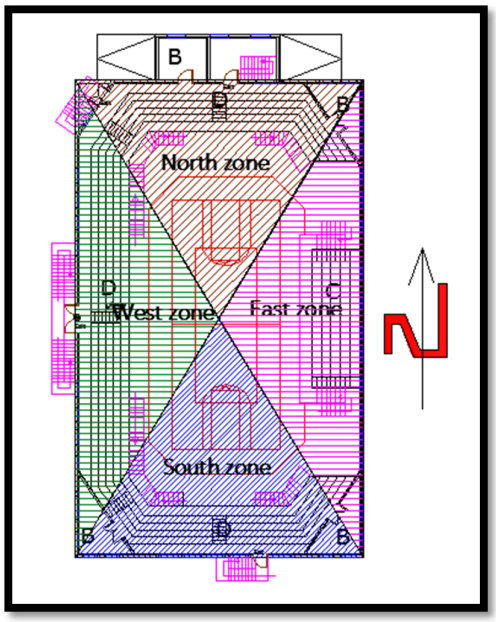


Figure 4.3: First floor plan

Table 4.1: Legend of floor plans
Source: Field Work (2016)

Ground floor (Gf) plan		**First floor (Ff) plan**
North zone	A= Convenience B= Office 1 C= Entrance D= Lobby 1 E= Meeting room Q= Main hall	B= Office D= Regular view
South zone	K= convenience L= Office Lobby 2 N= Convenience 2 Q= Main 4and5 M= Hall	B= Office D= Regular view
East zone	A= Convenience O=VIP convenience P= Office 3 N= Convenience 2 Q= Main hall	B= Office C= VIP view
West zone	E= Meeting room F= Board games G= Store room 2 H= Exit I= Store room 1 J= Table tennis K= convenience O=VIP convenience P= Office 3 Q= Main hall	B= Office D= Regular view

4.1.2.1 North zone

From figure 4.4 below, it was observed that spaces on the northern zone all experience their lowest temperature in the morning hours with the main entrance having the lowest temperature of 26°c, this may be due to the deep recess and also the size of openings provided. Also, the temperature of all spaces within this zone have their peak at 1pm with the ground floor (Gf) hall and meeting room having the highest temperature of about 29°c, and this may be due to the presence of few and fixed openings on the northern façade.

The northern region of the multipurpose hall experiences the highest temperature (29-31°c) throughout the day. The average daily temperature of this zone is 28°C on the ground floor and 30°C on the first floor (Ff). The temperature profile of the first floor is higher than that of the ground floor due to the principle that hot air rises and it has its maximum temperature at 1pm and 5pm due to its western orientation.

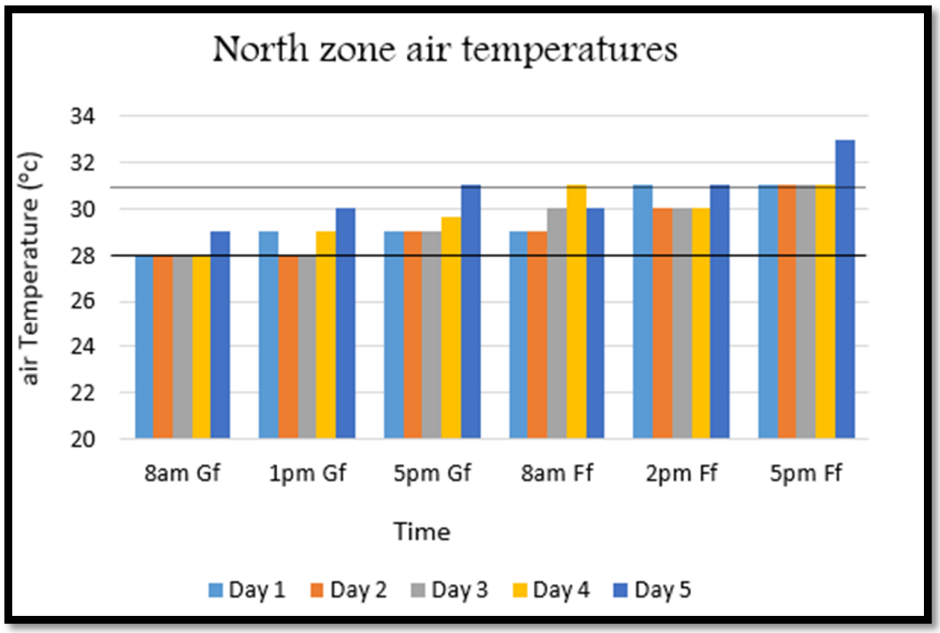


Figure 4.4: Temperature profile of North zone
Source: Field Work (2016)

4.1.2.2 West zone

From Figure 4.5, the temperature profile of the west zone tends to be relatively high throughout the day with a minimum of 29°C on the ground floor and 30°C on the first floor. The highest indoor air temperature for this zone is recorded at 1pm and 5pm respectively.

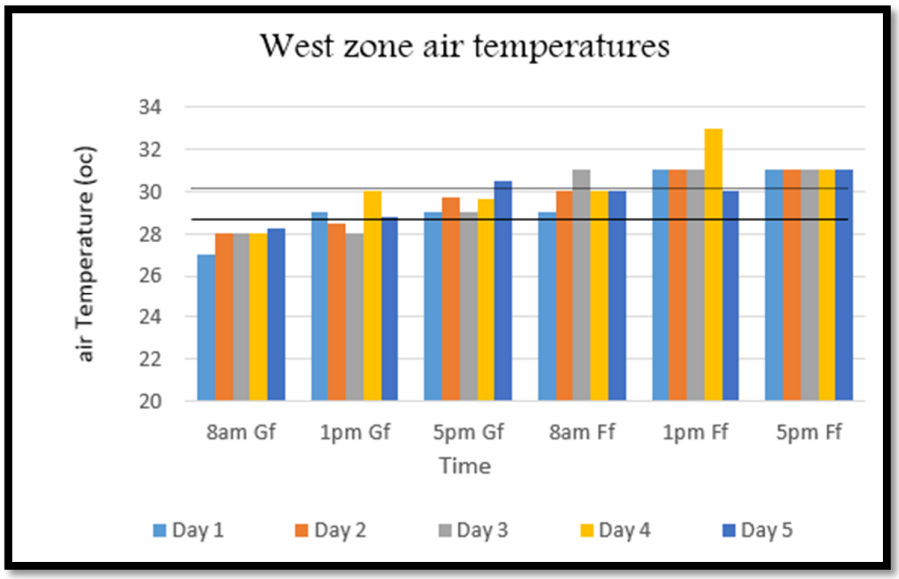


Figure 4.5: Temperature profile of West zone
Source: Field Work (2016)

4.1.2.3 South zone

From Figure 4.6, the spaces within this zone have similar temperature profile from 8am to 5pm. This zone has an average daily temperature of 28.5°c on the ground floor and 29.5 °c on the first floor. It was observed that the convenience (bath/changing room) space and circulation space on the south zone have similar temperature profile and has the lowest temperature range (25-29°c) from 8am to 5pm compared to other spaces. This may be due to the ceramic tile finishing on the wall and floor.

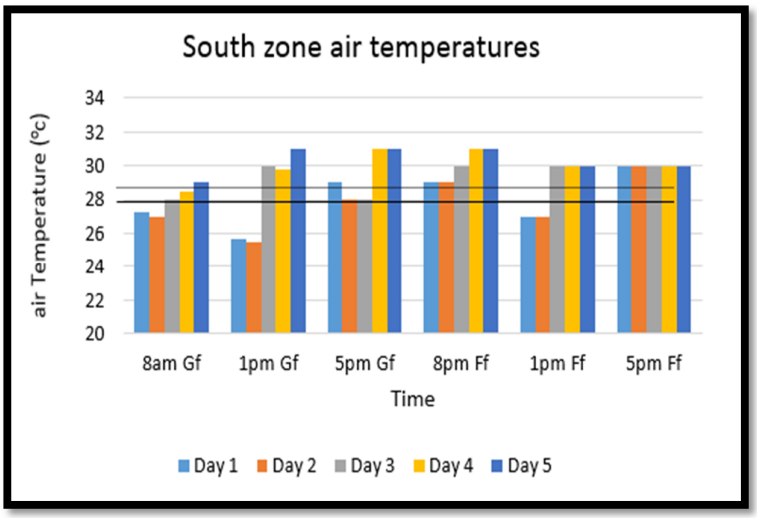


Figure 4.6: Temperature profile of South zone
Source: Field Work (2016)

4.1.2.4 East zone

From figure 4.7, it is observed that there are no much activities placed on the east zone and its maximum temperature is recorded to be 31°C at 1pm and 30°C at 8am. The average daily temperature recorded in this zone is 29.45°C on the ground floor and 30°C on the first floor. The different spaces within this zone experience temperature fluctuations and this may be as a result of the difference in their floor area and probably number of openings provided.

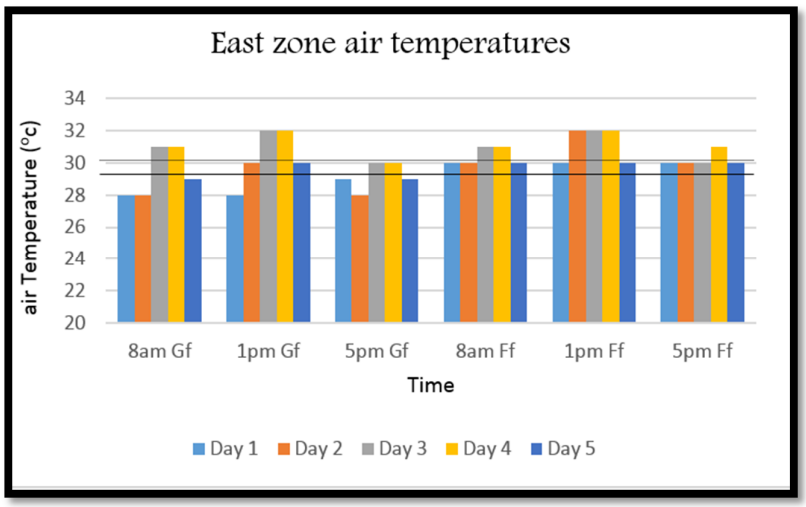


Figure 4.7: Temperature profile of East zone
Source: Field Work (2016)

4.1.3 Overall comments

Generic findings from the graphs suggest the following;

i. The different zones of the main hall all have different temperature for the different times of the day.
ii. The lowest internal air temperatures tend to occur in the convenience and circulation spaces.
iii. Temperature profile of the first floor is 2-3^{o}c higher than that of the ground floor profile
iv. Spaces with less openings tends to be warmer than those with more openings
v. The peak temperature for most zones tend to happen in the afternoon
vi. The North zone has the lowest internal air temperature throughout the day (28-30^{o}C)
vii. The South zone follows the north zone with a daily average temperature of 28.53^{o}C to 29.53^{o}C on the ground and first floor with a temperature difference of 0.53^{o}C and 0.47^{o}C from the North zone.
viii. The west and the east zone have the highest daily average temperature of 29.5 ^{o}C to 30^{o}C on both floors.

4.1.3 Validation of Result Using Ecotect Simulation Software

The existing base case model (University of Benin Indoor sport building) is modelled using AutoDesk Revit software as shown in Figure 4.8 and Figure 4.9 below. The data used for modelling such as building dimension and building material is collected during visual survey.

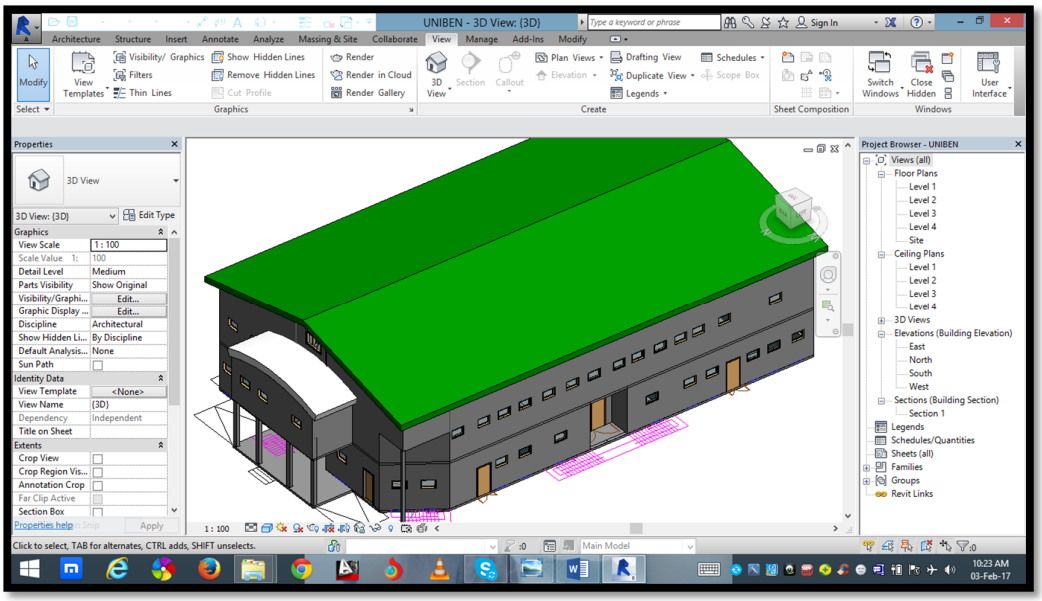


Figure 4.8: Base Case Model (indoor sport hall)
Source: Autodesk Revit architecture

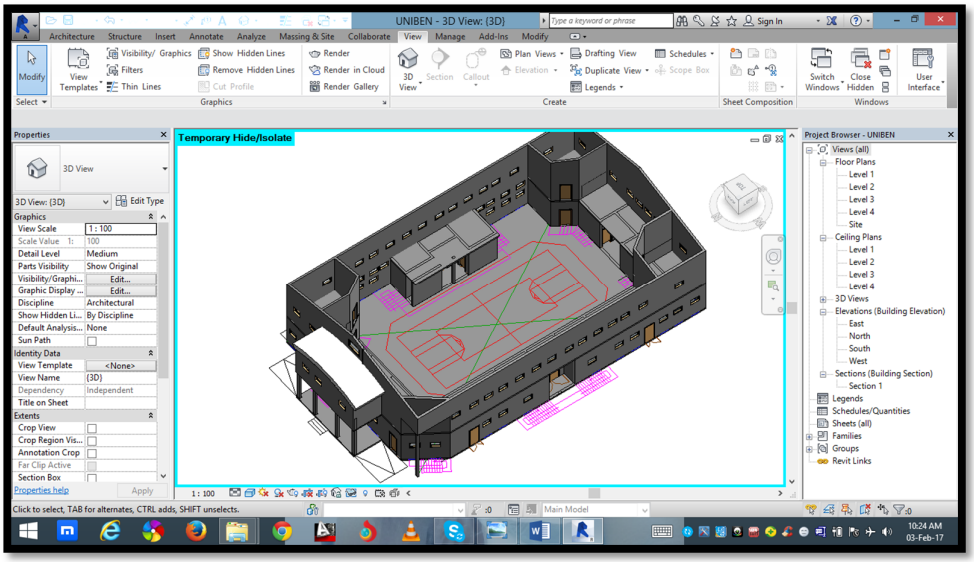


Figure 4.9: Base Case Model (Halls and offices)
Source: Autodesk Revit architecture

From figure 4.8 above, the internal air temperature of the different spaces are simulated by dividing the spaces into four different orientation; North, East, South and West. The model was exported to Ecotect simulation software where the different independent variables were applied such as the building materials, orientation, and weather file. And

also, for the analysis the inputs include; occupancy and hours of operation, internal design conditions, active system of cooling. See Figure 4.10 below.

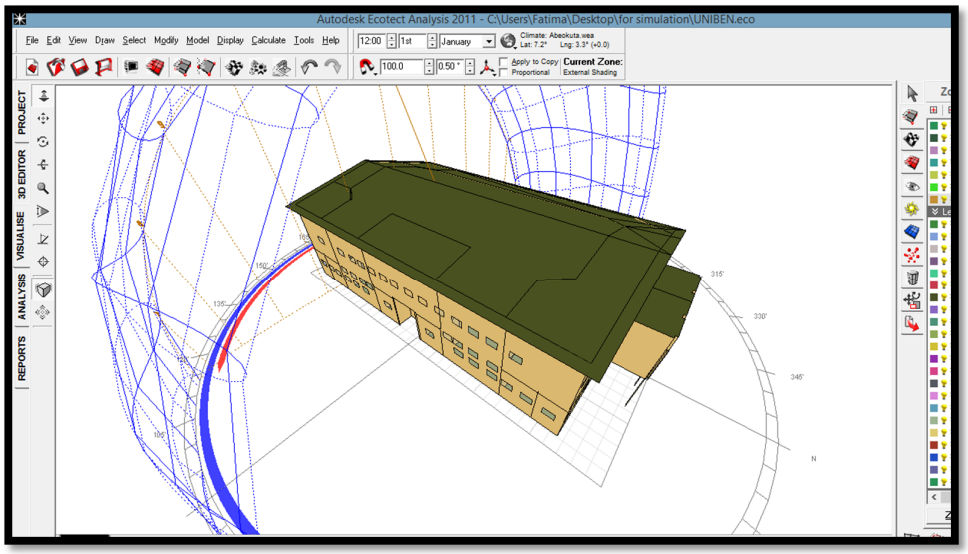


Figure 4.10: Interface of Autodesk Ecotect
Source: Autodesk Ecotect Analysis

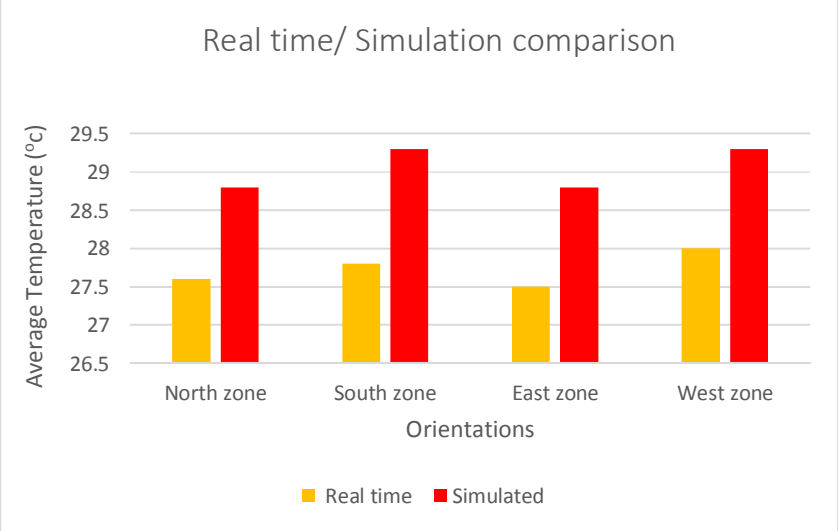


Figure 4.11: Comparison between Real time and Simulated Result
Source: Autodesk Ecotect Analysis

Figure 4.11 shows the comparative results between the real time and simulated results for the internal air temperature of the different orientations within the indoor sport hall of University of Benin. From the graph, it is seen that there's a difference of plus and minus 2°c. Details of the simulation will be attached to the appendix page.

4.1.4 Case Study Critique

The advantages and disadvantages of this case study are;

4.1.4.1 Advantages

i. Effective space management as indoor sports hall is multipurpose.

ii. Presence of soft and hard landscaped area.

iii. Availability of cross and stack ventilation

4.1.4.2 Disadvantages

i. Spatial organisation doesn't follow and precise order.

ii. Longer sides of the building faces the east and west direction thereby exposing the building to intense solar radiation.

iii. Larger percentage of the building is not shaded from climate.

4.2 Samuel Ogbemudia Stadium, Edo State Nigeria

Overview

Location: Ekenwan road, Edo State

Construction date: 1998

Regional climate: Warm humid climate

Samuel Ogbemudia Stadium is a multi-use stadium in Edo State, Nigeria. The stadium has a capacity of 30, 000 seating capacity used for sports and social events. The stadium provides modern sporting facilities including Olympic size swimming pools, indoor sports hall for about 3,000 people, gymnasium, outdoor games court, restaurant, police post, governors' lodge, etc. The stadium has a spread out plan just like the case of university of Benin sports complex. It consists of various sections; the main bowl, the swimming area, the indoor sport area, the administrative area, outdoor courts, and retail shops. The indoor sports hall is a multipurpose hall for playing games such as; basketball, volleyball, badminton, tennis, taekwondo, judo, karate, gymnastics,

wrestling etc. and also for hosting events like; wedding receptions, birthday parties, and religious programs. Other spaces in the indoor hall includes; weight lifting room, table tennis room, chess, scrabble, offices, convenience spaces, storage room, sickbay, restrooms, and accommodation. Figure 4.6 below shows the approach view of the indoor sports hall within the complex.



Plate 4.6. : Approach view of Indoor sports hall
Source: Field Work (2016)

4.2.1 Variable of Study

The buildings architectural characteristics will be discussed based on the following headings:

4.2.1.1 Building Orientation

According to study carried out, Samuel Ogbemudia indoor sports hall is rectangular in shape with a total square area of about 825m^2 and 8m high with its longer sides facing the north east - south west direction thereby exposing part of the building to solar radiation as seen in Figure 4.12 below.

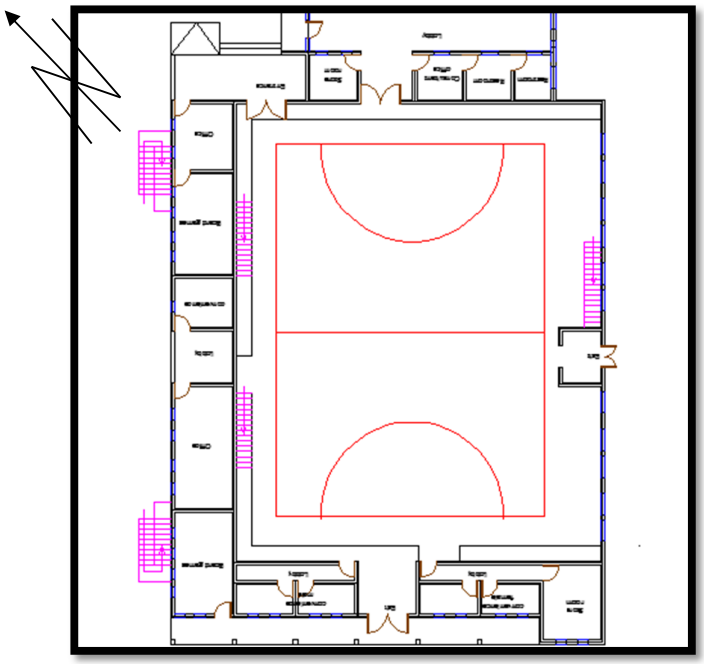


Figure 4.12. : Indoor sports hall rectangular form and orientation
Source: Field Work (2016)

4.2.1.2 Spatial Organization

The hall has a variety of spaces ranging from offices, multipurpose hall, meeting rooms, board game room, chess room, sick bay, accommodation, store rooms and changing rooms. The hall is divided into two floors where the multipurpose hall is a double volume hall and the spectators' area is on the first floor. All activities are concentrated on the North, South and West zone of the building like the first case. Offices are mainly on the West zone of the building.

4.2.1.2 Natural ventilation

The building has a stack and cross flow ventilation system with ground floor openings on just one side and first floor openings on all four sides to admit air for indoor environment comfort as shown in Plate 4.7. Apart from the natural ventilation system applied, there are also fans used as artificial ventilation. There is absence of trees or vegetation around the building to aid further ventilation.



Plate 4.7. : Natural and artificial ventilation
Source: Field Work (2016)

4.2.3.3 Building materials

The building is made of concrete block wall with steel sections and finished with a white colour as shown in Plate 4.8. The hall is finished with a non-slippery carpet tiles while the other spaces are finely finished with oversite concrete. Doors are mainly wooden doors with burglary proof and wide enough for mass entry and exit.



Plate 4.8. : Door and floor finish
Source: Field Work (2016)

4.2.1.4 Openings/glazing/shading devices

The provision of sliding and projected windows in the hall aid natural light and ventilation into the spaces. Just like the first case, the building façade and other exit points are shaded with a recess and also overhangs in order to protect the indoor environment from the glaring sun and to provide a buffer between the indoor spaces and the outdoor environment as shown in plate 4.9.



Plate 4.9. : Recessed entrance and projected window
Source: Field Work (2016)

4.2.1.5 Landscape features

The building environment is mostly surrounded by hard landscape. Despite the shading technique introduced in the design, there are no trees located near the building which is a demerit to the Sport hall because large tress can provide shading against the elements of weather and also reduce indoor air temperature.



Plate 4.10. : Hard landscape throughout
Source: Field Work (2016)

4.2.2 Discussion and findings

Procedures are similar to case study one. See floor plans in Figures 4.13 and 4.14.

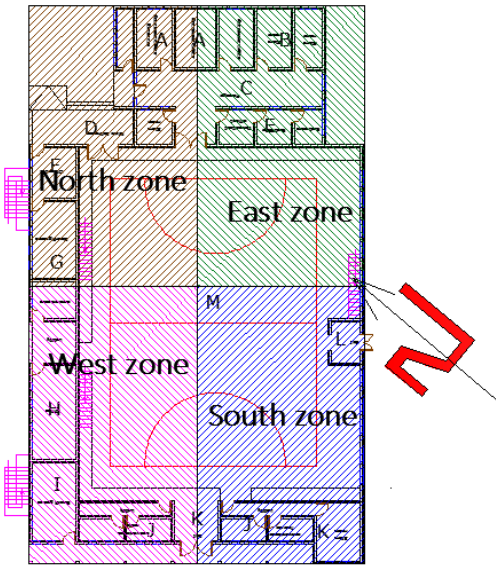


Figure 4.13: ground floor plan

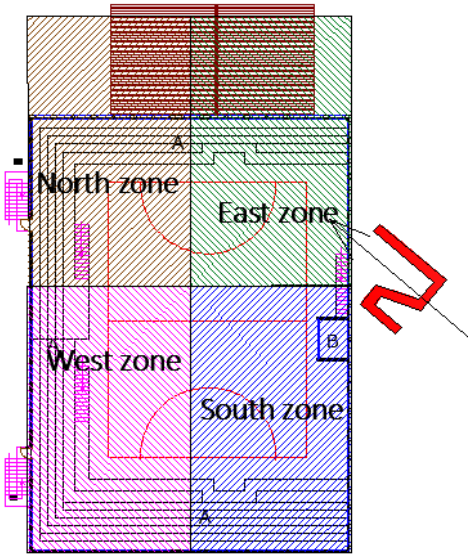


Figure 4.14: First floor plan

Table 4.2: Legend of floor plans

Ground floor plan		First floor plan
North zone	A= Bedroom D= Main entrance E= Office 1 G= Board games M= Main hall	A= View area
South zone	J= Convenience K= Exit L= Spectators view M= Main hall	A= View area B= Spectators view
East zone	B= Store room C= Passage F= Sick bay M= Main hall	A= View area B= Spectators view
West zone	H= Office I= Board games J= Convenience K= Exit M= Main hall	A= View area

Source: Field Work (2016)

4.2.2.1 North zone

From figure 4.15, the highest daily average temperature recorded on the North zone is 29.5°C on the ground floor and 32°C on the first floor which has an average difference of 2°C from the Northern zone of the first case.

The entrance on the north zone was observed to have the lowest and stable temperature throughout the day, this may be due to its recessed and properly shaded nature and absence of direct solar radiation. There is also variation of temperature within the hall and this may be due to the large floor area and building height.

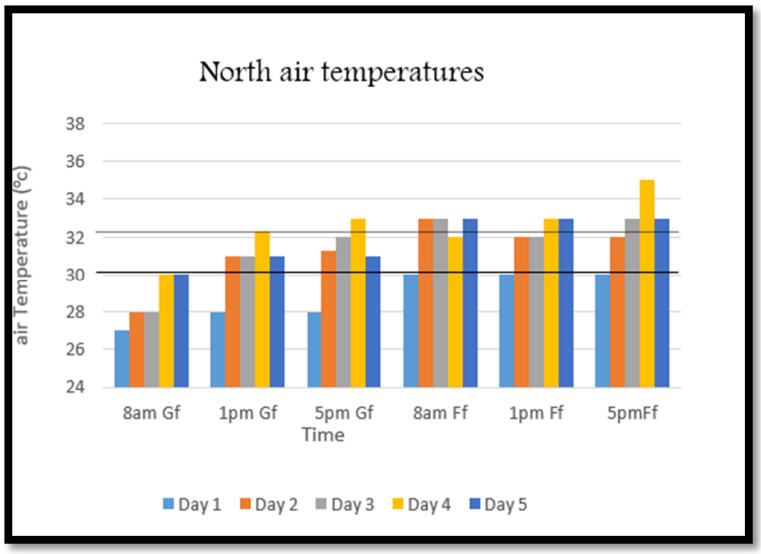


Figure 4.15: Temperature profile of North zone
Source: Field Work (2016)

4.2.2.2 West zone

The result from figure 4.16 shows that the west zone experience its highest temperature at 1pm and 5pm respectively and the lowest indoor air temperature recorded on this zone is 31°c at 8am. The average daily temperature recorded on this zone is 32°C on the ground floor and 33°C on the first floor with an average difference of 3°C from the Western zone of the first case. Spaces within this zone will require more energy for cooling.

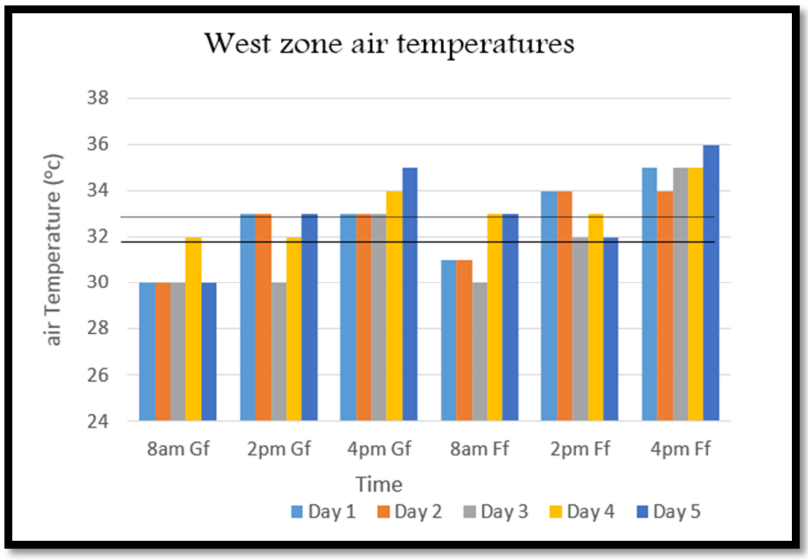


Figure 4.16: Temperature profile of West zone
Source: Field Work (2016)

4.2.2.3 South zone

The temperature profile of this zone is similar to that of the west zone with the lowest indoor air temperature recorded at 8am and the highest at 1pm and 5pm respectively as shown in figure 4.17. The average daily temperature recorded on this zone is 31°C on the ground floor and 33°C on the first floor with an average difference of 3°C form the Southern zone of the first case.

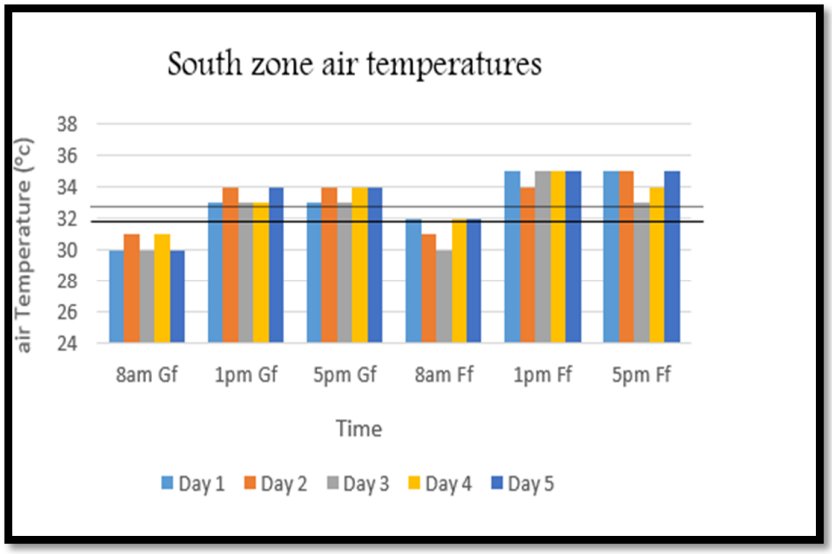


Figure 4.17: Temperature profile of South zone
Source: Field Work (2016)

4.2.2.4 East zone

From figure 4.18, it is observed that the average daily temperature is lower than that of the northern zone. The average daily temperature is recorded to be 29.9°c on the ground floor and 31.5°c on the first floor.

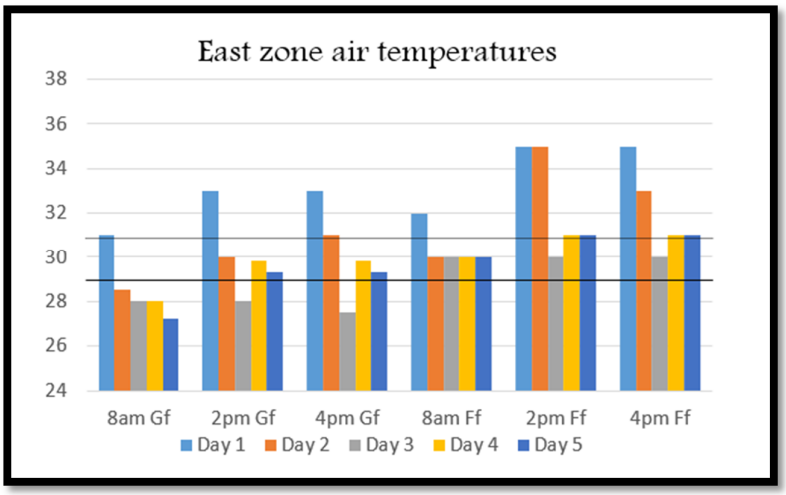


Figure 4.18: Temperature profile of East zone
Source: Field Work (2016)

Comments

Generic findings from the graphs suggest the following;

i. The different zones of the main hall all have different temperature for the different times of the day.

ii. The hall has a maximum temperature average of 32°c on the ground floor and 35°c on the first floor and this value is way more than the recommended 22°c from literature findings, hence it requires more energy for cooling compared to the first case.

iii. The lowest internal air temperatures tend to occur in the east and north zones

iv. All zones have their peak temperature at 2pm.

v. Temperature profile of the first floor is 2-3°c higher than that of the ground floor profile

vi. The North zone has the lowest internal air temperature of 29.5 ^{o}C-32 ^{o}C for ground floor and first floor.

vii. The East zone follows the north zone with a daily average temperature of 29.9 ^{o}C to 31.5 ^{o}C on the ground and first floor with a temperature difference of 0.4 ^{o}C and 0.5 ^{o}C from the North zone.

viii. The South and West zones have the highest daily temperature of 32 ^{o}C-33 ^{o}C on both floors.

4.2.3 Validation of Result Using Ecotect Simulation Software

The existing base case model (Samuel Ogbemudia Stadium Indoor sport building) is modelled using AutoDesk Revit software as seen in Figures 4.19 and 4.20. The data used for modelling such as building dimension and building material is collected during visual survey.

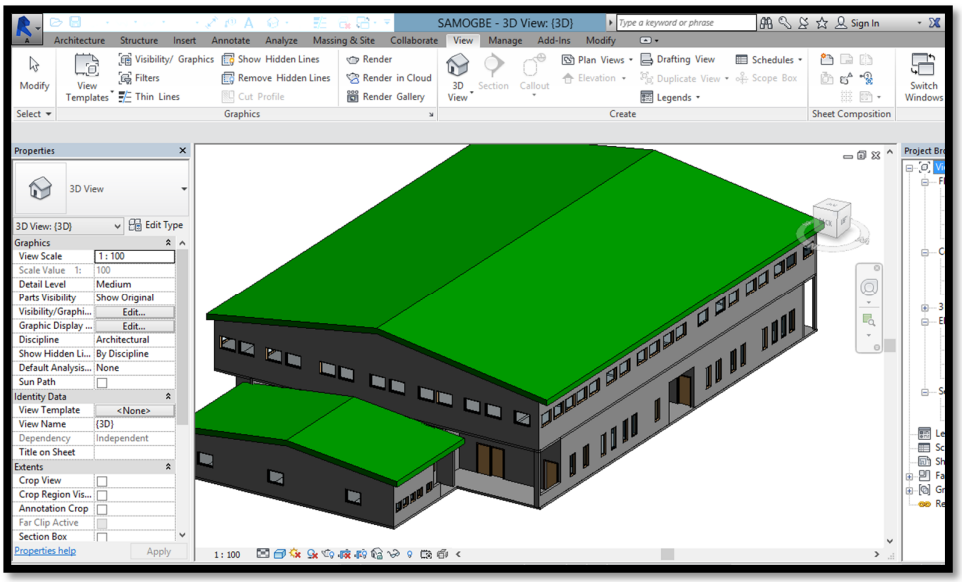


Figure 4.19: Base Case Model (indoor sport hall)
Source: Autodesk Revit architecture

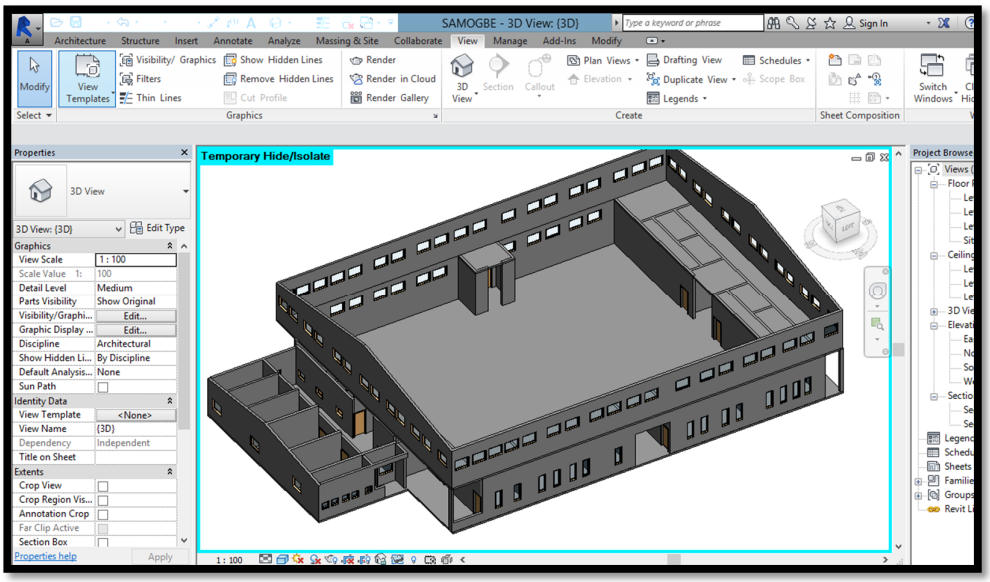


Figure 4.20: Base Case Model (Halls and offices)
Source: Autodesk Revit architecture

From figure 4.20 above, the internal air temperature of the different spaces are simulated by dividing the spaces into four different orientation; North, East, South and West. The model was exported to Ecotect simulation software where the different independent variables were applied such as the building materials, orientation, and weather file. And also, for the analysis the inputs include; occupancy and hours of operation, internal design conditions, active system of cooling as seen in Figure 4.21.

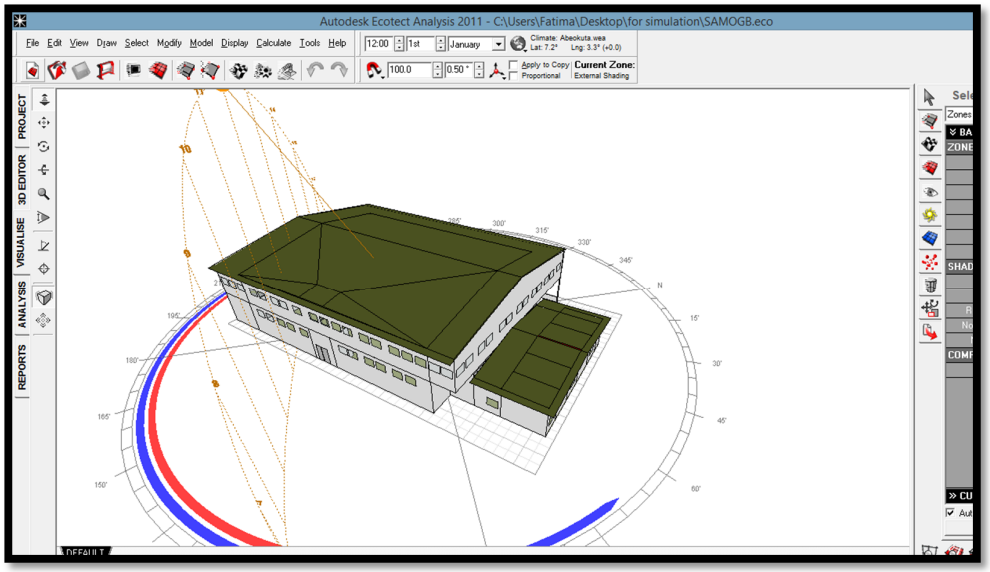


Figure 4.21: Interface of Autodesk Ecotect
Source: Autodesk Ecotect Analysis

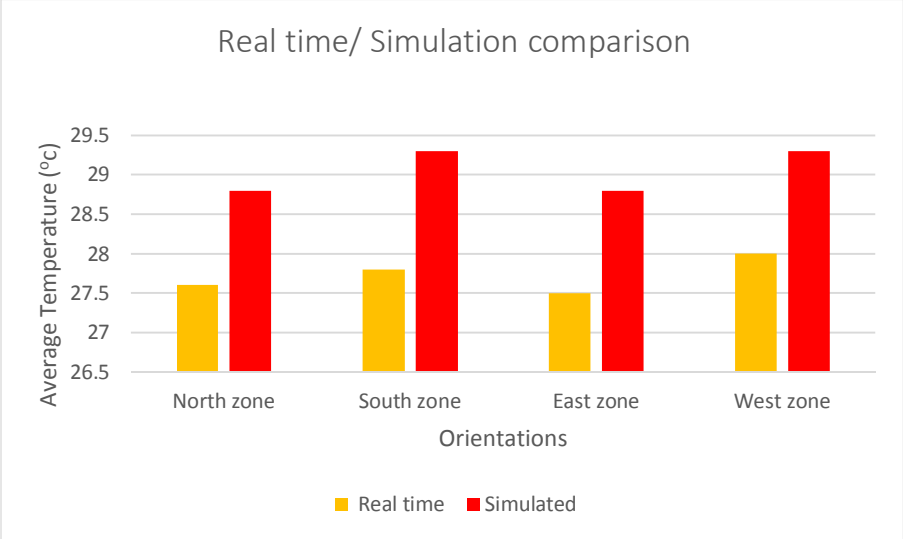


Figure 4.22: Comparison between Real time and Simulated Result
Source: Autodesk Ecotect Analysis

Figure 4.22 result shows the comparative results between the real time and simulated results for the internal air temperature of the different orientations within the indoor sport hall of Samuel Ogbemudia Stadium. From the graph, it is seen that there's a slight difference of +2-3°c. Details of the simulation will be attached to the appendix page.

4.2.4 Case Study Critique

The advantages and disadvantages of this case study are;

4.2.4.1 Advantages

i. Effective space management as indoor sports hall is multipurpose.

ii. Presence of stack ventilation

iii. Proper shading technique on the ground floor.

iv. There is no use of heat generating sport equipment and machines.

4.2.4.2 Disadvantages

iv. Spatial organisation doesn't follow and precise order.

v. Poor orientation which exposes a better part of the building to solar radiation

vi. The roof steel members are exposed and as result causes heat generation to the multipurpose sport hall.

vii. The fitness and sport centre doesn't provide space for a variety of sport activities.

viii. The sport environment is mainly made up of hard landscape.

4.3 Mayfair Garden Fitness Centre, Awoyaya, Lagos State

Overview

Location: Awoyaya, Lagos state

Construction date: 2011

Regional climate: Warm humid climate

Mayfair Garden park is a multi-use building that is attached to the Mayfair garden estate in a, Lagos state Nigeria. The park was designed to host a number of activities ranging from outdoor restaurant, fitness club, event hall, fast food restaurant, pools and playground and other private clubs.

The building is a single building with three floors; the ground floor houses the main reception area, fast food restaurant, outdoor seating area, and swimming pool, the second floor consist of 2 event halls, private club and beauty salon while the third floor houses the fitness centre. The fitness centre have activities like; reception, 2 fitness room, outdoor seating area, office, outdoor board games, spa, children's play area, massage room, store room, changing room and convenience. The fitness space has a total capacity of 20 persons, while the spa accommodates a maximum of 2 people per session. The approach view of the building is shown in Plate 4.11



Plate 4.11. : Mayfair Gardens, Approach view
Source: Field Work (2016)

4.3.1 Variable of Study

The buildings architectural characteristics will be discussed based on the following headings:

4.3.1.1 Building form and orientation

The fitness centre is rectangular in shape with a total floor area of about 270m^2 and 3.5m. The main halls used for fitness activities are also rectangular in shape and have their longer sides facing the north south direction which is a good orientation for a rectangular building as shown in Figure 4.23

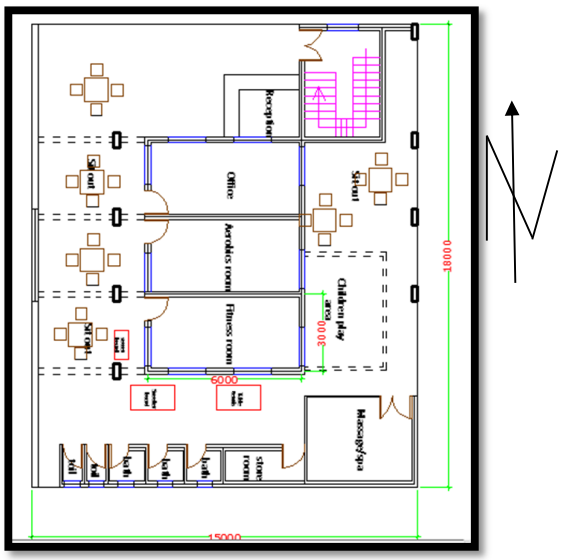


Figure 4.23. : Fitness centre orientation
Source: Field Work (2016)

4.1.1.2 Spatial Organization

The building is a single building with three floors; the ground floor houses the main reception area, fast food restaurant, outdoor seating area, and swimming pool, the second floor consist of two event halls, private club and beauty salon while the third floor houses the fitness centre. The fitness centre have activities like; reception, 2 fitness room, outdoor seating area, office, outdoor board games, spa, children's play area, massage room, store room, changing room and convenience. The main activities in the fitness centre are located in the centre of the building while the perimeter houses the changing room and relaxation spaces.

4.3.1.3 Natural ventilation

The building has a cross flow ventilation system as demonstrated in Figure 4.24. Apart from the natural ventilation system applied, there are also air conditioning system used for cooling the spaces. There is absence of trees or vegetation around the building to aid further ventilation.

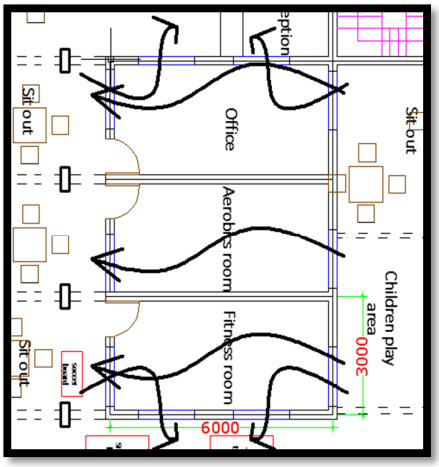


Figure 4.24. : Natural ventilation
Source: Field Work (2016)



Plate 4.12. : Artificial ventilation
Source: Field Work (2016)

4.3.1.4 Building materials

The building is made of block wall and finished with a light brown colour on the interior and a mixture of light brown and dark brown on the exterior (Plate 4.13). The

floor is finished with a non-slippery ceramic tiles while the fitness room is covered with a rug carpet. Doors are mainly metal and wooden doors.



Plate 4.13. : Wall and floor finish of fitness centre
Source: Field Work (2016)

4.3.1.5 Openings/glazing/shading devices

The provision of projected windows in the fitness area aid natural light and ventilation into the spaces as seen in Plate 4.14 and Figure 4.25. Unlike the other cases, the entire fitness centre is shaded all round by a double skin which serves as a buffer hence protecting it from varying climatic conditions and providing comfortable indoor environment.



Plate 4.14. : Projected reflected opening
Source: Author's Field Work

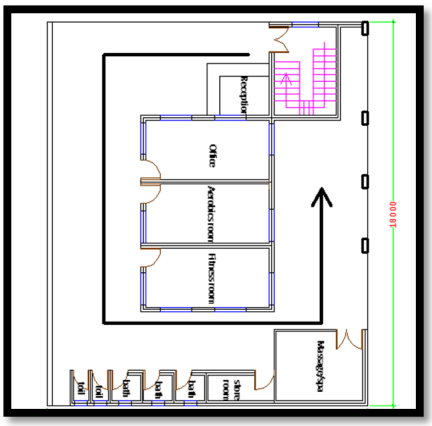


Figure 4.25. : Shading (buffer zone)
Source: Author's Field Work

4.3.1.6 Landscape features

The building environment is mostly surrounded by hard landscape (interlocking tiles) as seen in Plate 4.15. Despite the shading technique introduced in the design, there are no trees located near the building.



Plate 4.15. : Interlocking tiles as exterior floor finish
Source: Field Work (2016)

4.3.2 Discussion and findings

The procedure followed in this section is same with that of the previous. Figure 4.26 below shows the floor plan and zone layout of the fitness area.

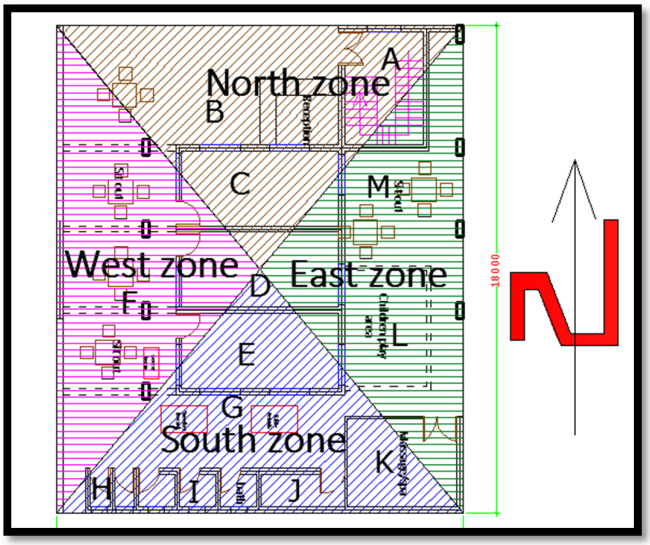


Figure 4.26. : Floor plan
Source: Field Work (2016)

Table 4.3: Legend of floor plan

Ground floor plan	
North zone	A= Stair hall B= Reception C= Office D= Aerobics
South zone	D= Aerobics E= Fitness room G= Board games H= Toilets I= Baths J= Store room K= Massage/spa
East zone	E= Fitness room K= Massage/spa L= Children's play area M= sit out
West zone	D= Aerobics E= Fitness room F= Sit out

Source: Field Work (2016)

4.3.2.1 North zone

From figure 4.27, the north zone has an average daily temperature of 27.8^{o}c which is lower than that of the first two cases studied. The highest indoor air temperature recorded on this zone is at 2pm while the lowest is at 8am and 5pm respectively.

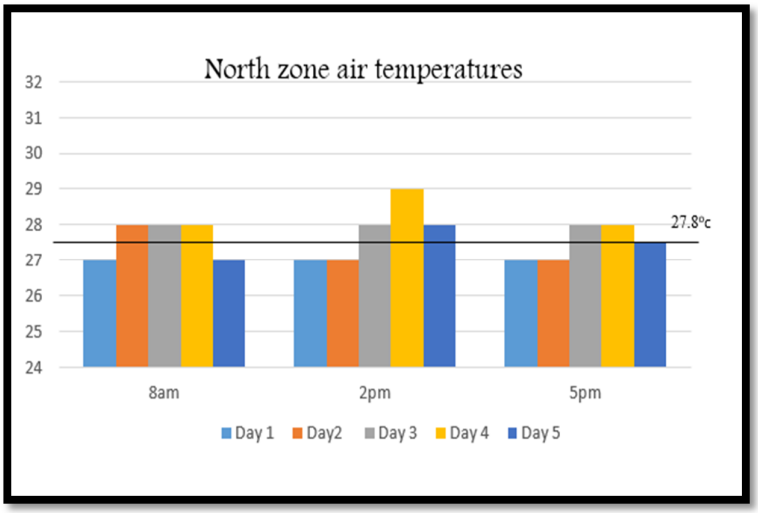


Figure 4.27: Temperature profile of South zone
Source: Field Work (2016)

4.3.2.2 West zone

The west zone has an average temperature of 27°c at 8am which is 2°c lower than that of the east zone. Though the spaces on the east and west are properly shaded and receive less amount of radiation during the day as shown in Figure 4.28.

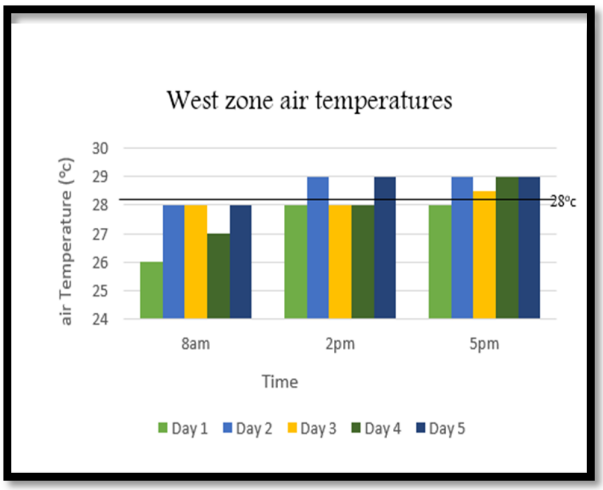


Figure 4.28: Temperature profile of West zone
Source: Field Work (2016)

4.3.2.3 South zone

The south zone has its peak temperature in the afternoon (28-29°c) as shown in Figure 4.29. The thermal behaviour of the office on the north zone and the fitness room on the south zone are quite similar throughout the day, this is likely because they both have the same floor area, number and size of openings and same internal gain.

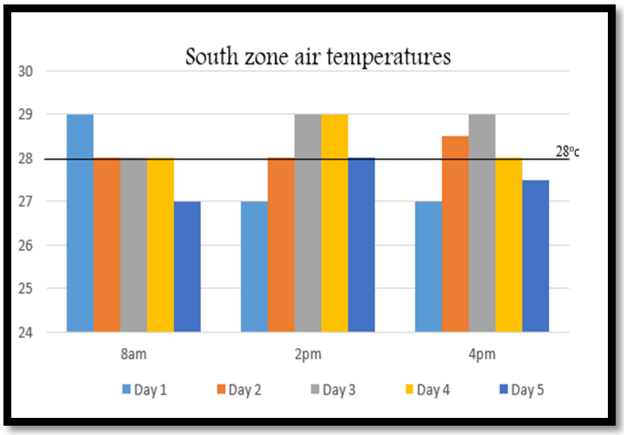


Figure 4.29: Temperature profile of South zone
Source: Field Work (2016)

4.3.2.4 East zone

From figure 4.30, the east zone has an average daily temperature of 28°c with its lowest temperature recorded at 5pm.

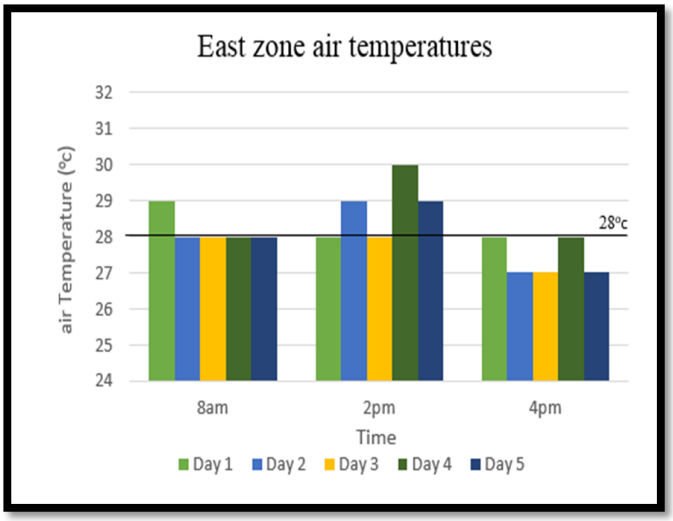


Figure 4.30: Temperature profile of East zone
Source: Field Work (2016)

Overall comments

Generic findings from the graphs suggest the following;

i. All spaces have their peak temperature at 2pm and 5pm
ii. The only zone that has a stable morning temperature profile is the centre zone.
iii. The lowest air temperatures tend to occur in the sitting area of the west zone.
iv. There are more activities on the southern zone compared to other zones.
v. The east and west zones are mainly used for outdoor sitting.
vi. The general low temperature of all zones may be as a result of the double skin nature of the fitness centre.

4.3.3 Validation of Result Using Ecotect Simulation Software

The existing base case model (Mayfair Fitness Centre) is modelled using AutoDesk Revit software as seen in Figures 4.32 and 4.32. The data used for modelling such as building dimension and building material is collected during visual survey.

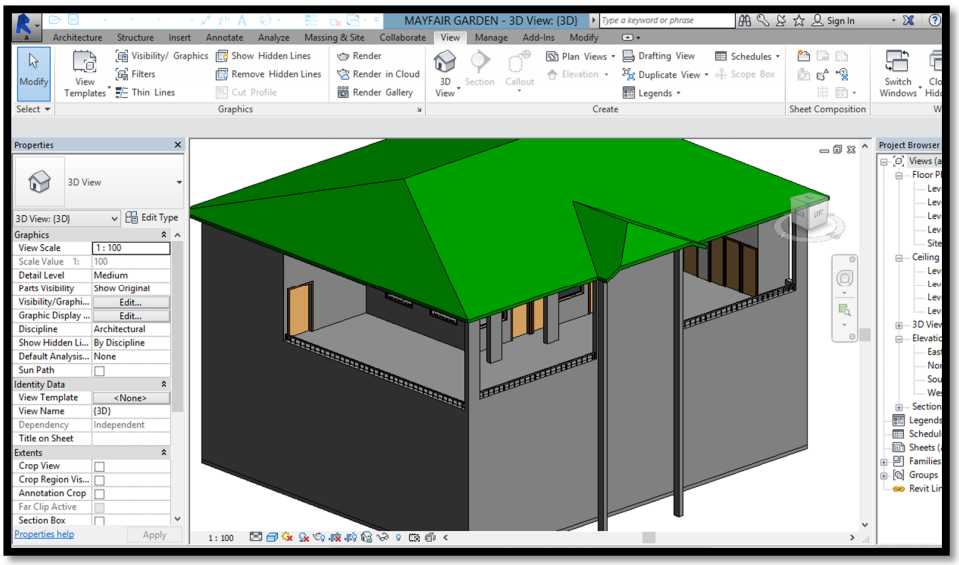


Figure 4.31: Base Case Model (indoor sport hall)
Source: Autodesk Revit architecture

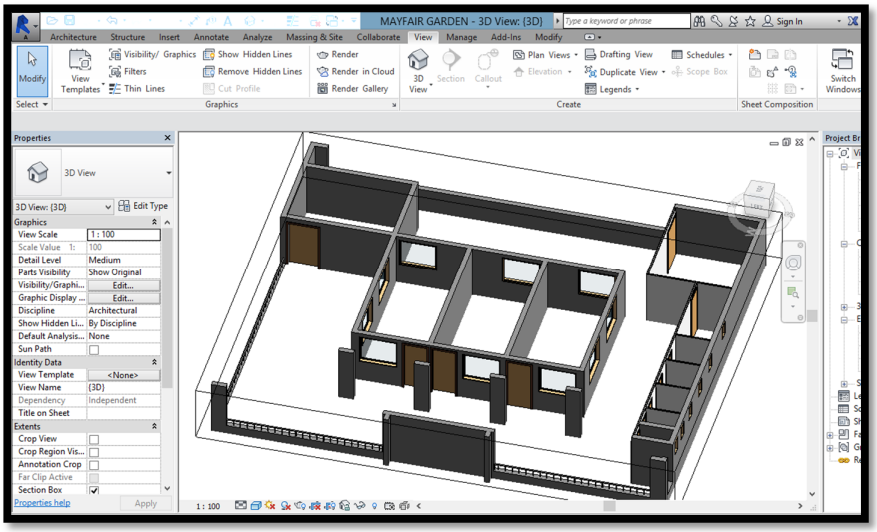


Figure 4.32: Base Case Model (Halls and offices)
Source: Autodesk Revit architecture

From figure 4.32 above, the internal air temperature of the different spaces are simulated by dividing the spaces into four different orientation; North, East, South and West. The model was exported to Ecotect simulation software where the different independent variables were applied such as the building materials, orientation, and weather file. And also, for the analysis the inputs include; occupancy and hours of operation, internal design conditions, active system of cooling as shown in Figure 4.33.

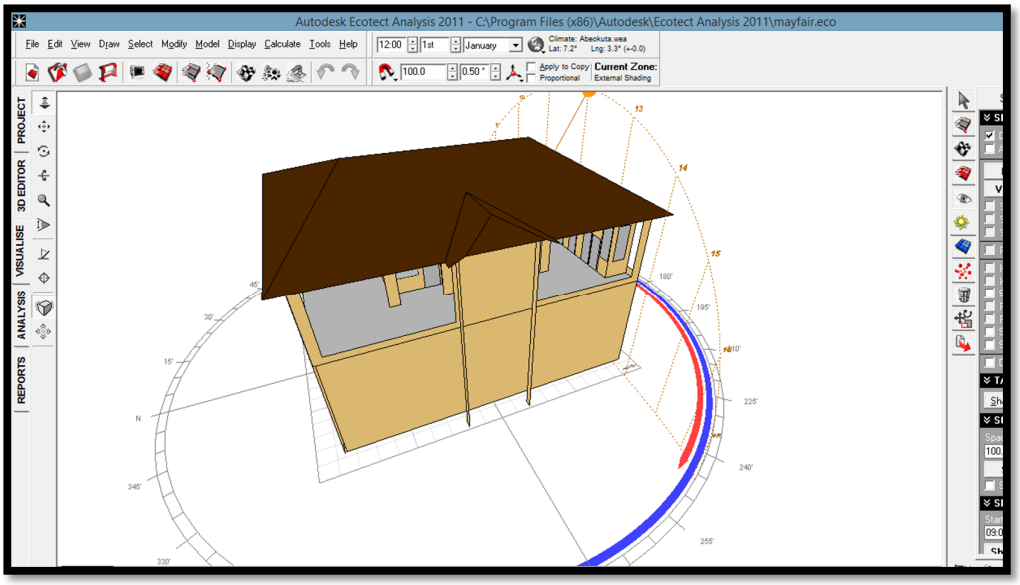


Figure 4.33: Interface of Autodesk Ecotect
Source: Autodesk Ecotect Analysis

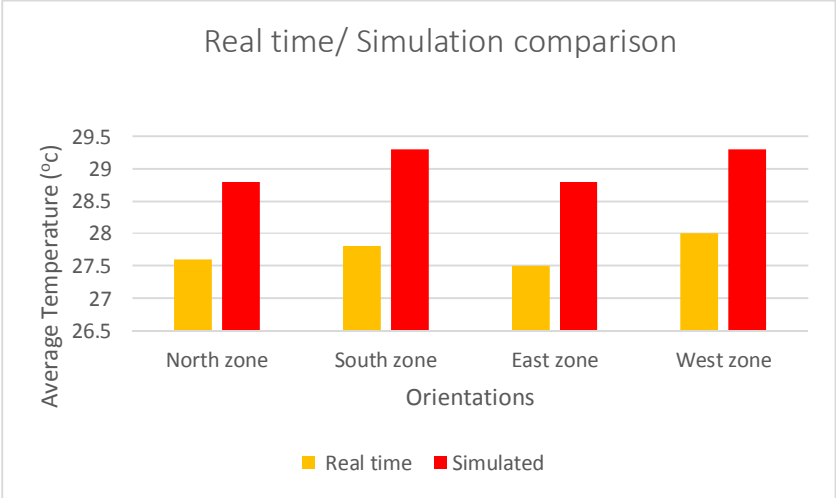


Figure 4.34: Comparison between Real time and Simulated Result
Source: Autodesk Ecotect Analysis

Figure 4.34 result shows the comparative results between the real time and simulated results for the internal air temperature of the different orientations within the indoor sport hall of Mayfair Fitness centre. From the graph, it is seen that there's a slight difference of +1-2°c. Details of the simulation will be attached to the appendix page.

4.3.4 Case Study Critique

The advantages and disadvantages of this case study are;

4.3.4.1 Advantages

i. Use of a double skin façade for shading.

ii. Presence of cross ventilation within spaces

iii. This facility provides a massage and spa section which is different from the others.

iv. Window openings that allow for maximum air circulation.

4.3.4.2 Disadvantages

ix. Spatial organisation doesn't follow and precise order.

x. Longer side of the building faces the East and West orientation thereby exposing a better part of the building to intense solar radiation

xi. The fitness and sport centre doesn't provide space for a variety of sport activities.

xii. The sport environment is mainly made up of hard landscape.

xiii. Presence of heat generating equipment like cardio-machines in the fitness hall.

4.4 Zone Comparison

The chart on Figures 4.35 and 4.36 below shows the average daily temperature of each zone for the three case studies

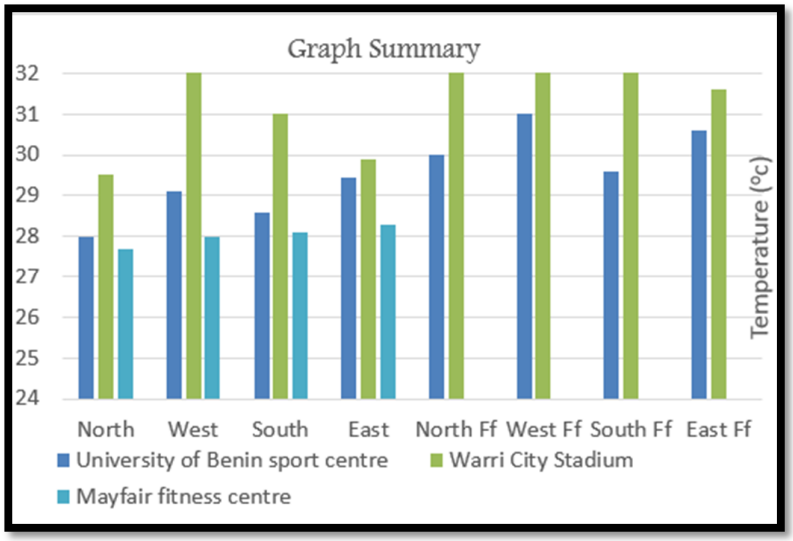


Figure 4.35: Comparison between Real time and Simulated Result
Source: Autodesk Ecotect Analysis

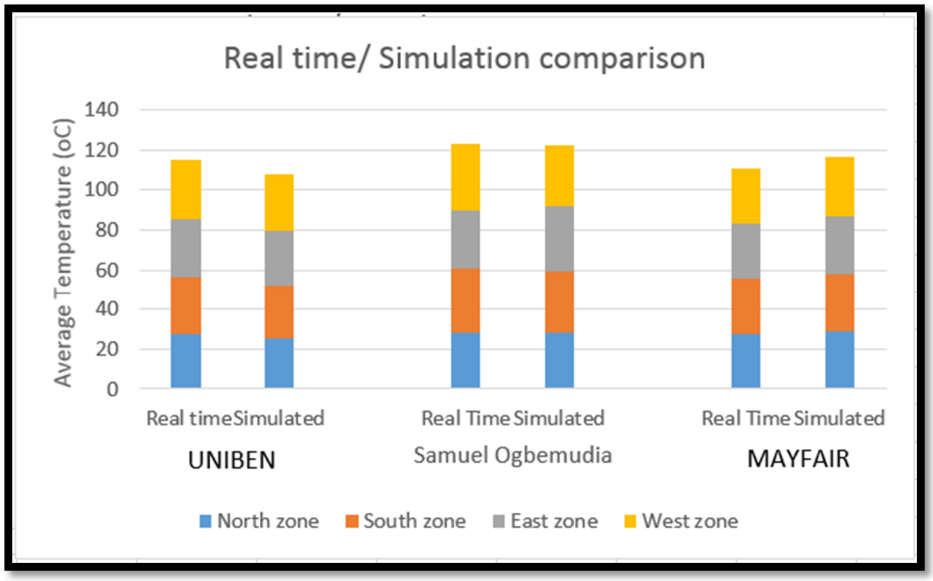


Figure 4.36: Comparison between Real time and Simulated Result
Source: Autodesk Ecotect Analysis

Summary of Findings from Zone Comparison

Generic findings from the three cases studied suggests that;

i. All zones experience their lowest internal air temperature at 8am
ii. The lowest internal air temperatures tend to occur in the north and south zones for the first case and north and east for the second case while the third case has an almost stable daily temperature profile.
iii. There is temperature difference of about 2-3^{o}C between all orientations.
iv. Temperature profile of the first floor is 2-3^{o}C higher than that of the ground floor profile
v. The peak temperature for most zones tend to happen in the afternoon
vi. The West zone seem to have the highest daily temperature for all case
vii. The volume of a space can affect the air temperature

4.5 Energy Consumption of Case Studies

The results of energy consumption presented here are with the mechanical cooling set to adequate. The indoor temperature maintained for the different zones are as derived from literature. The dependent variable used to examine the thermal performance of the variables is annual and monthly energy consumption. Detail results of the simulation can be found in the appendices of this research. Also hourly weather data for the specific location of this research is also in the appendix. The cooling energy demand is shown in Table 4.4

The input for this simulation includes

i) Building properties (Building dimensions and type of materials)

ii) Weather file; Edo state weather file for all cases

iii) Building use; building use is for Sports purpose

iv) Operation hour; number of hours per day including peak periods

v) Cooling system; Artificial or natural ventilation as the case may be including the number of fans and air conditioning unit per space (this was done individually for the different cases).

Table 4.4: Monthly cooling energy demand for Case Studies

	COOLING (kWh)		
MONTH	**University of Benin Sport hall**	**Samuel Ogbemudia Sport hall**	**Mayfair Fitness Centre**
Jan	37284.66	61181.711	12003.452
Feb	38914.53	63136.055	12632.127
Mar	38040.88	62656.848	12309.334
Apr	35507.62	58136.027	11479.427
May	36795.07	59922.637	12201.068
Jun	32333.69	52582.719	11026.246
Jul	30687.47	50183.125	10421.418
Aug	29942.43	49526.434	9991.061
Sep	29759.67	49115.227	9733.634
Oct	34322.77	55848.57	11156.903
Nov	36346.01	58638.027	11743.528
Dec	35765.93	58163.324	11575.197
TOTAL	**415700.8**	**679090.688**	**136273.391**

PER M²	**655.046**	**765.847**	**295.603**
Floor Area:	**634.613 m²**	**886.718m²**	**461.002m²**

Source: Autodesk Ecotect Analysis

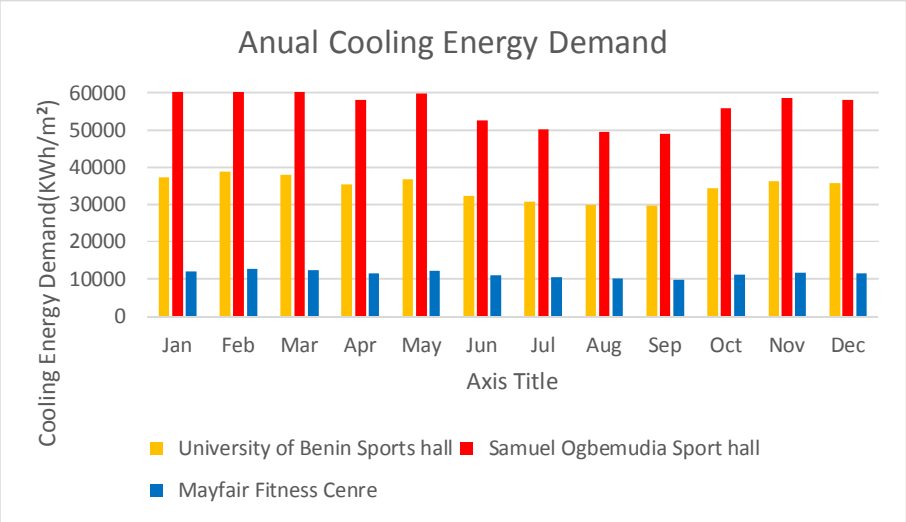


Figure 4.37: Monthly distribution of cooling energy demand of the different cases
Source: Autodesk Ecotect Analysis

The cooling energy demand for the different cases are calculated in KWh/m2. From table 4.4 above, it is observed that Samuel Ogbemudia Indoor sport hall with a total floor area of 887m^2 requires a total energy of about 652KWh/m^2 to cool down the building. This simulation was carried out with a comfort band of 14^{o}C-18^{o}C which is the temperature range to be maintained by a cold zone as derived from literature. m^2

4.6 Findings from Research Questions

i. What is the thermal condition of indoor fitness and sport centres in warm humid regions of Nigeria?

   Results from case studies show that the indoor fitness and sport centres have an average daily indoor air temperature of 29^{o}c and also a temperature difference of 2^{o}c to 3^{o}c across the four orientations.

ii. How can the principle of thermal zoning be applied in the design of a fitness and sport centre?

The principle of thermal zoning can be effectively applied in the design of indoor fitness and sport sports centres by first of all identifying spaces with similar air temperature requirements and grouping them together before laying out on plan. Each group should belong to different zones on the plan.

iii. What percentage of cooling energy can be saved from applying the principle of thermal zoning?

At the end of the research it was discovered that the cooling energy demand within indoor fitness and sports centres can be reduced by about 18% after applying the principle of thermal zoning.

5.0 SITE SELECTION AND PRELIMINARIES

This section discusses the preliminary design proposal and exceptional characteristics that form the bedrock for the proposed design. The design solution for the proposed design were based on similar case studies, space requirements, site location criteria, and schematic designs while applying the principle of thermal zoning which is aimed at minimizing cooling energy consumption in the entire design project.

5.1 Site Location

The indoor fitness and sport centre is to be located in Warri, Delta state, the southern part of Nigeria as shown in Figure 5.1. Its coordinates are approximately 5°30′N 6°.45′E/5.500°N 6°.30′E with a total area of 17,698 km^2 (6,833 sq. mi). Delta state lies in the warm humid region of Nigeria. The state is generally low-lying without remarkable hills and has a wide coastal belt inter-lace with rivulets and streams, which form part of the Niger Delta.

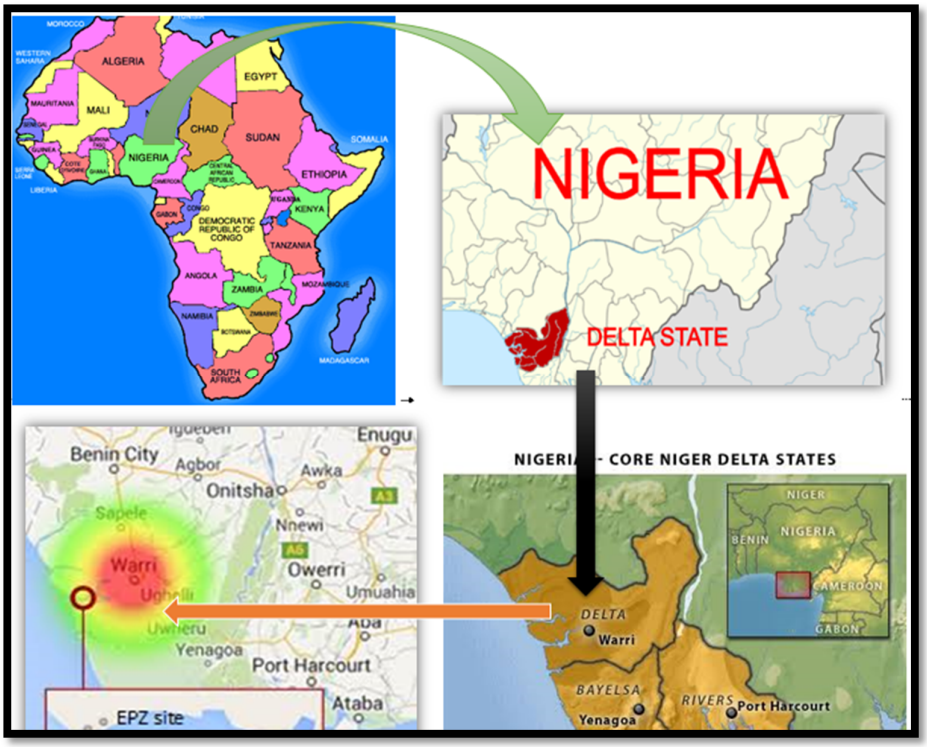


Figure 5.1. : Site location
Source: Field Work (2016)

5.2 Site Selection Criteria

Selection of the most suitable site is important to the development of sports establishments. Three different sites with suitable conditions at delta state are considered. The most suitable site is selected for the development of the proposed indoor fitness and sport centre based on the following criteria:

i. Accessibility- it should be easily accessible by both pedestrian and vehicular means

ii. Possibility of Future Expansion- it should have a large area of land for flexible design and possible future expansion

iii. Nearness to Attraction Centres- should be close to attraction centres like hotels, parks, to increase patronage.

iv. Land Use- site layout should comply with urban development authority

v. Availability of Services and Utilities- services like power lines, water supply, telecommunication networks, etc. should be available on or close to the site.

vi. Nearness to residential areas, schools- proposed site should be close to residential areas, schools for easy access.

vii. Availability of construction materials- site should be close to the sales of construction materials for easy transportation.

5.3 Site Selection

Three alternative sites were considered for the location of the centre. The three sites are as follows:

5.3.1 Site A

The site is located at Uti road near the Otokutu River in Uvwie local government warri south, Delta state. See Plate 5.1 below.



Plate 5.1. : Site A
Source: Google Earth, 2016

5.3.2 Site B

The site is located at the plantation estate about 5 to 10 minutes' drive from the Otokutu village, warri, Delta state. See Plate 5.2 below.



Plate 5.2: Site B
Source: Google Earth, 2016

5.3.3 Site C

The site is located in Okpaka town along D.S.C express way, close to steel village warri south, Delta state. See Plate 5.3 below.



Plate 5.3: Site C
Source: Google Earth, 2016

Table 5.1: Site assessment

Weighing scale: **Excellent5, Very good=4, Good=3, Fair=2, Poor=1, Very poor=0.**

S/N	CRITERION	SITE A	SITE B	SITE C	REMARKS
i.	Accessibility	3	2	5	All sites are accessible from major roads.
ii.	Possibility of Future Expansion	1	2	5	Site A and C have a larger land mass
iii.	Nearness to Attraction Centres	5	1	4	Site A is closest to the towns tourism site
iv.	Land Use	2	3	4	Site B and C are more compliant
v.	Availability of Services and Utilities	3	4	5	Presence of most services in site B and C
vi.	Nearness to residential areas, schools	5	5	5	All sites are close to residential areas but site A and C is closer to school environment
vii.	Availability of construction materials	3	2	5	Site C is closest to raw material market
	Total	**22**	**19**	**33**	

Source: Field Work (2016)

According to Table 5.1, site C being the site with most suitable features is therefore selected for the design of the proposed indoor fitness and sport centre

5.4 Site Analysis

This section covers the analyses of the climatic condition (Temperature, wind, Relative Humidity, precipitation, sunshine) as shown in figure 5.2. It also covers the topography, soil, vegetation, services and neighbouring structures as shown in figure 5.3.

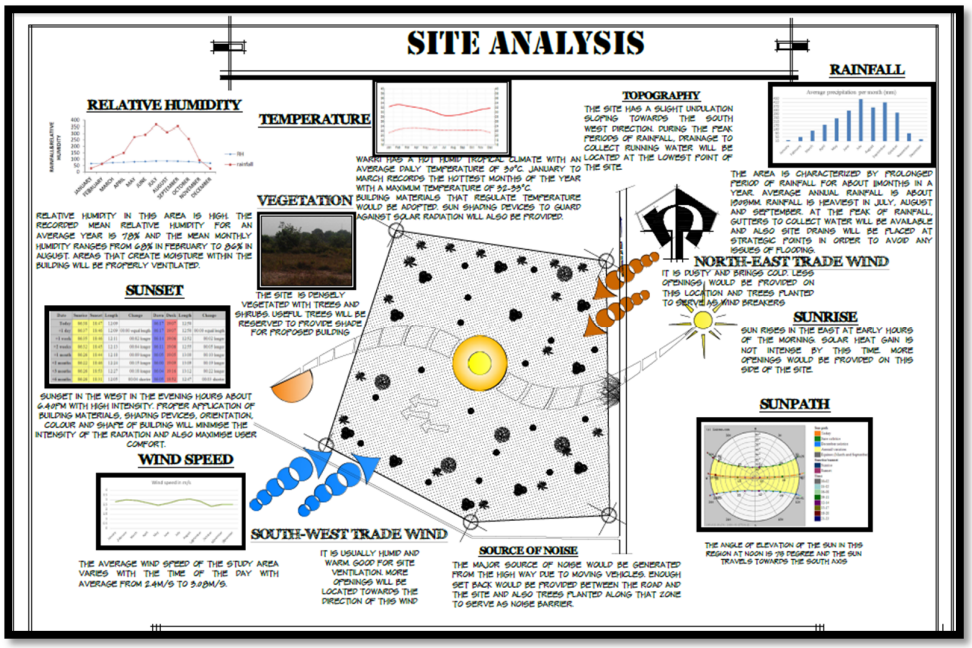


Figure 5.2: Climatic analysis the study area
Source: Field Work (2016)

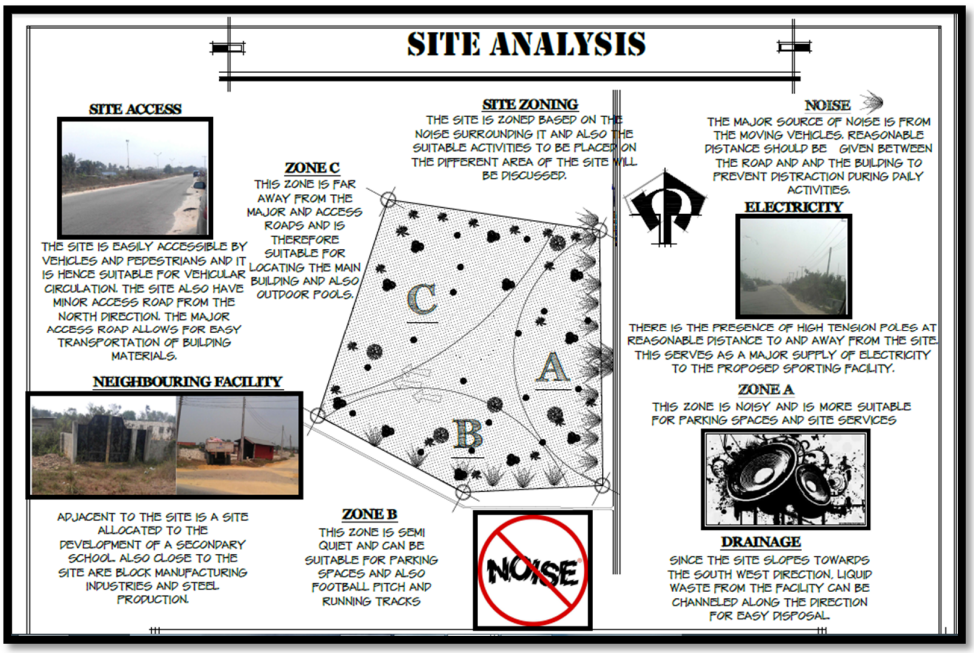


Figure 5.3: Site analysis (existing features)
Source: Field Work (2016)

5.4.1 Climate

Delta state is situated in the tropics and therefore experiences a fluctuating climate, ranging from the humid tropical in the south, to the sub humid in the northeast. The lessening of humidity towards the north is accompanied by increasingly marked dry season.

5.4.1.1 Temperature

Temperature increases from the south to the north. In Warri, which is located in the south, the average daily temperature is 30^{o}c as seen in Figure 5.4 below. February and March records the hottest moths of the year.

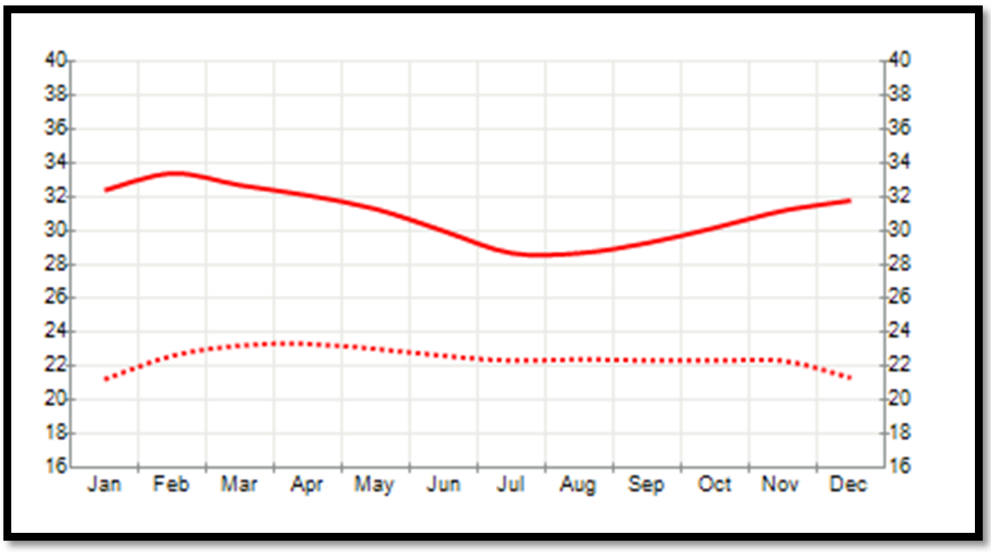


Figure 5.4. : Warmest and coldest temperature graph for Warri, Delta state
Source: www.gaisma.com

5.4.1.2 Wind

The average wind speed of the study area varies with the time of the day with average from 2.4m/s to 3.08m/s as seen in Figure 5.5. The region is characterised by strong South-West and weak North-East trade winds attributed to the displacement of inter-tropical convergence zone.

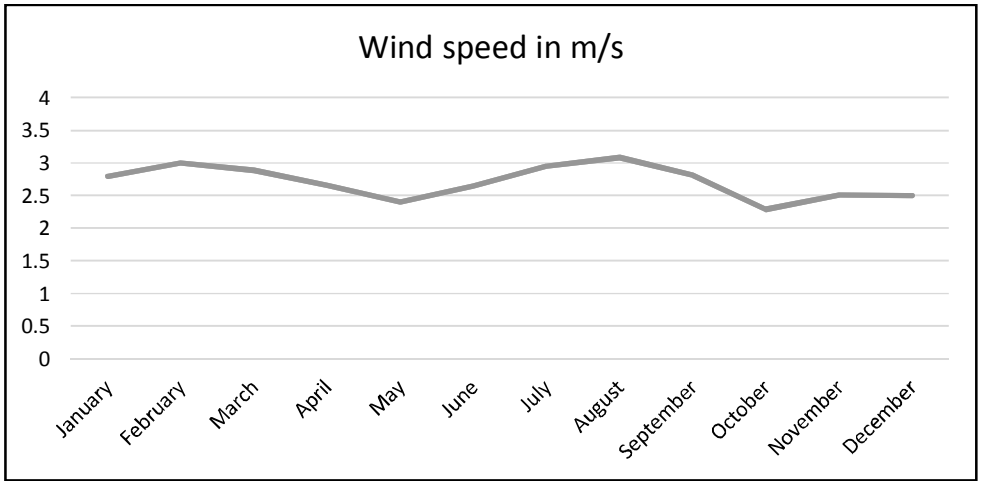


Figure 5.5. : Annual wind speed chart of Warri, Delta state
Source: www.gaisma.com

5.4.1.3 Relative Humidity

The study area is characterised by relatively high humidity. The recorded mean relative humidity for an average year is 78% and the mean monthly humidity ranges from 68% in February to 86% in August as shown in Figure 5.6.

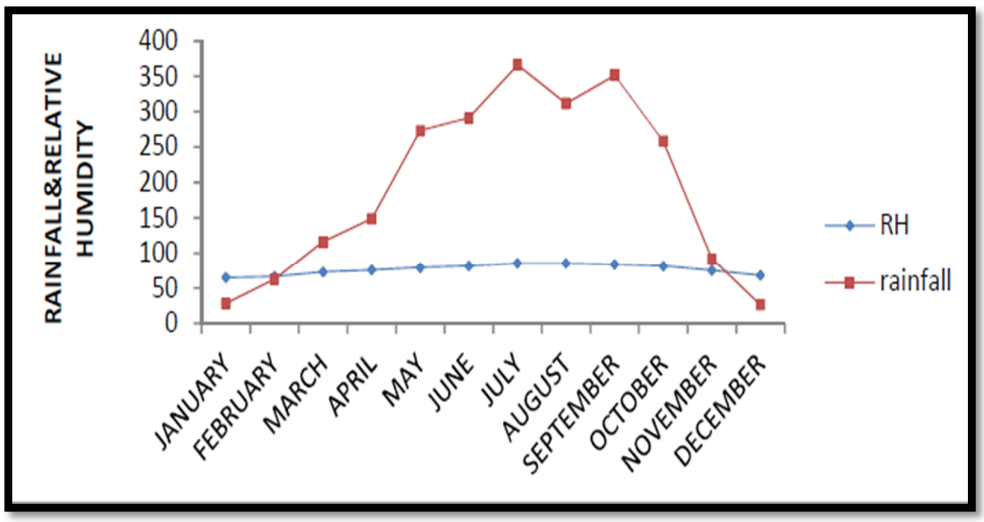


Figure 5.6. : Relative humidity chart for Warri, Delta state
Source: www.gaisma.com

5.4.1.4 Precipitation

The average rainfall is about 266.5mm in the coastal areas and 1905mm in the extreme north. Rainfall is heaviest in July, august and September. January and December are the month with the driest weather with no rainfall (harmattan).

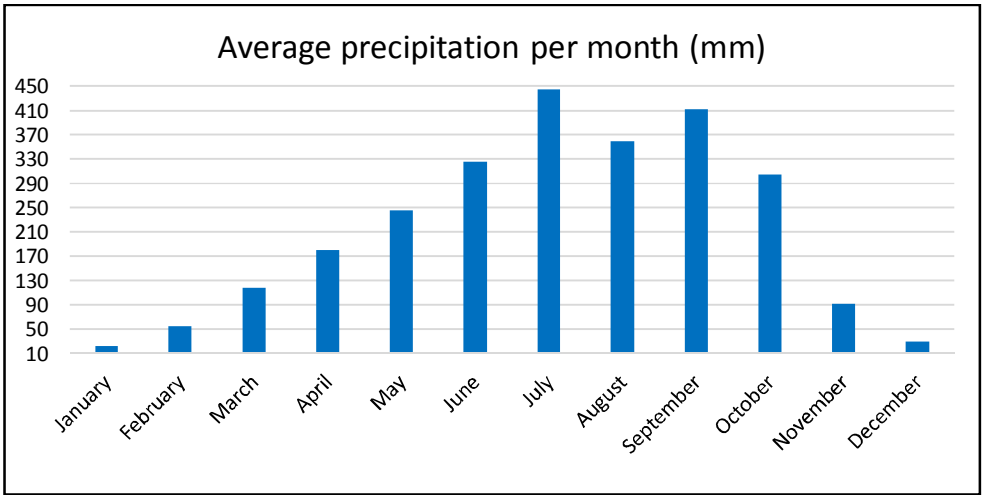


Figure 5.7. : Precipitation chart for Warri, Delta state
Source: www.gaisma.com

5.4.1.5 Sunshine and Radiation

From Figure 5.8 and 5.9, the hours of sunshine vary considerably with time of the year with estimated average of 6.5 hours per day in August (wet season) and 10 hours per day in November (dry season).

Date	Sunrise	Sunset	Length	Change	Dawn	Dusk	Length	Change
Today	06:38	18:47	12:09		06:17	19:07	12:50	
+1 day	06:37	18:46	12:09	00:00 equal length	06:17	19:07	12:50	00:00 equal length
+1 week	06:35	18:46	12:11	00:02 longer	06:14	19:06	12:52	00:02 longer
+2 weeks	06:32	18:45	12:13	00:04 longer	06:11	19:06	12:55	00:05 longer
+1 month	06:26	18:44	12:18	00:09 longer	06:05	19:05	13:00	00:10 longer
+2 months	06:22	18:46	12:24	00:15 longer	06:00	19:09	13:09	00:19 longer
+3 months	06:26	18:53	12:27	00:18 longer	06:04	19:16	13:12	00:22 longer
+6 months	06:26	18:31	12:05	00:04 shorter	06:05	18:52	12:47	00:03 shorter

Figure 5.8. : Sunrise, sunset, dawn and dusk times, table
Source: www.gaisma.com

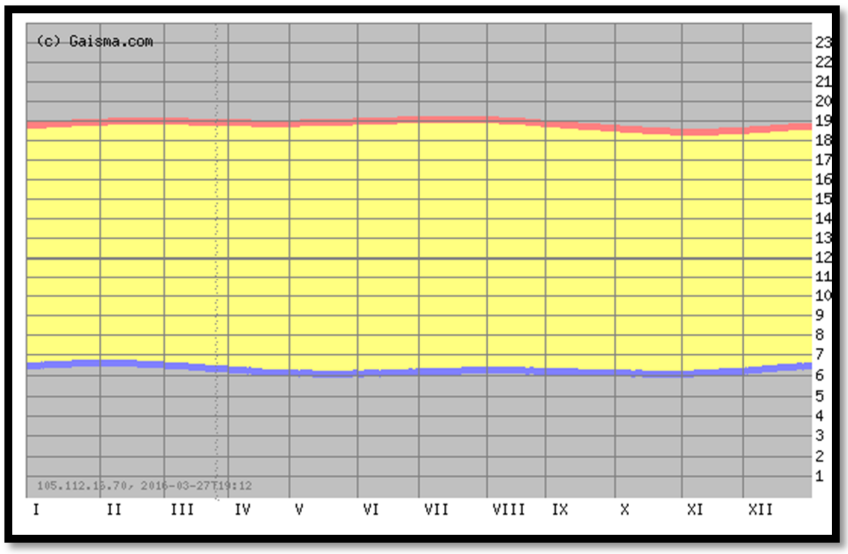


Figure 5.9. : Sunrise, sunset, dawn and dusk times, graph
Source: www.gaisma.com

5.4.1.6 Sun path

Figure 5.10 shows the sun path diagram of delta state. Right from June solstice to equinox. It also shows the time of sunrise and sunset at different times of the day.

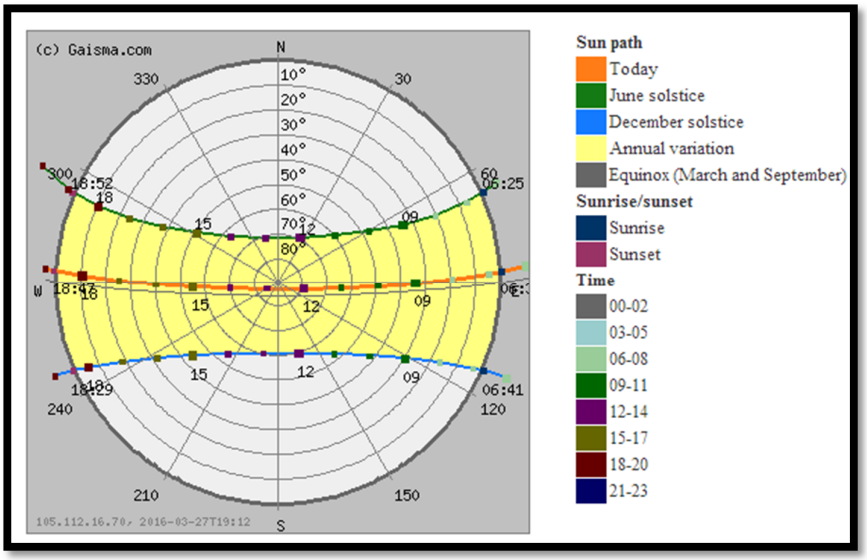


Figure 5.10. : Sun path diagram
Source: www.gaisma.com

5.4.2 Topography and soil

The topography of the site relatively flat and has a gentle slope towards the south-west of the site. Site drainage would take this direction in order to use the concept of natural

gravity. The soil is sandy which has an average bearing capacity but the hydrological and geological survey should be conducted to confirm the actual load bearing capacity of the site. See Plate 5.4.



Plate 5.4: Site topography and soil
Source: Field Work (2016)

5.4.3 Vegetation

The vegetation of the study area is rainforest which is floristically diverse and structurally complex with several layers of trees. The presence of trees on the site can serve as a means of shading and passive cooling. Also the site is widely covered with shrubs as seen in Plate 5.5.



Plate 5.5: Site Vegetation
Source: Field Work (2016)

5.4.4 Services

Services like electricity power lines, water supply lines, telephone services, well-constructed tarred roads and pedestrian paths, well designed drainages are all available on site (see plate 5.6). The site is accessed from the main D.S.C expressway. Also, high tension electrical cables can also be sited from the site.



Plate 5.6: Site services
Source: Field Work (2016)

5.4.5 Neighbouring Developments

The area has been developed by the State Government to support commercial activities, therefore most of the neighbouring developments are commercial. Adjacent to the site is a site allocated to the development of a secondary school as seen in Plate 5.7. Also close to the site are block manufacturing industries and steel production as seen in Pate 5.8.



Plate 5.7: Government Secondary school
Source: Field Work (2016)



Plate 5.8: Block industry
Source: Field Work (2016)

5.4.6 Source of Noise

The site is not located along the major road and therefor the possible source of noise is from moving vehicles along the road. Since the proposed design is a sporting facility, it can be located closer to the major road while the other facilities that require privacy be located at the other end of the site.

5.5 Design Brief

The Governor of Delta State has been working towards reviving sports at the basics (secondary, tertiary and community levels) in order to create a platform on which students and youths can compete for trophies and prizes so as to encourage an early appreciation for sports and instill a sense of sportsmanship and healthy competition in the state. The present administration stresses the importance of promoting sports by investing in the provision of quality fitness and sport facilities in various part of the state. The proposal is to design a thermally zoned indoor fitness and sport complex that will reflect the 21st century architectural trends and patterns. In the development of the design brief, the activity type is used as a guideline for the development and allocation of spaces required in the indoor fitness and sports complex with inspiration drawn from existing case studies and literature. Spaces are categorized based on the following headings (whole building design guide, 2014)

i. Administrative spaces
ii. Gymnasium
iii. Pool and enhanced spaces
iv. Fitness spaces
v. Support spaces
vi. Outdoor sport spaces
vii. Refreshment area

5.6 Schedule of Accommodation

Schedule of accommodation gives an approximate or precise number and size of spaces that will be required and the relationships between the spaces as shown in the table 5.2. Literature review and case study findings form the basis for an in depth analysis of detail schedule requirement of individual spaces critical to the design of an indoor fitness and sport complex.

Table 5.2a: Schedule of Accommodation

Gymnasium			
Functional space	**Room Area**	**No. required**	**Total Area**
Basketball	510sqm	2	1020sqm
Badminton	159sqm	6	960sqm
Handball	968sqm	1p	968sqm
Hockey	968sqm	1	968sqm
Volleyball	646sqm	1	646sqm
Lawn Tennis	162sqm	4	648sqm
Squash court	66sqm	2	132sqm
Changing Room/toilet	150sqm	4	600sqm
Store room	18sqm	3	54sqm
First aid	15sqm	3	45sqm
Instructors office	36sqm	3	108sqm
Retails shops	18sqm	2	36sqm
Spectators seating	0.7-1sqm/person	3000	3000sqm
Sauna/Spa Section			
Functional space	**Room Area**	**No. required**	**Total Area**
Reception	45sqm	2	90sqm
Changing room	24sqm	2	48sqm
Cleansing	15sqm	1	15sqm
Massage	180sqm	1	180sqm
Sauna	30sqm	2	60sqm

Table 5.2b: Schedule of Accommodation

Rest room	18sqm	2	36sqm
Plunge pool	30sqm	1	30sqm
Foot massage area	12sqm	1	12sqm
Hydrotherapy	100sqm	1	100sqm
Outdoor pool changing	50sqm	2	100sqm
Plant filters	28sqm	1	28sqm
Life guards	20sqm	1	20sqm
	Indoor Pool Area		
Ticket office	24sqm	1	24sqm
Instructors office	24sqm	1	24sqm
10 lane pool	1250sqm	1	1250sqm
Accessories room	24sqm	1	24sqm
Changing room/toilet	35sqm	2	70sqm
Spectators seating	0.7-1sqm/person	2000	2000sqm
First aid	15sqm	1	15sqm
Pump/battery room	45sqm	1	45sqm
Chlorine/filter plant	45sqm	1	45sqm
	Fitness Studios		
Functional space	**Room Area**	**No. required**	**Total Area**
Boxing	50sqm	1	50sqm
Martial art/taekwondo	440sqm	1	440sqm
Acrobatics	440sqm	1	440sqm
Fitness gym	250sqm	1	250sqm
Yoga class	150sqm	1	150sqm
Dance studio	250sqm	1	350sqm
Table tennis	250sqm	1	250sqm
Changing Room/toilet	35sqm	3	105sqm
Store room	18sqm	3	54sqm
First aid	15sqm	3	45sqm
Instructors office	36sqm	3	108sqm

Table 5.2c: Schedule of Accommodation

Restaurant			
Servery	25sqm	1	25sqm
Kitchen	48sqm	1	48sqm
Bar	80sqm	1	80sqm
Lounge	180sqm	1	180sqm
Toilet	18sqm	2	36sqm
Cloak room	18sqm	1	18sqm
Administrative Spaces			
Reception	48sqm	1	48sqm
Sports program manager	36sqm	1	36sqm
Operations manager	36sqm	1	36sqm
Secretary's office	36sqm	1	36sqm
General office	72sqm	1	72sqm
Booking office	36sqm	1	36sqm
Conference Room	72sqm	1	72sqm
General supervisor	36sqm	1	36sqm
Personnel office	36sqm	1	36sqm
Toilet	5sqm	2	10sqm
Sick bay			
Waiting	24sqm	1	34sqm
Consultancy	24sqm	1	34sqm
Resting room	36sqm	1	36sqm
Toilet	14sqm	2	28sqm
Crèche			
Play area	150sqm	1	150sqm
Bedroom	45sqm	1	45sqm
Changing room	20sqm	1	20sqm
Toilet	15sqm	1	15sqm
Accommodation			
Reception	48sqm	1	48sqm
Single room	30sqm	32	960sqm
Double room	45sqm	16	720sqm
Kitchen	25sqm	1	25sqm
Laundry	30sqm	1	30sqm

5.7 Functional Flow

A functional flow chart is a diagrammatic representation that illustrates the relationship between spaces in the early stage. A functional flow within a fitness and sport centre shows the relationship between sport facilities and other areas like circulation, reception, services, changing, and offices (see Figure 5.11).

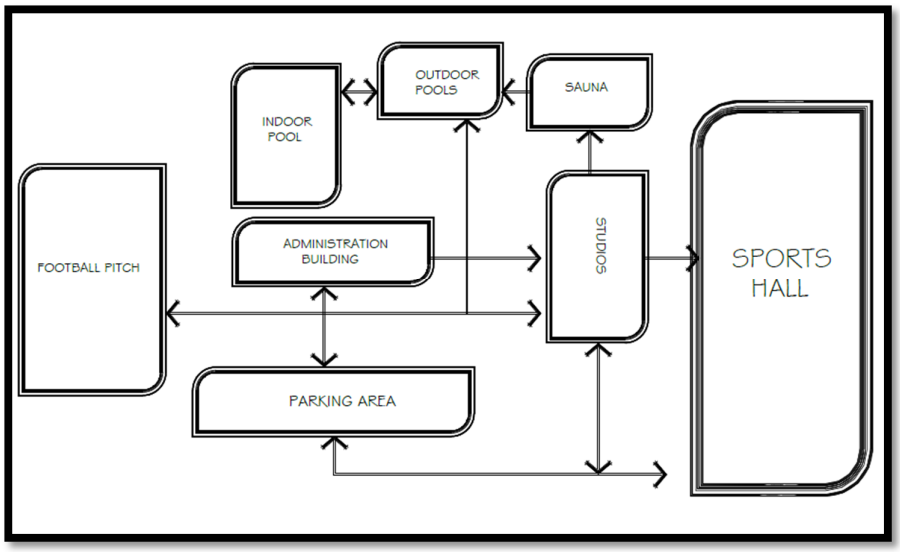


Figure 5.11: Site Flow Chart
Source: Design Proposal (2016)

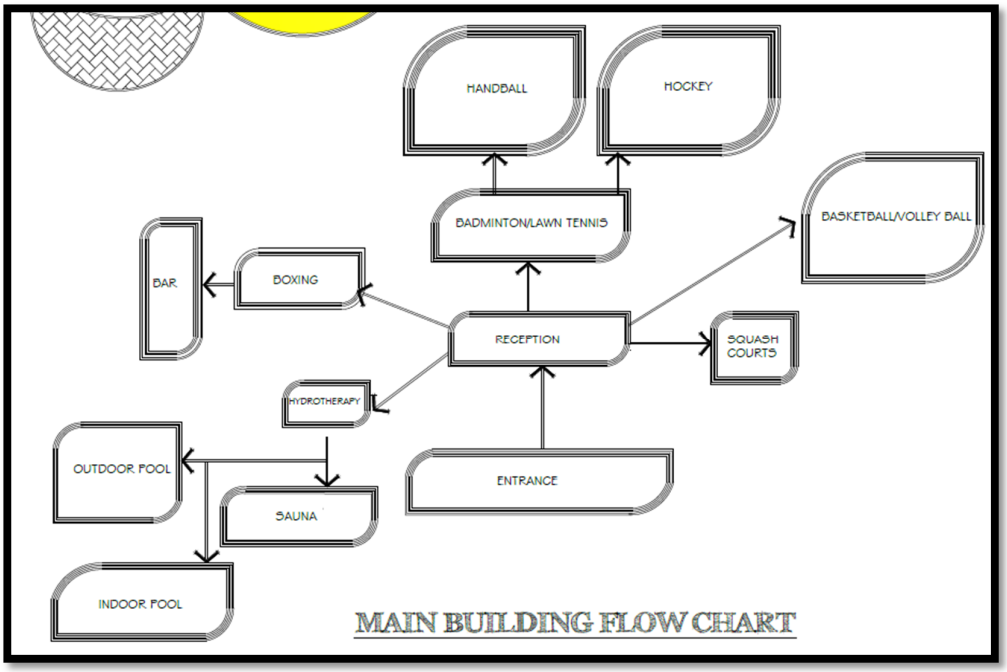


Figure 5.12: Main Building Flow chart
Source: Design Proposal (2016)

6.0 DESIGN REPORT

6.1 Introduction

This chapter presents the architectural design of the proposed indoor fitness and sport complex in Warri, Delta State, and the application of thermal zoning principle in the proposed design. The thermal zoning strategies adopted for this design are zoning based on different spatial activities and zoning based on different solar gains while the independent variables considered for the design are categorized under the following headings: natural ventilation, shading techniques, building materials, landscape features.

6.2 Zoning based on different Spatial Activities

The various spaces are grouped together based on their use as seen in Figure 6.1. That is to say the spaces which share common facilities and same use are grouped together and also strategically linked to other spaces. The building is divided into five sections: administrative unit, dry sport area (gymnasium), wet sport area (spa and pool), fitness studios (weightlifting, dance studio, acrobatics) and sickbay. The activities which have the largest number of spectators are all spread on the ground floor while the central core of the building goes up to four floors with the upper most floor containing the restaurant and lounge. Also activities that produce a lot of vibration are also limited to the ground and first floor. The different activities all have easy and visible assess from every point and as such makes it easier for people to move around and locate other activities.

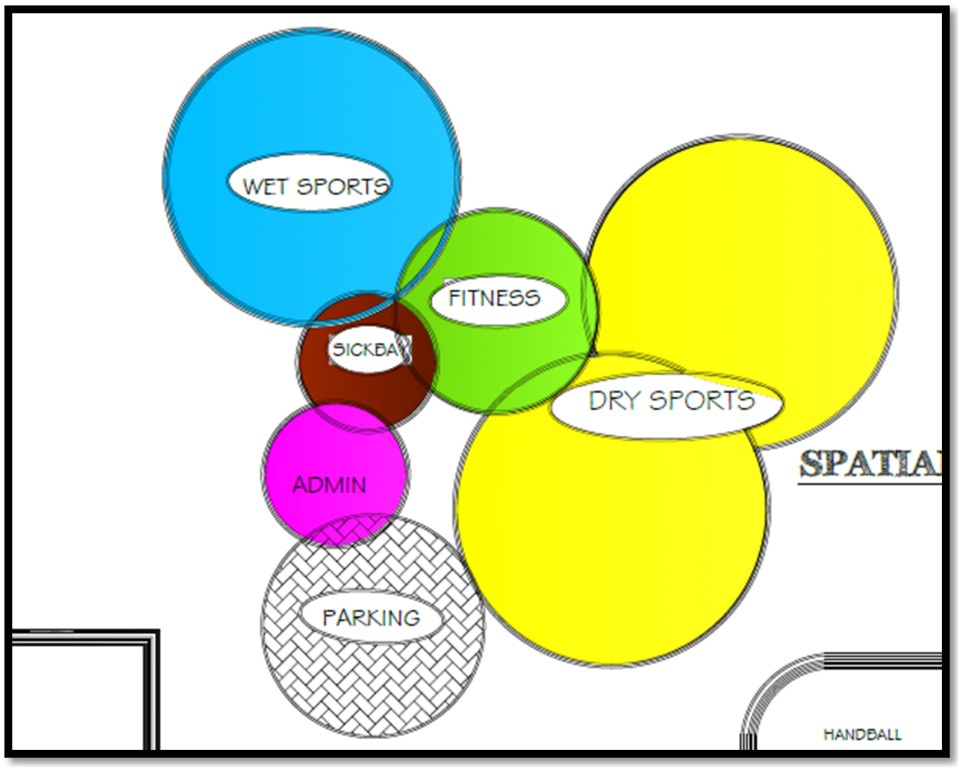


Figure 6.1: Zoning based on spatial activities
Source: Design Proposal (2016)

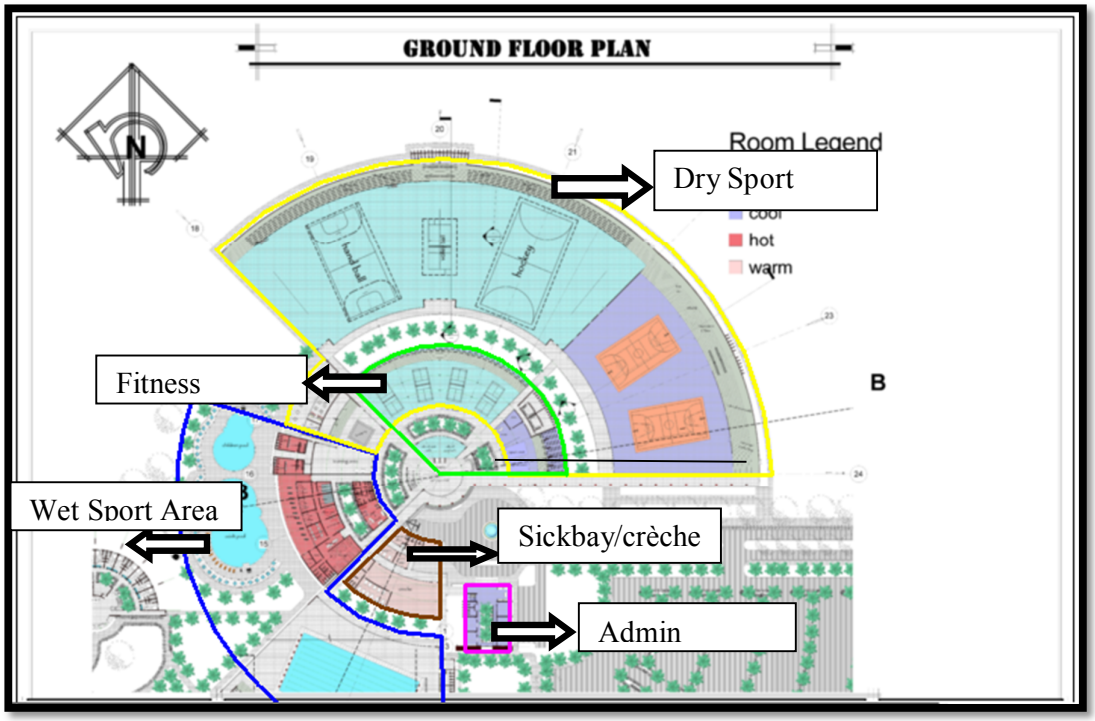


Figure 6.2: Ground floor plan showing the different spatial activities
Source: Design Proposal (2016)

6.3 Zoning based on different Solar Gains

From the research, it has been established that the different spaces within an indoor fitness and sport complex all fall within the different orientations investigated based on their temperature requirements and as such a framework has been derived for the design as shown in Figure 6.3.

	FUNCTIONAL SPACE	RECOMMENDED TEMPERATURE (°C)	ZONE	LOCATION ON PLAN
1.	Sport halls	12-18	Cold/Cool	North/North east
2.	Weight lifting	14-16	Cold	North
3.	Fitness Gym	16-18	Cold	North
4.	Squash courts	16-18	Cold/Cool	North/North east
5.	Martial Arts	18	Cold/Cool	North/North east
6.	Dance Studios	18	Cold/Cool	North/North east
7.	Yoga	18	Cold/Cool	North/North east
8.	Ancillary halls	18-21	Cool	North East
9.	Offices	20	Cool	North East
10.	Restaurant/ bar	20	Cool	North East
11.	Creche	21-23	Warm	South/ S.East
12.	Changing rooms	20-25	Warm	South/ S.East
13.	Indoor Pools	25-29	Warm/Hot	South/ S.East
14.	Spa/Sauna	40	Hot	West/ S.West
15.	Physical/Hydrotherapy	32-40	Hot	West/ S.West
16.	Massage	32-40	Hot	West/ S.West
	SOURCES	Carbon Trust 2006	Marshall, G. 2012	Almusaed et al. 2006

Figure 6.3: Design framework as derived from literature and case study
Source: Design Proposal (2016)

From Figure 6.3 above, it is seen that the various spaces within the indoor fitness and sport complex have been classified into different zone and orientation based on their thermal requirements. While the dry sport halls and other fitness studios occupy the

cold and cool zone on the North and North east orientation, the spa and pool area occupies the hot and warm zones on the west, south, south west and south east orientation as seen in Figure 6.4.

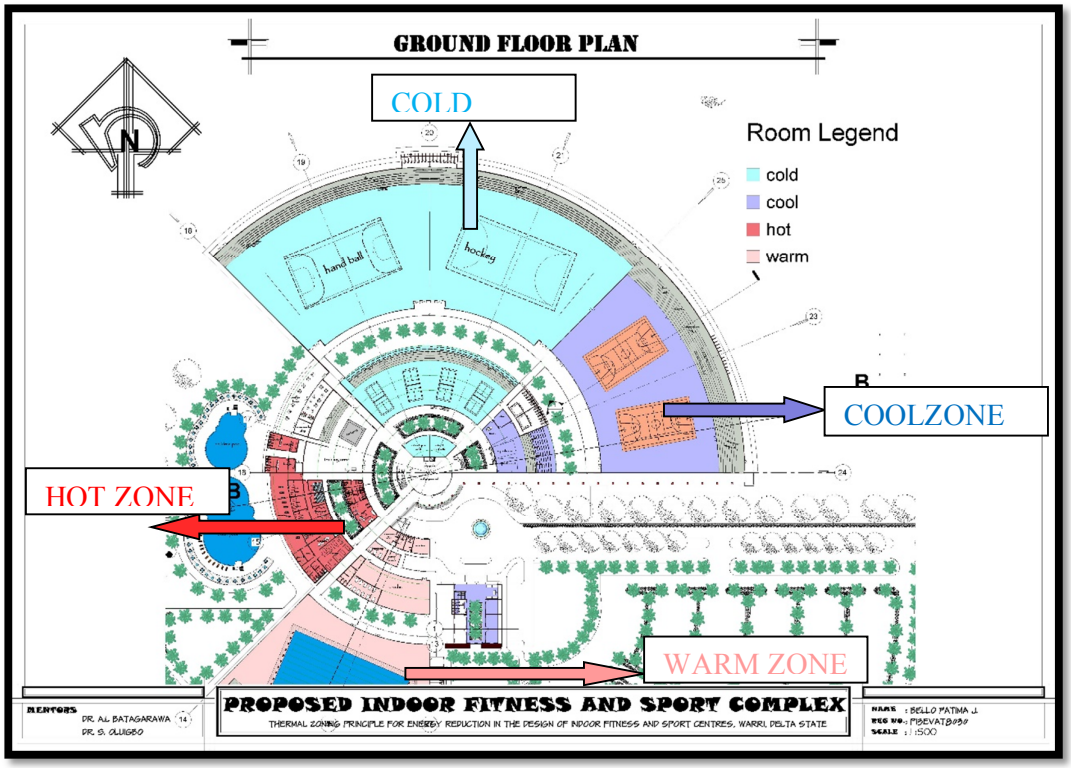


Figure 6.4: Ground floor plan showing the different zones within the building
Source: Design Proposal (2016)

6.4 Natural Ventilation

From Figure 6.5 below, the method of ventilation used in this building is a cross ventilation and also stack ventilation in some areas. This ventilation technique has been found to be effective in this type of building structure since it has a large floor area and volume. Thus artificial ventilation and lighting is optional except in areas where entire cross ventilation could not be achieved. Operable and glass windows are designed along with the curtain wall system for air circulation. The windows are designed with a small sensor on the window frame which turns off the mechanical system when the windows are open. There is also the presence of courtyards at relevant

points within the building to enhance natural ventilation. The essence of this natural ventilation system is to reduce the amount of cooling energy consumed in the building.

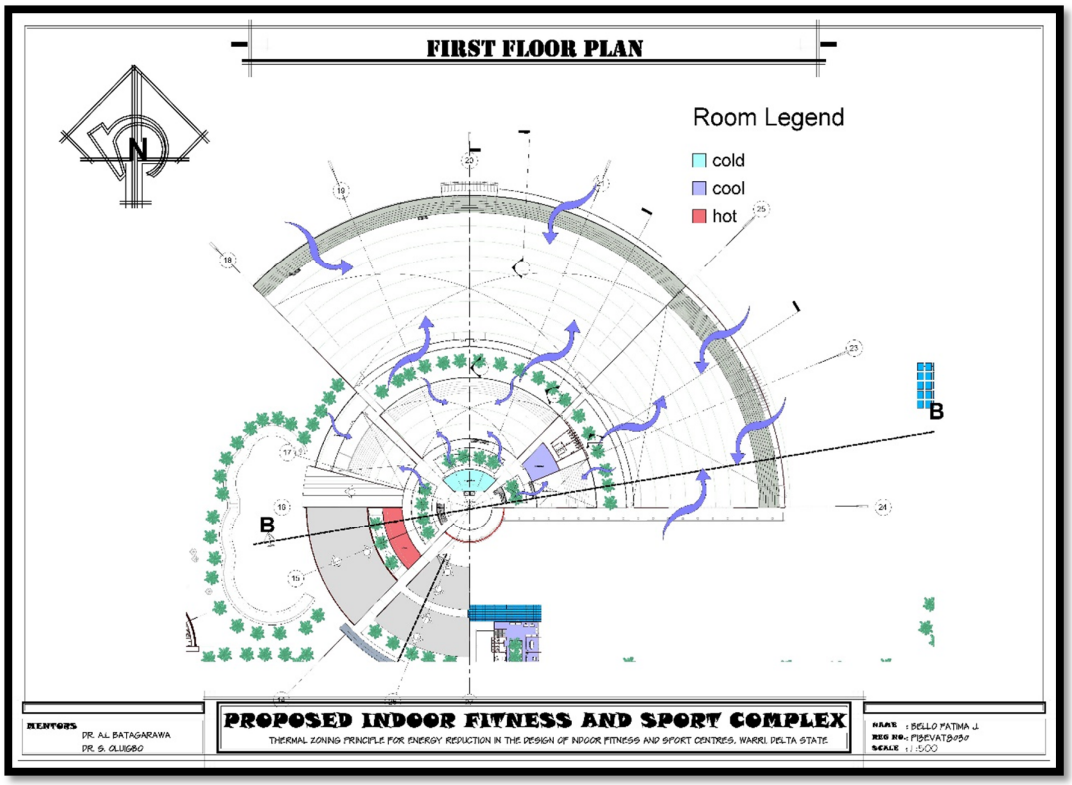


Figure 6.5: First floor plan showing ventilation across the spaces
Source: Design Proposal (2016)

6.5 Shading Technique

The various spaces around the building are shaded in different ways; through the use of covered walkways to create double skin, horizontal and vertical shading device, screen wall in form of organic wall, roof overhang and the use of trees. Total amount of direct solar radiation is reduced through the application of the different shading techniques. Though the west facades are exempted from excess shading since the activities around it are specifically zoned for that area. See Figures 6.6 and 6.7.

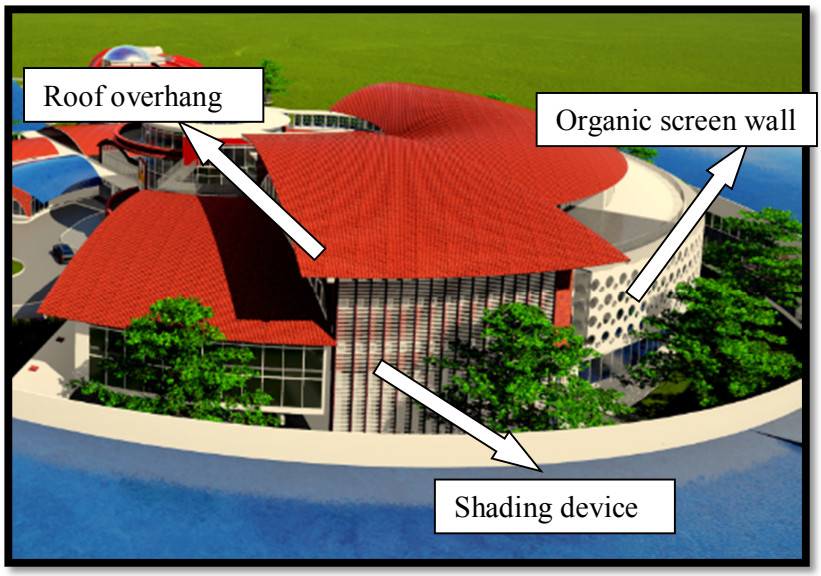


Figure 6.6: The different shading techniques on the buildings perspective
Source: Design Proposal (2016)

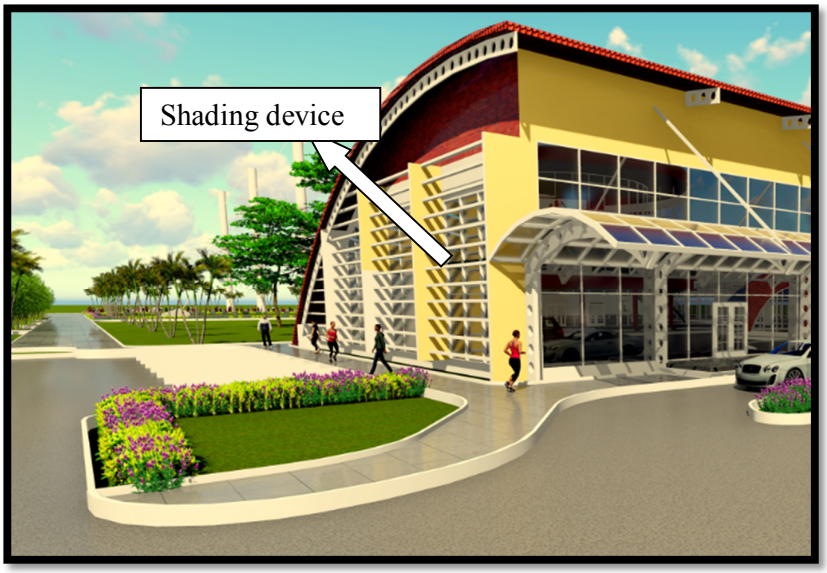


Figure 6.7: Horizontal shading device on the eastern façade of the Admin building
Source: Design Proposal (2016)

6.6 Building Materials

A structural grid framework of construction is adopted. Appropriate techniques are applied to the external envelope and its openings to protect the building from elements of weather primarily by shading but also by the appropriate treatment of the building envelope (i.e. use of reflective colours and surfaces). Concrete and steel is used as the major structural materials. Concrete has structural integrity and fluidity while the steel

serve as reinforcing element and roof members due to its rigidity and strength. The concrete used has 20% fly ash, the structural steel contain 80-100% recycled content, wood panelling would be supplied from sustainably harvested forests and local materials were specified to come from within a 100km radius of the site. Efficient glazing strategies are employed in the building; highly reflective plastic (Teflon) and low emissivity glazing. The Teflon reflects solar radiation and enhances daylighting and it is applied in spaces with large floor area such as the sport halls (dry and wet). The low-E glass is mainly applied on the southern and eastern facades of the proposed indoor fitness and sport complex to help reduce the inferred heat transference from the sun's rays. See Figures 6.8, 6.9 and 6.10.

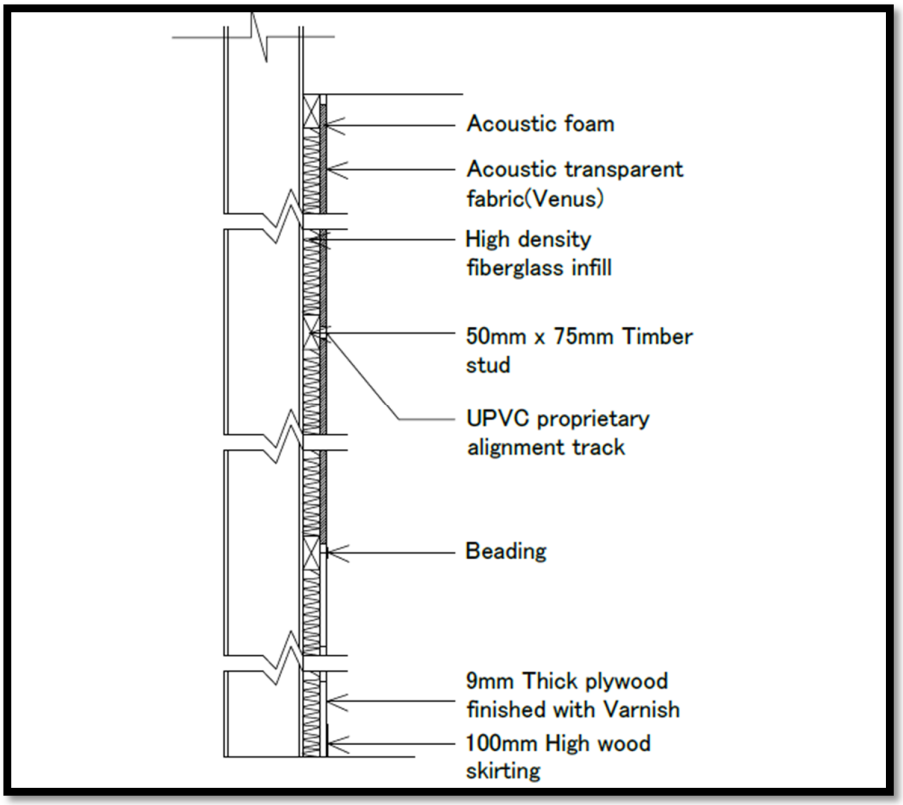


Figure 6.8: Wall detail showing interior wall paneling
Source: Design Proposal (2016)

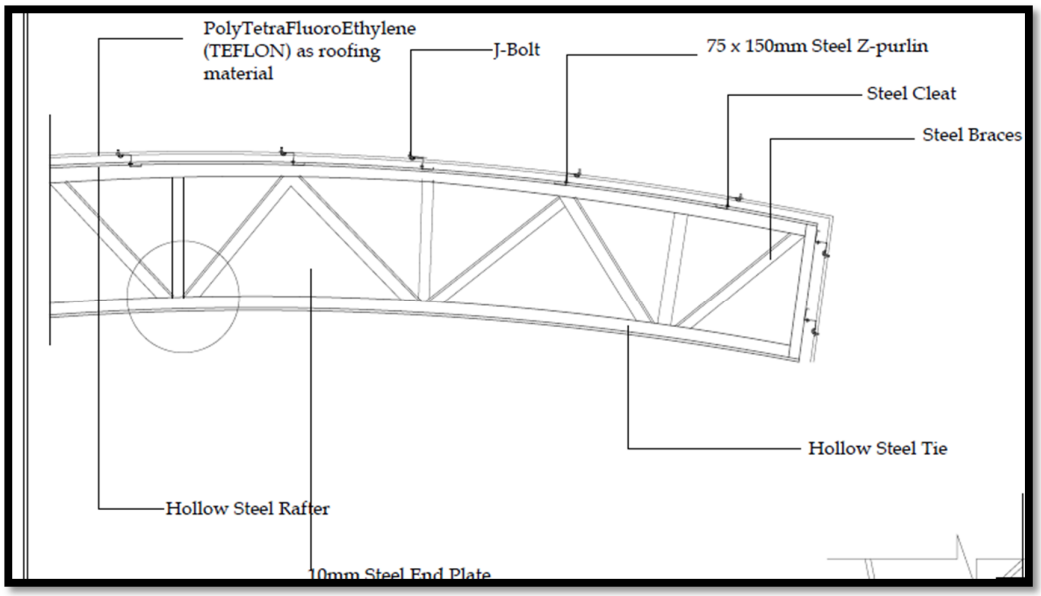


Figure 6.9: Roof detail showing Lattice steel section
Source: Design Proposal (2016)

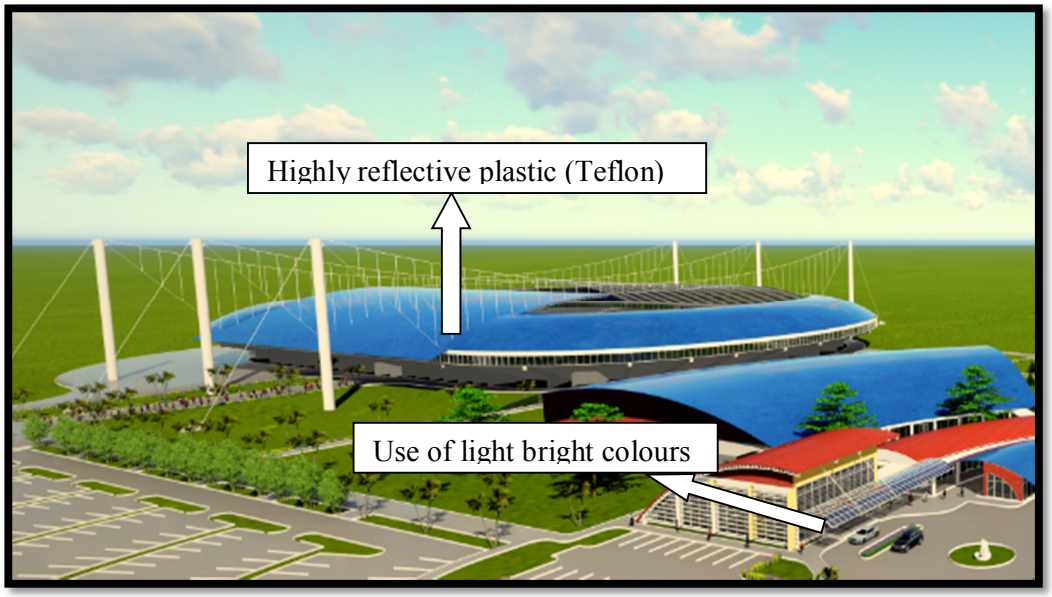


Figure 6.10: Perspective of building showing building materials
Source: Design Proposal (2016)

6.7 Landscape Features

The fitness and sport complex has a large site area which is well landscaped with green areas, green courtyard, green roofs, large trees and shrubs for shading and reducing heat gain as seen in Figures 6.11, 6.12, 6.13 and 6.14. The court yards are properly landscaped with shrubs and trees (Moringa Oleifera) to help absorb and filter radiation

through photosynthesis, provides shade and as a result cools the spaces surrounding it. The leaves at the bottom receive less radiation and are much cooler and hence radiate less heat. The tree also allows air to rise through the leaves to the top of the tree, thereby preventing hot air from being trapped under the treeThe parking areas are also shades with trees to improve the microclimate for thermal comfort.

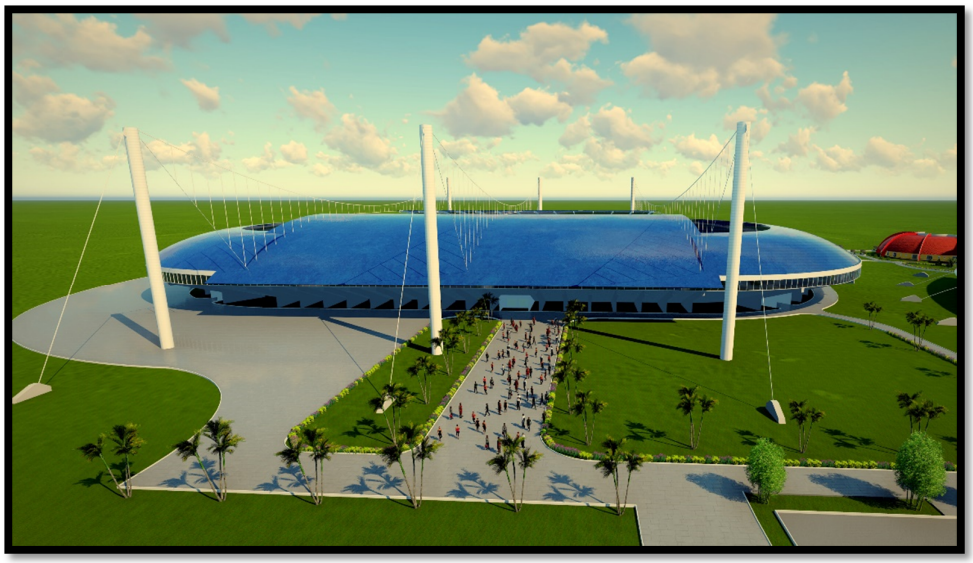


Figure 6.11: Landscaped area surrounding the proposed football stadium
Source: Design Proposal (2016)



Figure 6.12: Façade of main building showing landscape features
Source: Design Proposal (2016)

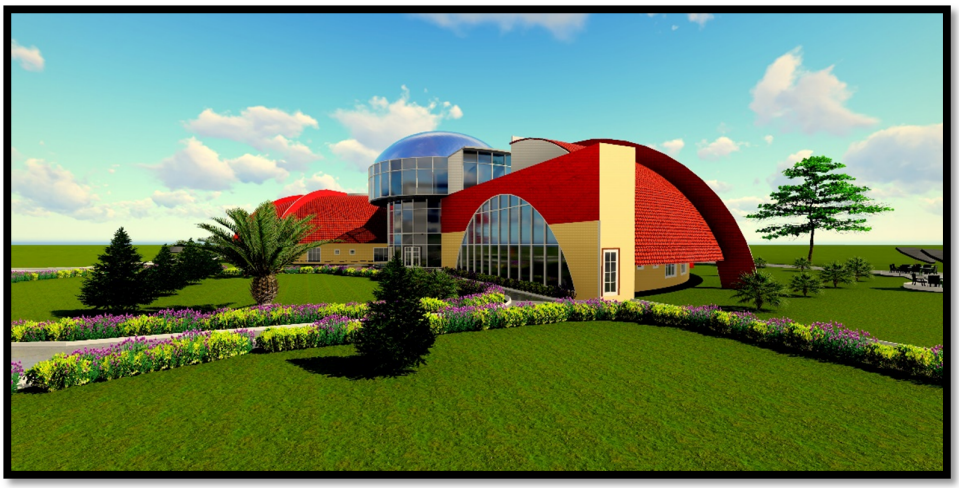


Figure 6.13: Façade of the proposed accommodation for the complex
Source: Design Proposal (2016)

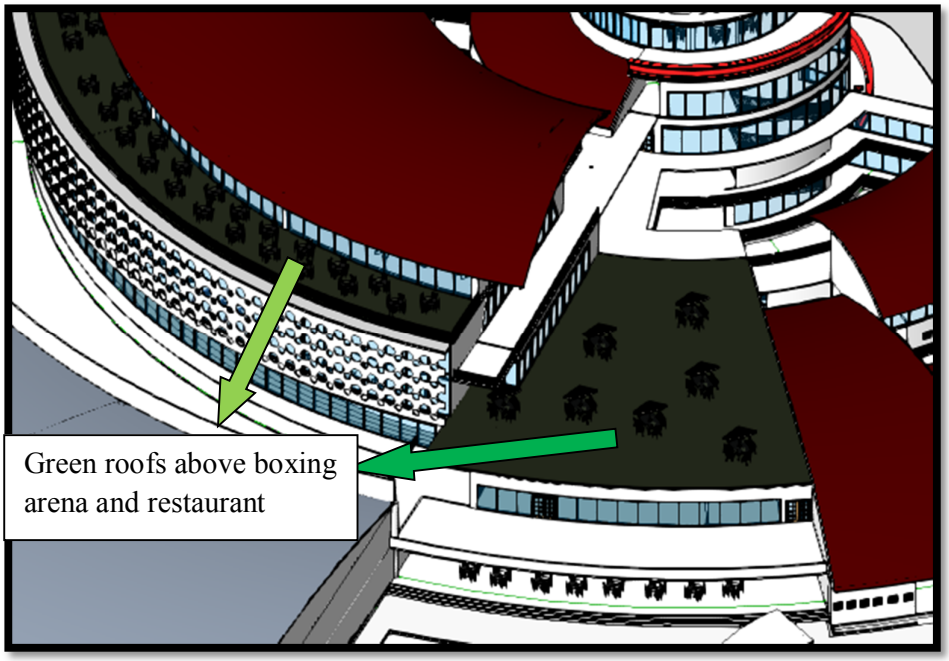


Figure 6.14: Roof Gardens on upper floors to cool spaces below
Source: Design Proposal (2016)

6.8 Computer Simulation Assessment for the Proposed Indoor Fitness and Sport Complex

At the end of the design, a computer simulation is conducted to investigate the thermal condition and cooling energy savings in the proposed indoor fitness and sport complex using Autodesk Ecotect simulation software. A comparison of thermal condition (internal air temperature) and cooling energy demand between the case study and the

proposed design are derived. Due to the complexity of the proposed design model, only spaces which are common between the three cases studied and the proposed design are compared. The case studies are going to be referred to as the base case.

6.8.1 Comparing Indoor Temperature between the Base case and Proposed Design

A comparison between the results predicted for the base case (case studies) and the proposed indoor fitness and sport complex design is shown in table 6.2 and Figure 6.16 respectively. All conditions for simulating the proposed design are same with base case conditions except for building materials (colours, walls and roof)

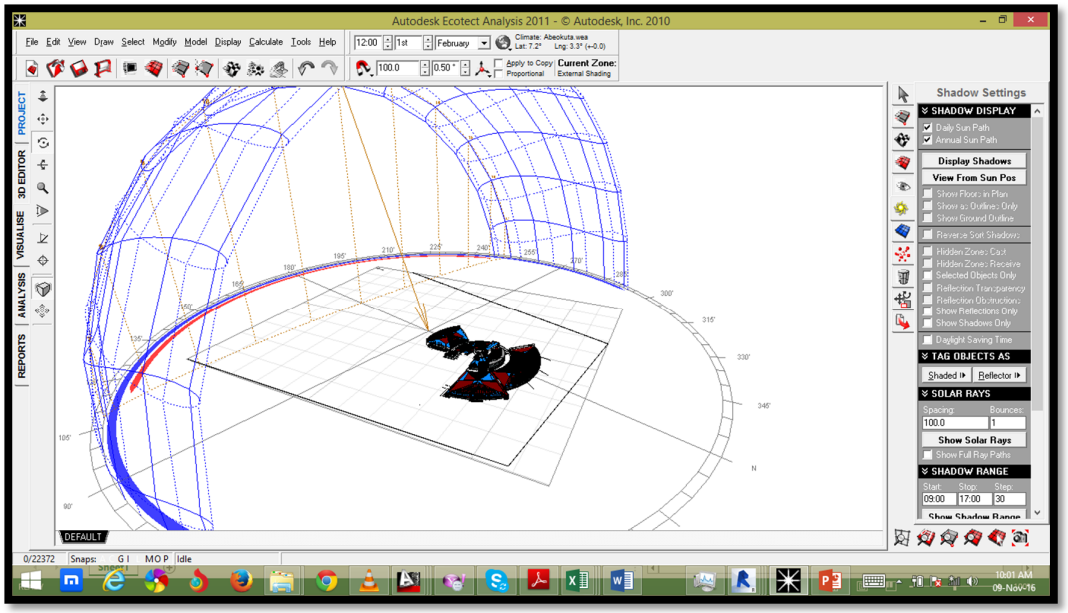


Figure 6.15: Simulation interface of proposed design
Source: Autodesk Ecotect Analysis

Table 6.1 below shows the selected spaces between the base case and the proposed design and also their location (orientation) on the floor plans.

Table 6.1: Orientation of spaces between base case and proposed design

S/N	COMMON SPACE	LOCATION (ORIENTATION) ON PLAN			
		CASE I	CASE II	CASE III	PROPOSED DESIGN
1	Sport hall	Centre	Centre	_	North
2	Sport hall	_	_	_	North east
3	Board games	West	West	Buffer	North east
4	Board games	_	North	_	North east
5	Fitness gym	_	_	South	North
6	Spa	_	_	South	West
7	Office	North	North	North	North
8	Office	South	West	_	North east

Source: Design Proposal (2016)

At the end of the simulation, the predicted indoor air temperature of selected spaces of the base case and proposed design is shown in table 6.2

Table 6.2: Predicted indoor air temperature between base case and proposed design

S/N	COMMON SPACE	PREDICTED INDOOR TEMPERATURE (^{0}C)			
		CASE I	CASE II	CASE III	PROPOSED DESIGN
1	Sport hall	27.24	28.51	_	25.02
2	Sport hall	_	_	_	24.07
3	Board games	27.43	28.11	Buffer	25
4	Board games	_	28.05	_	25
5	Fitness gym	_	_	24.55	23.05
6	Spa	_	_	28.7	31.61
7	Office	25.98	25.13	25.04	24.08
8	Office	27.12	27.60	_	25.38

Source: Autodesk Ecotect Analysis

From table 6.2 above, the application of the principle of thermal zoning has an effect on the internal air temperature of spaces. There is at least an average temperature reduction of about 3^0c across all spaces while there is a temperature increase of about 3^0c in the spa area, this is beneficial because spas generally require high temperatures.

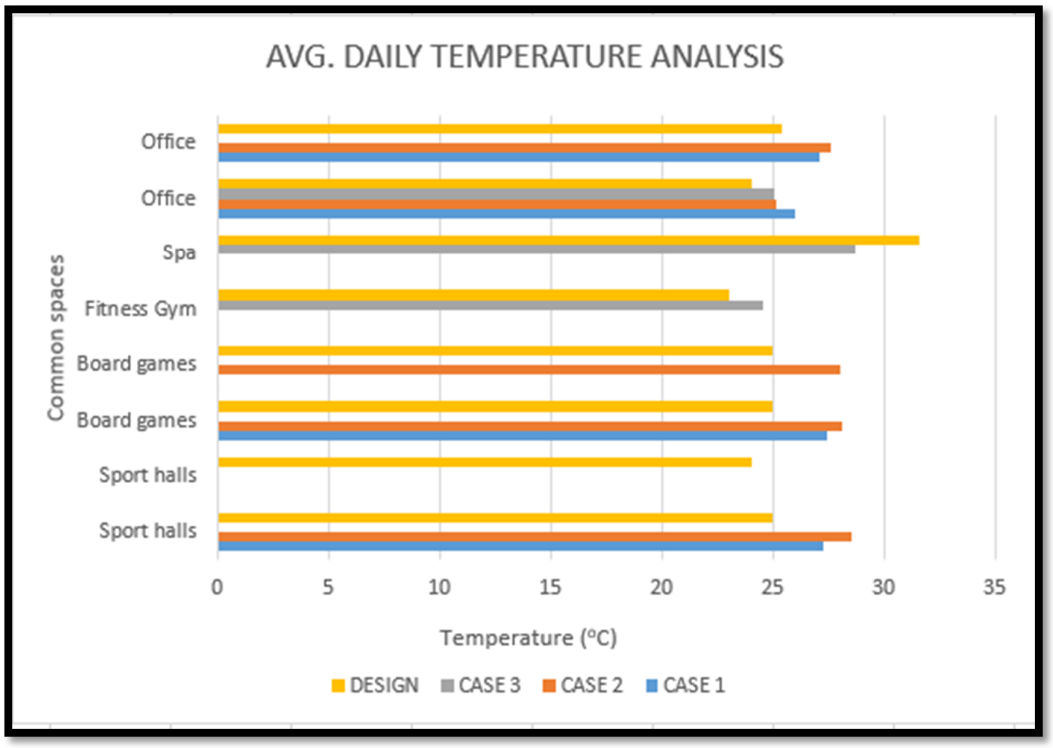


Figure 6.16: Indoor air temperature comparison
Source: Autodesk Ecotect Analysis

6.8.2 Comparing Cooling Energy Demand between the Base case and Proposed Design

A comparison between the results predicted for the base case (case studies) and the proposed indoor fitness and sport complex design is shown in figure 6.17 and 6.18 respectively. All conditions for simulating the proposed design are same with base case conditions except for building materials (colours, walls and roof). From figure 6.17, it is seen that there can be a total energy savings of about 18% by adopting the thermal zoning strategies in the proposed design as compared to the base cases. Just by placing

the sport halls on the north and north east orientation, there can be a savings of 19-25% cooling energy.

S/N	COMMON SPACE	THERMOSTAT RANGE	COOLING DEMAND				% SAVINGS
			CASE I	CASE II	CASE III	PROPOSED DESIGN	
1.	Sport Hall	14-18°C	812.27Kwh/m^2 Sqm= 362.3m^2	942.76Kwh/m^2 Sqm= 588.2m^2	___	706.32Kwh/m^2 Sqm= 362.3m^2	19.61%
2.	Sport Hall	23-27°C	___	___	___	665.27Kwh/m^2 Sqm= 362.3m^2	25.76%
3.	Board Games	23-27°C	367.21Kwh/m^2 Sqm= 20m^2	386.27Kwh/m^2 Sqm= 24m^2	___	339.27Kwh/m^2 Sqm= 355m^2	10.23%
4.	Board Games	23-27°C	___	346.27Kwh/m^2 Sqm= 24m^2	___	___	10.47%
5.	Fitness gym	14-18°C	___	___	247.27Kwh/m^2 Sqm= 36m^2	232.27Kwh/m^2 Sqm= 600m^2	7.07%
6.	Spa	28-40°C	___	___	1.854Kwh/m^2 Sqm= 29m^2	1.321 Kwh/m^2 Sqm= 29m^2	28.75%
7.	Office	23-27°C	167.71Kwh/m^2 Sqm= 12m^2	196.76Kwh/m^2 Sqm= 25m^2	143.37Kwh/m^2 Sqm= 18m^2	138.37Kwh/m^2 Sqm= 106m^2	16.88%
8.	Office	23-27°C	190.23Kwh/m^2 Sqm= 12m^2	221.22Kwh/m^2 Sqm= 25m^2	___	177.37Kwh/m^2 Sqm= 18m^2	13.20%

Figure 6.17: Cooling energy demand of selected spaces between base case and proposed design
Source: Autodesk Ecotect Analysis

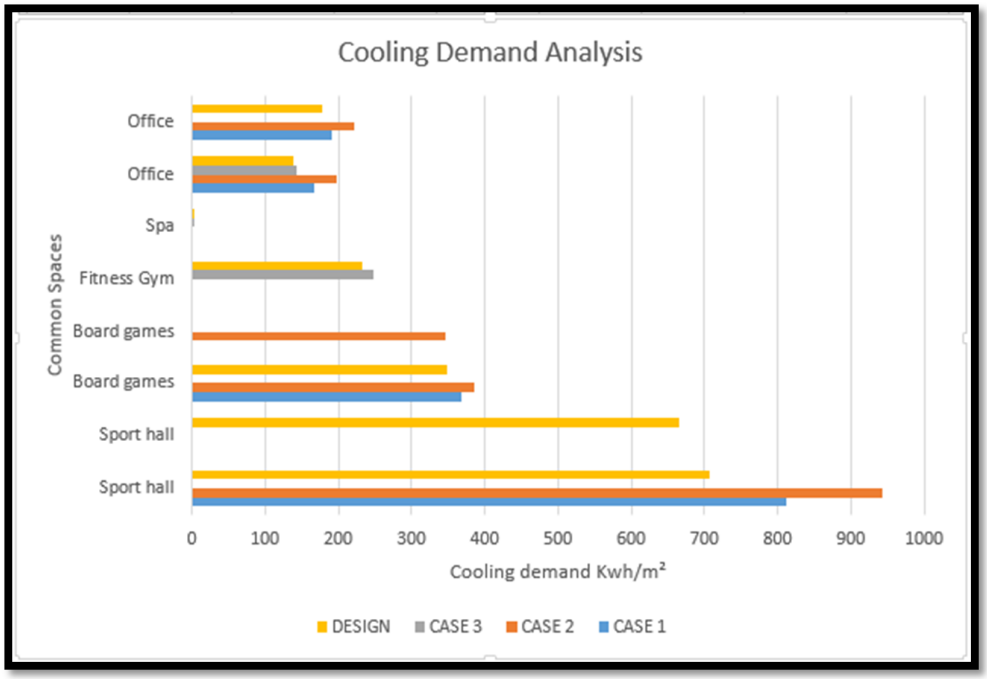


Figure 6.18: Graphical representation of cooling energy demand
Source: Autodesk Ecotect Analysis

7.0 CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

From the research carried out, majority of the fitness and sport complexes in warm humid region of Nigeria generate their energy privately to sufficiently cater for the energy demands of the users and this is mainly due to the electricity shortage in Nigeria. This resulted in the corresponding increase in the cost of running and operating the fitness and sport complexes. This high cost is associated more with the provision of cooling and ventilation due to the unbearable heat discomfort experienced in the complexes. This research aims to evaluate the effect of thermal zoning on cooling energy consumption in the design of an indoor fitness and sport complex, warri, Delta state. Thermal zoning principle is not widely applied in fitness and sport centre designs in Nigeria as seen in the cases studied in chapter 4. The efficiency of thermal zoning principle is justified by computer simulation results. The simulation analyzed the three cases studied and the proposed design using Autodesk Ecotect analysis software and the result indicates that there can be a temperature reduction of about 4^0c across all orientations by incorporating the various independent variables to the design and also there can be a cooling energy demand savings of about 18% by applying one or more of the thermal zoning strategies in a design.

The design establishes that the over dependence on non-renewable energy sources can be reduced and there are possibilities that in the near future, thermal zoning principle can be an alternative solution to architectural developments in developing countries like Nigeria.

7.2 Recommendations

The outcome of this research has outlined the benefits of the application of thermal zoning principle on cooling energy reduction in the design of indoor fitness and sport complex in the warm humid region of Nigeria such as Delta state. However, findings from the research recommends the following;

i. It is important to incorporate the principle of thermal zoning and its strategies at the early stages of designs in order to achieve energy efficiency and sustainable designs for thermal comfort of the target occupants.

ii. With the recent awareness about the future climate, thermal zoning design strategies and new sustainable methods will be more important for the future climate. Therefore, building professionals should work together in an integrated approach focusing on how to improve the energy performance of buildings; introducing new environmental and thermal zoning policies and encourage the development of more efficient, integrated and accessible simulation techniques for predicting and improving the future environment.

iii. Exploration of more court yard options to provide proper air circulation within interior spaces.

iv. It is important to know the temperature requirements of various spaces to help plan effectively for them.

v. In addition to thermally zoning spaces, the indoor air temperature of sport complexes can be improved by other measures such as efficient building materials, effective shading design, proper landscaping, etc. in order to reduce cooling energy demand.

7.3 Contribution to Knowledge

i. The study demonstrates that the application of thermal zoning principle in the design of indoor fitness and sport complexes which is analysed using Ecotect simulation software can achieve a total cooling energy savings of about 18%.

ii. The study also demonstrates that effective space zoning in conjunction with the independent variables (shading, natural ventilation, landscape, efficient building materials) reduces indoor air temperature to about 3^0c to 4^0c.

iii. The study establishes that the indoor air temperature and cooling energy demand of a space is greatly influenced by the volume of the space.

7.4 Areas of Further Research

The challenge for this dissertation has been to design an indoor fitness and sport complex building in warm humid region that will be energy efficient by applying the principle of thermal zoning. So further research can be;

i. This study as stated earlier is only restricted to the micro-climate of warm humid region so further research can be done in other cities within the hot and dry climate of Nigeria.

ii. There is need to replicate this research on another building typology to confirm the effect of the adopted thermal zoning strategies in such building.

iii. Study on effect of each individual building element such as Glazing by modifying various property of that element to find out the contribution of each property of that element in reducing or increasing heat within the building.

iv. More research should be carried on the actual thermal requirements for spaces within and indoor fitness and sport complex especially within the tropics.

v. There is need to have adequate input data for computer simulation in order to compare and contrast simulation results with real tie measurements.

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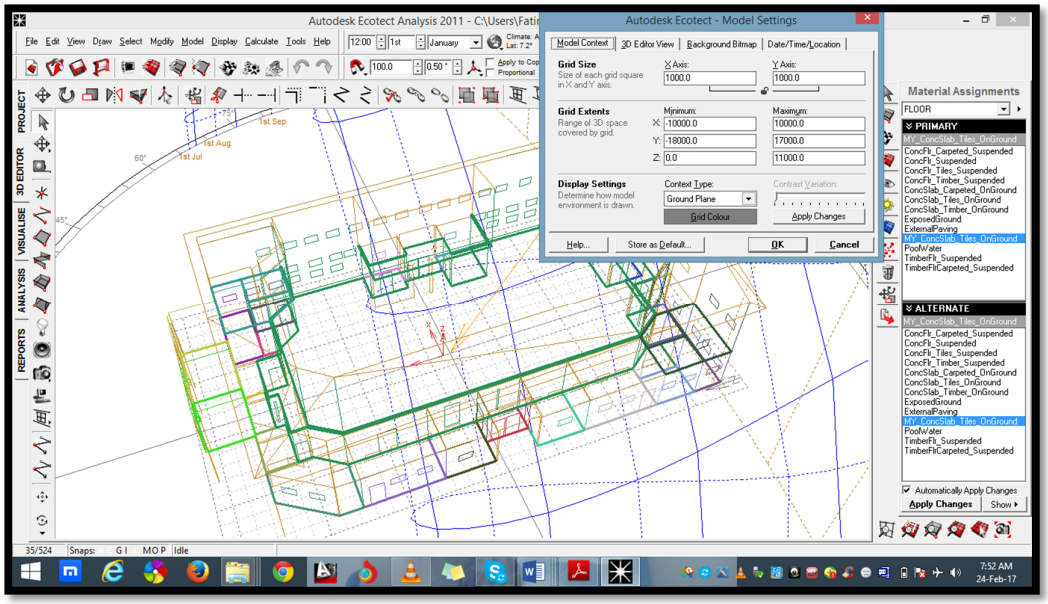
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APPENDICES

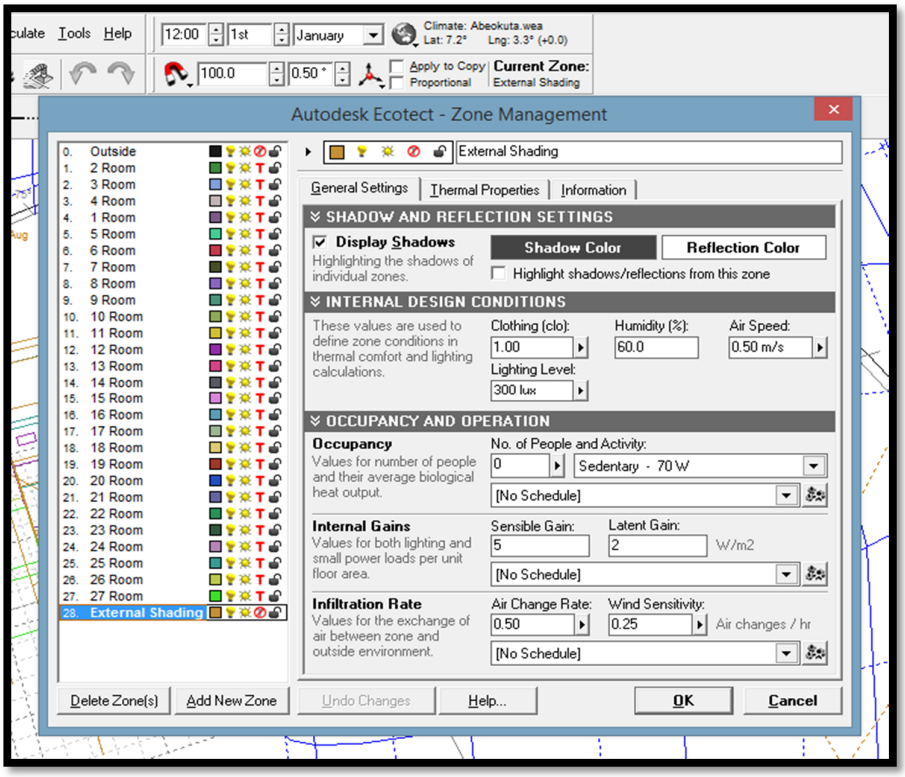
APPENDIX I

Project information of the baseline model in ECOTECT



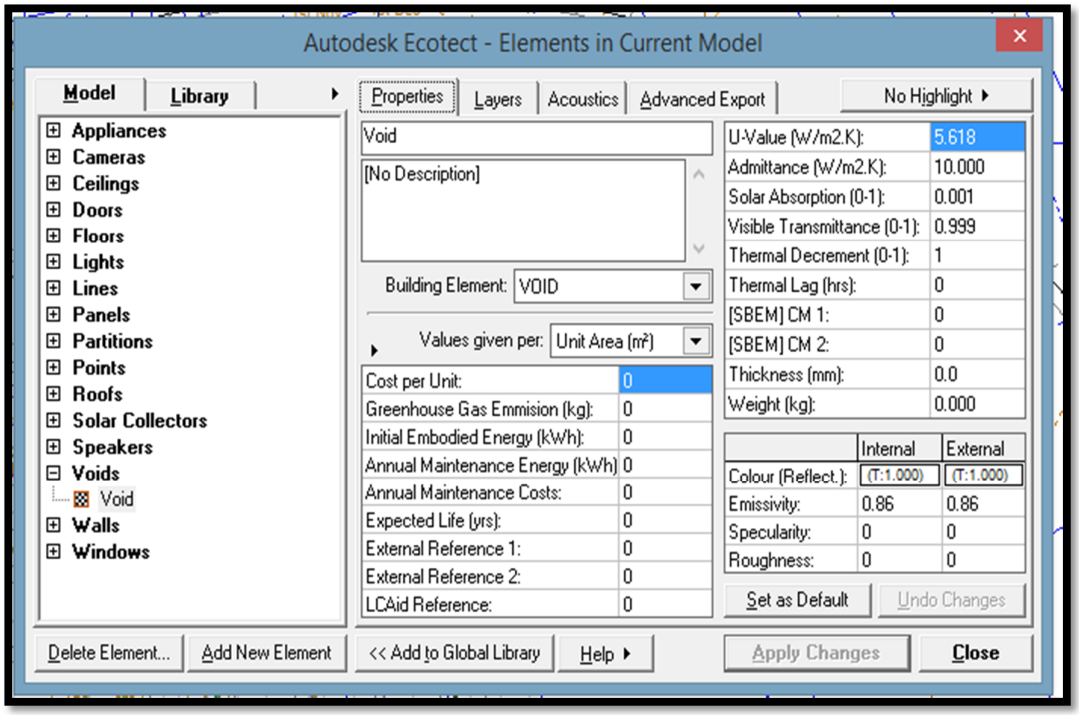
APPENDIX II

General zones settings in ECOTECT



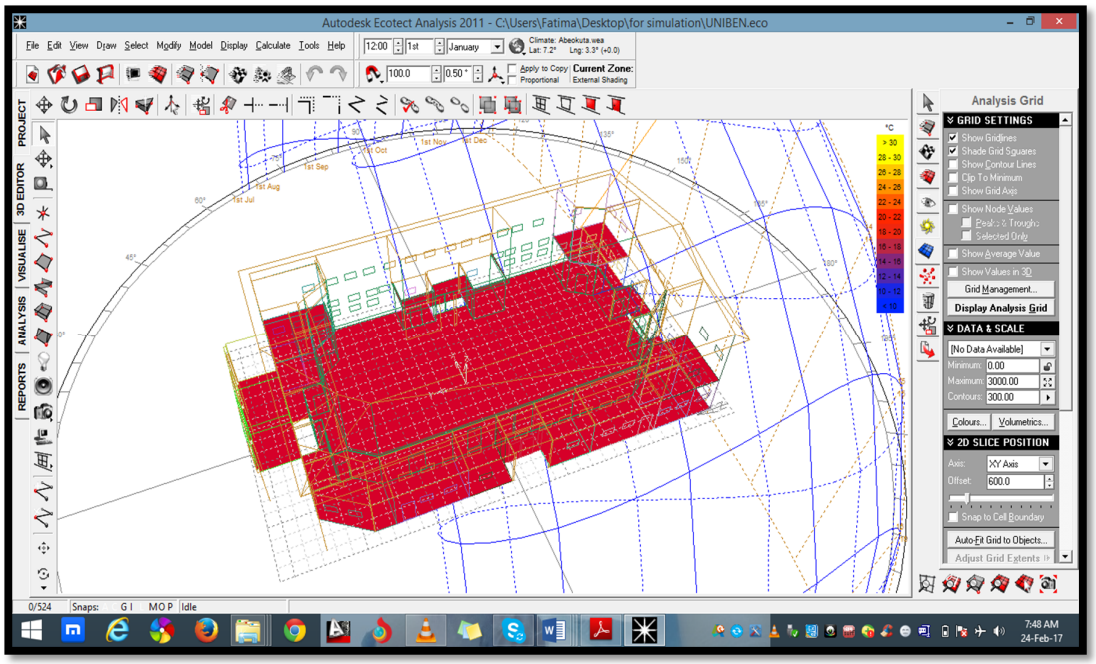
APPENDIX III

Element library for simulation



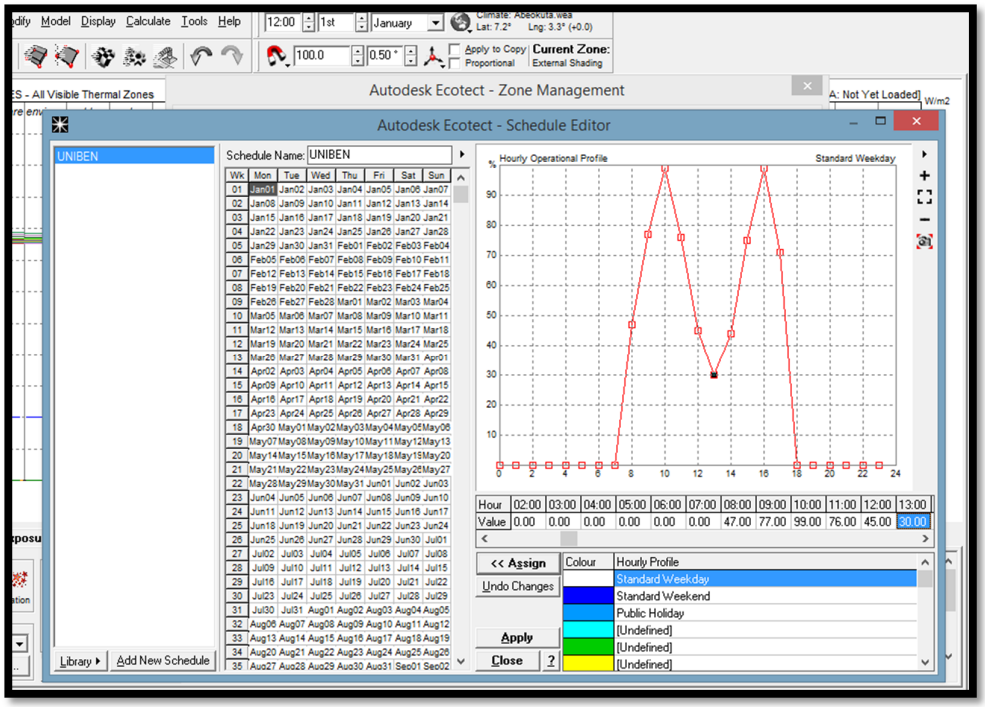
APPENDIX IV

Temperature analysis of University of Benin indoor sports hall



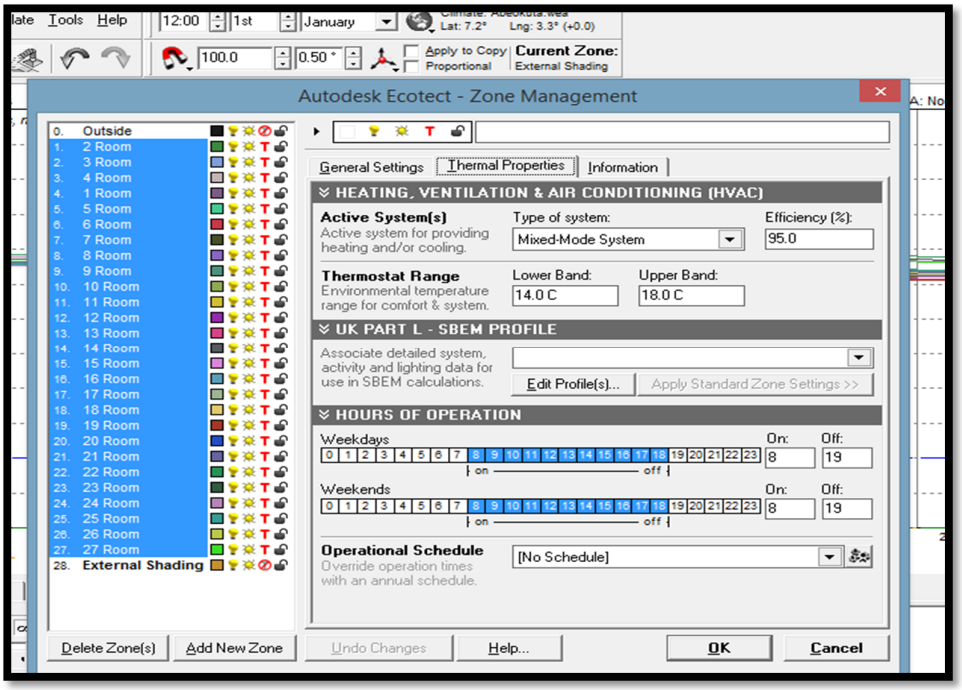
APPENDIX V

Daily schedule of activity for indoor fitness and sports hall



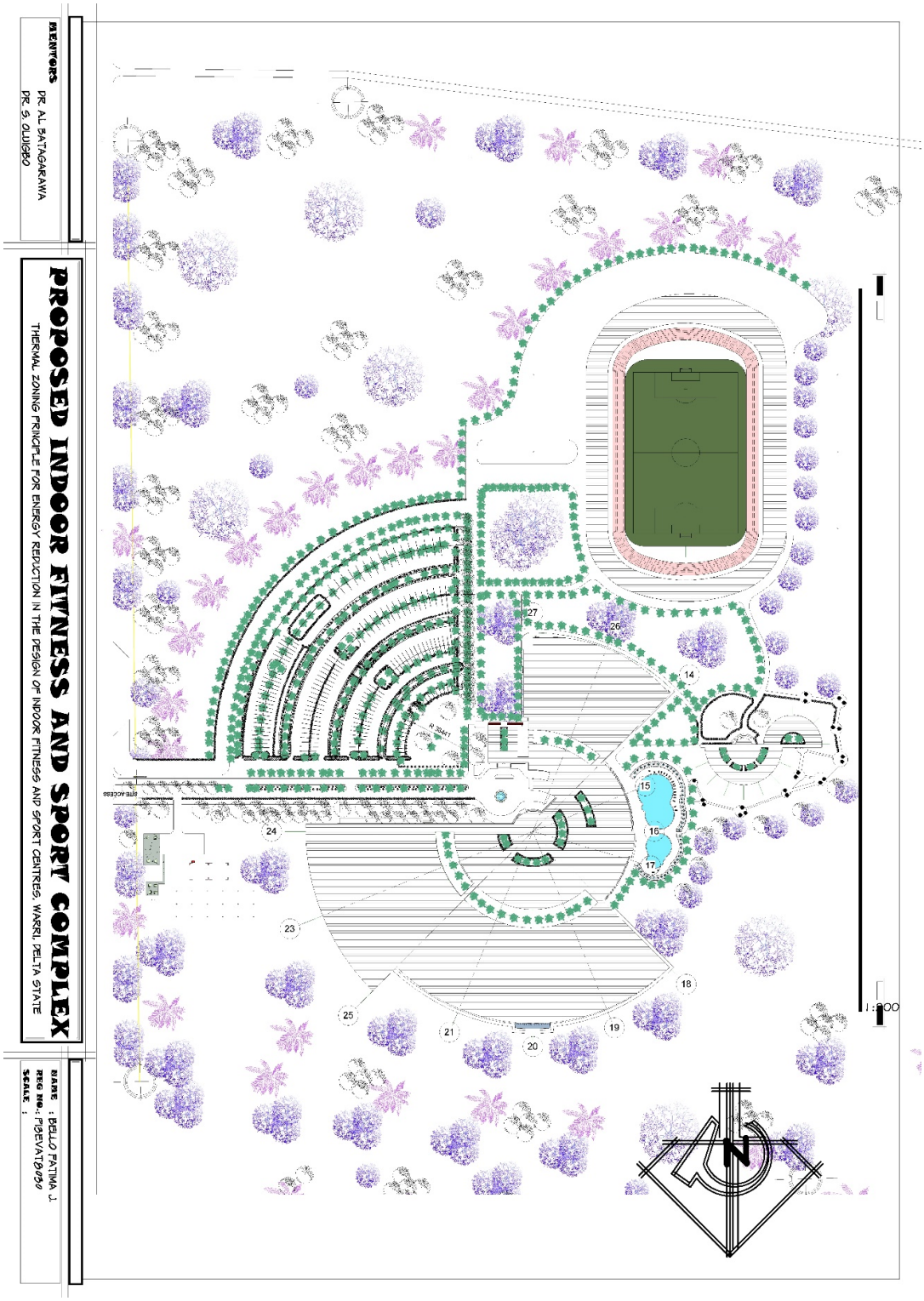
APPENDIX VI

Thermal properties of zones settings for energy simulation



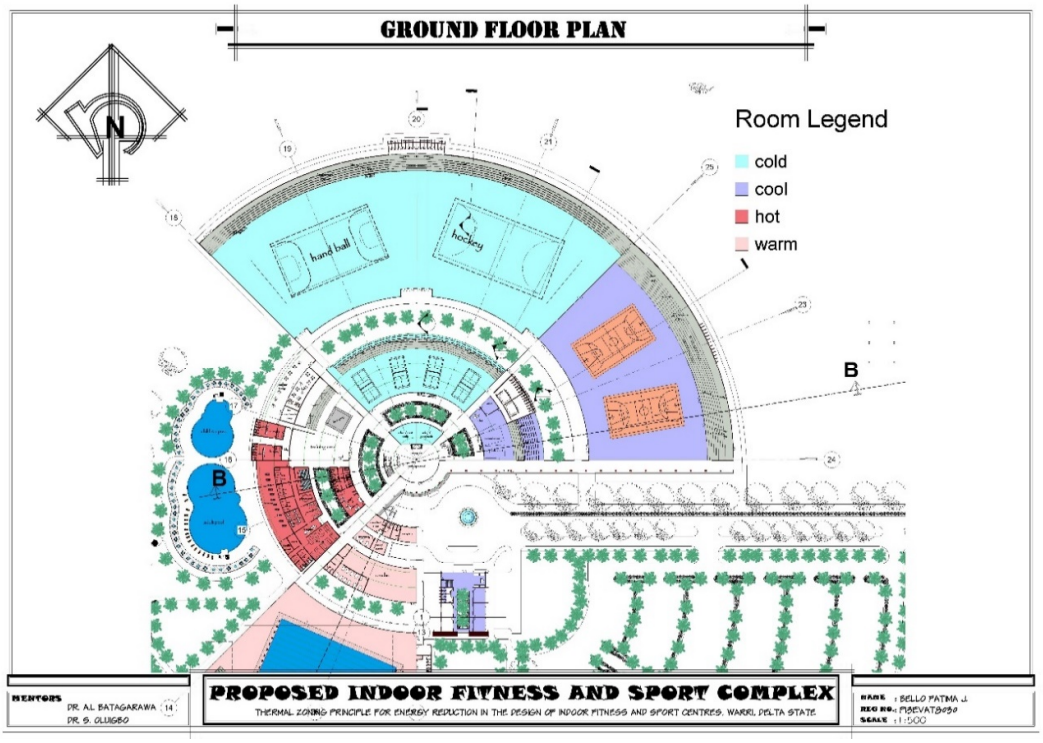
APPENDIX VII

Site plan of proposed indoor fitness and sport complex



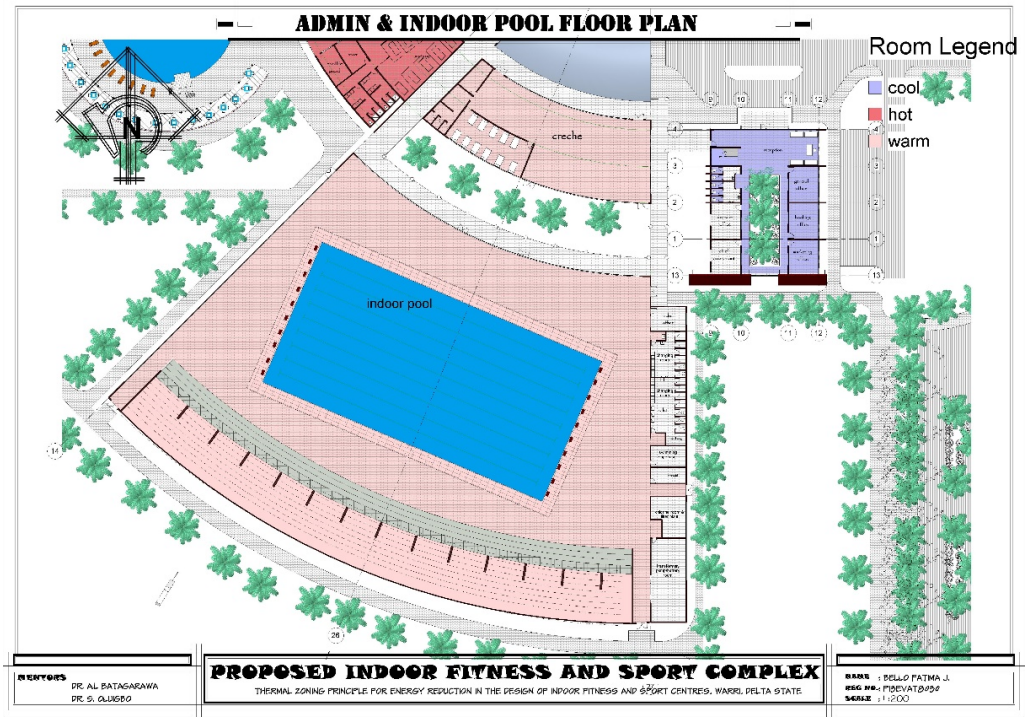
APPENDIX VIII

Ground floor plan



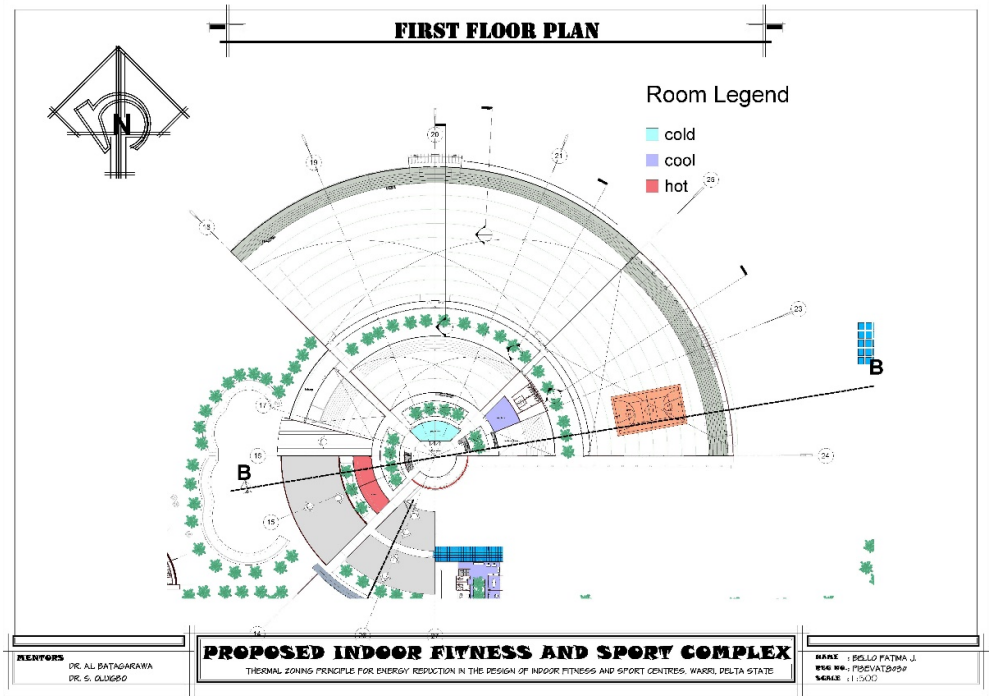
APPENDIX IX

Ground floor plan (pool and Admin building)



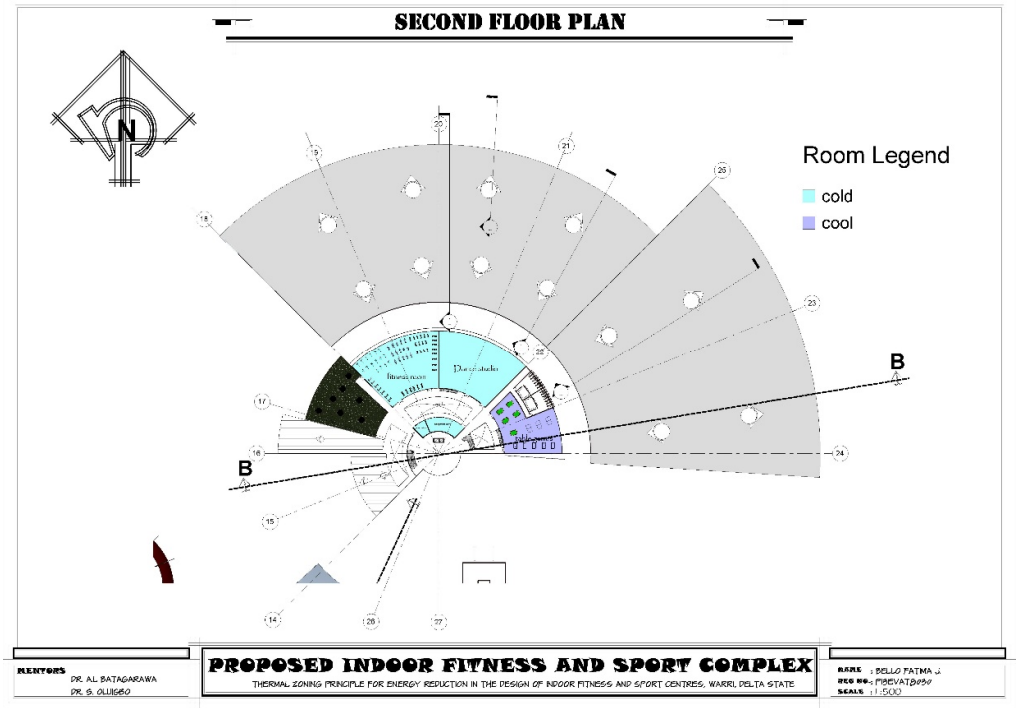
APPENDIX X

First floor plan (Main building)



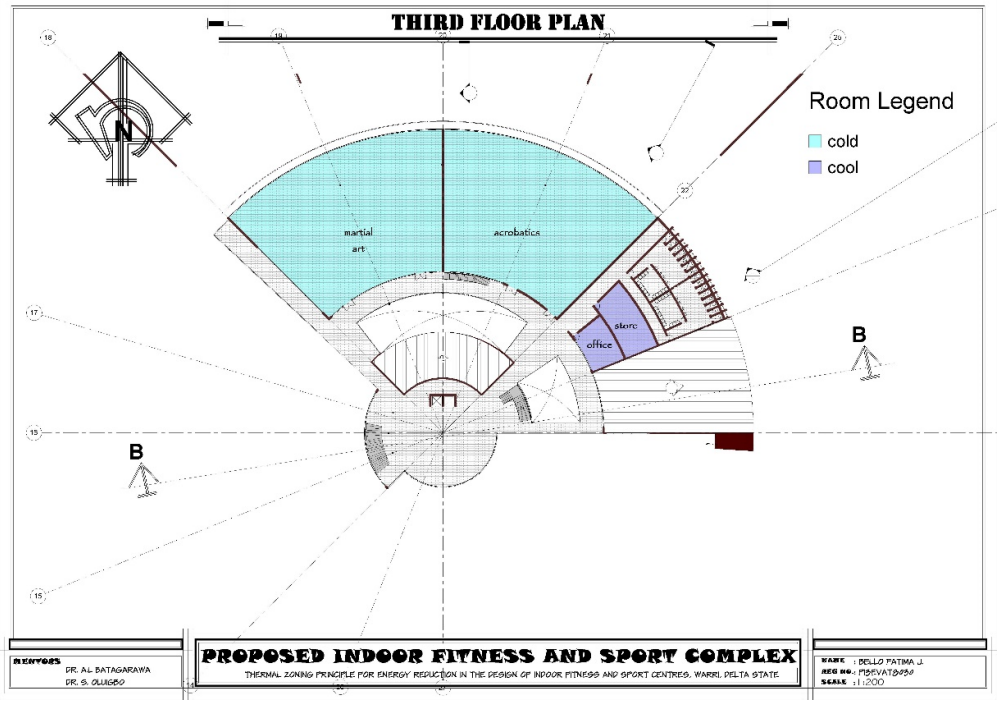
APPENDIX XI

Second floor plan (main building)



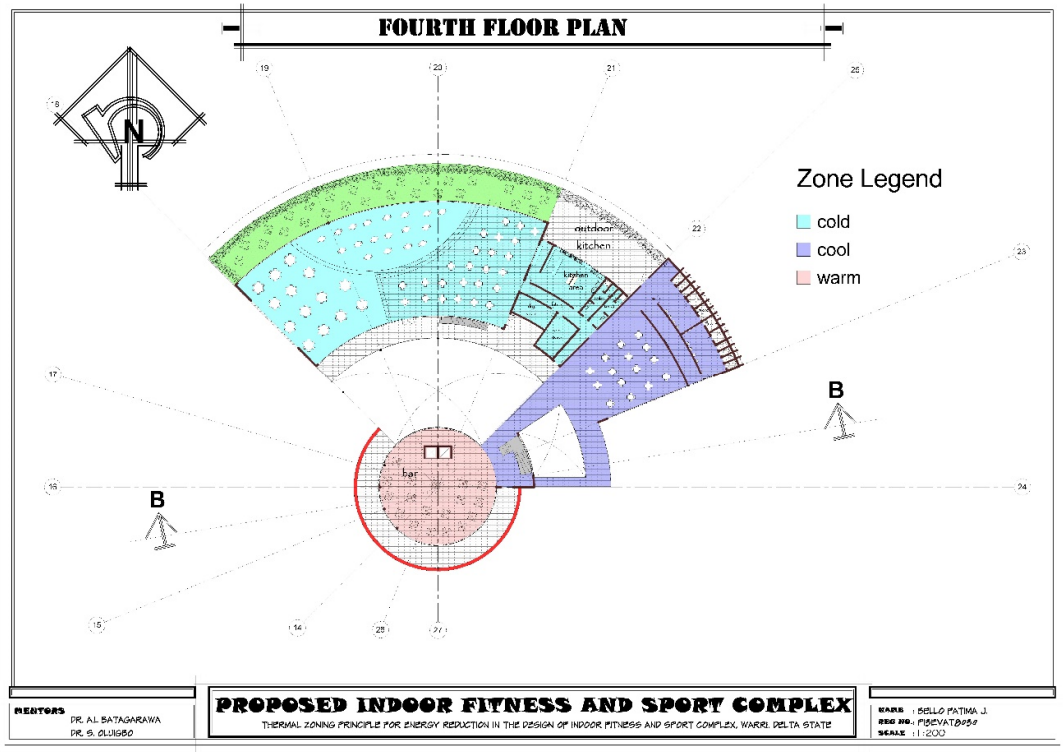
APPENDIX XII

Third floor plan (main building)



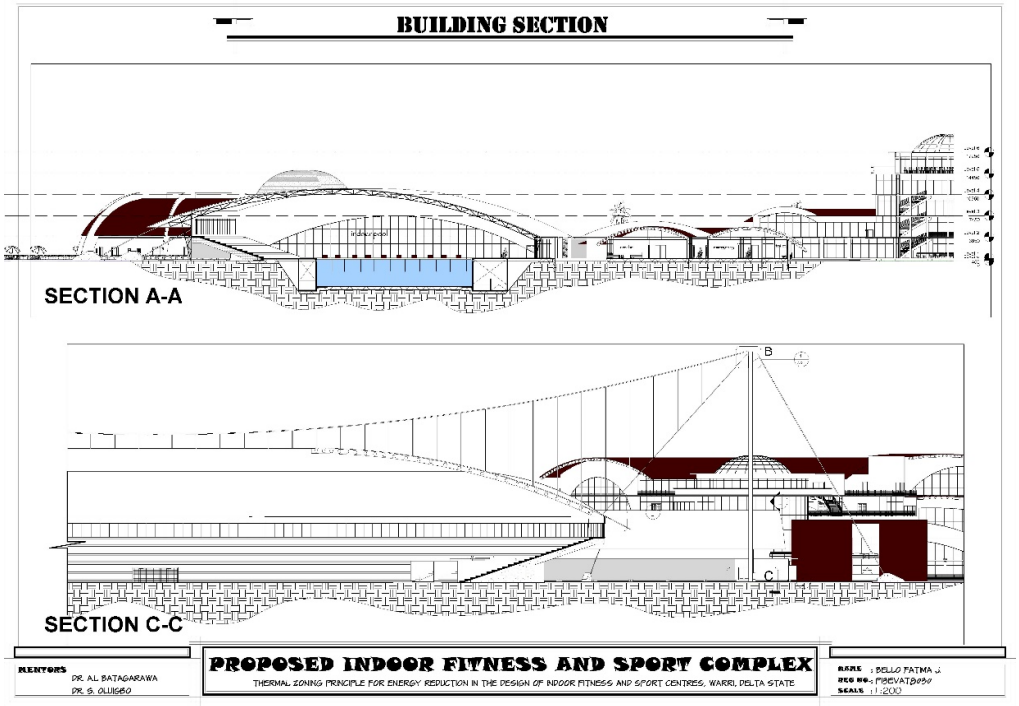
APPENDIX XIII

Fourth floor plan (Main building)



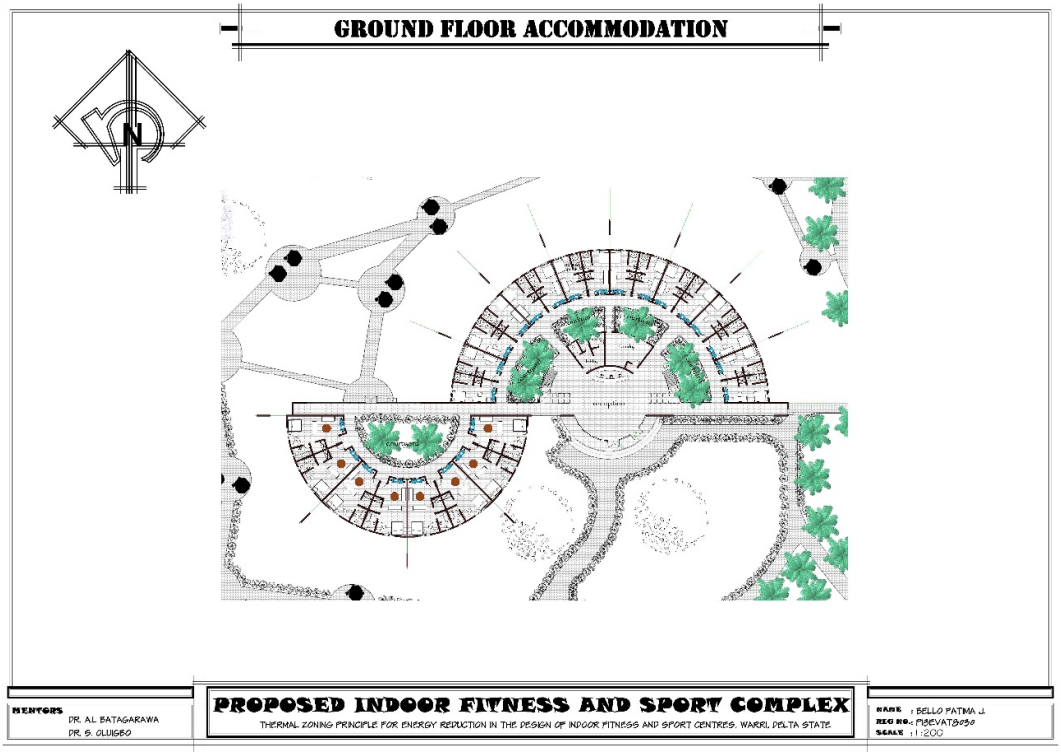
APPENDIX XIV

Sections



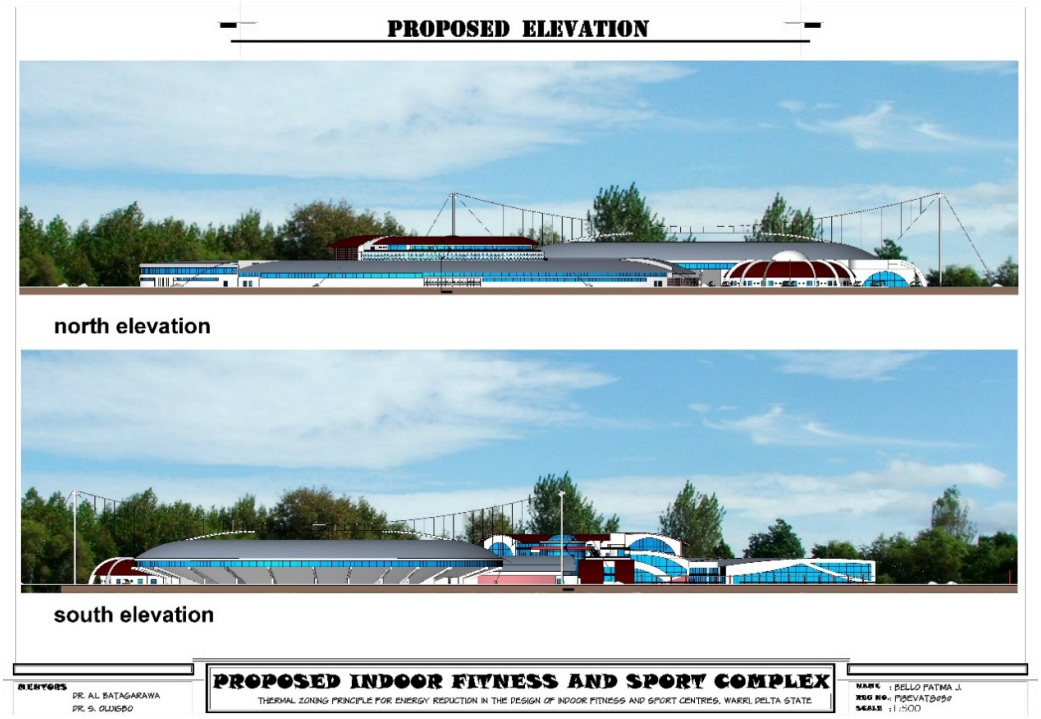
APPENDIX XV

Ground floor plan (Proposed accommodation)



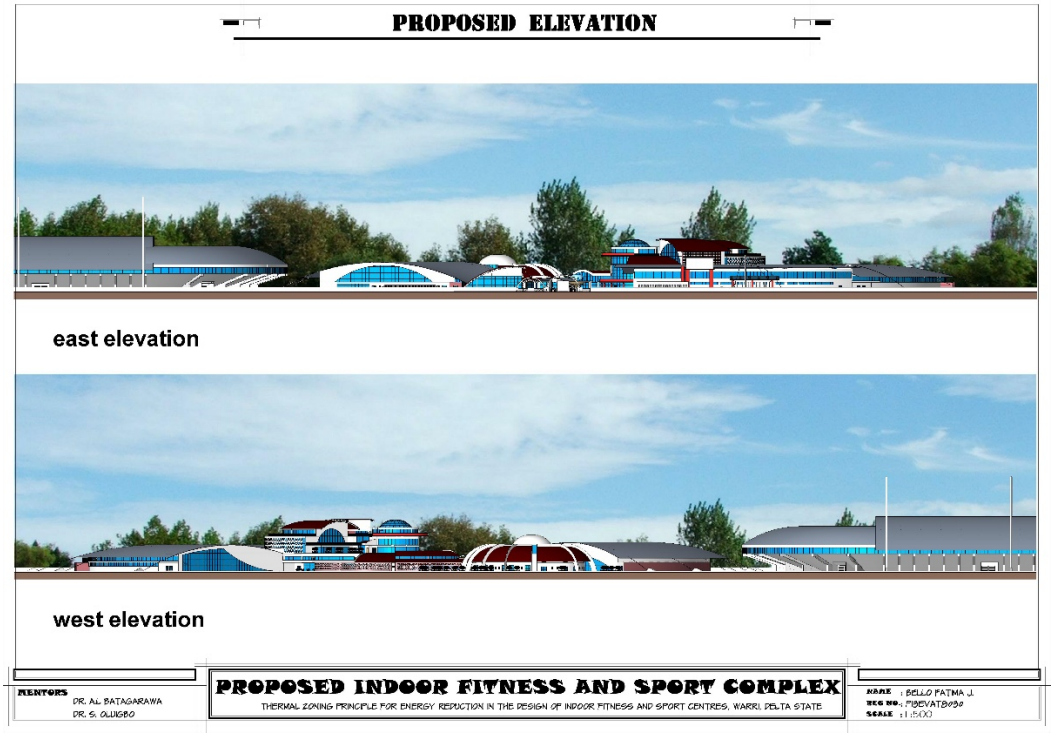
APPENDIX XVI

Proposed North and South Elevations



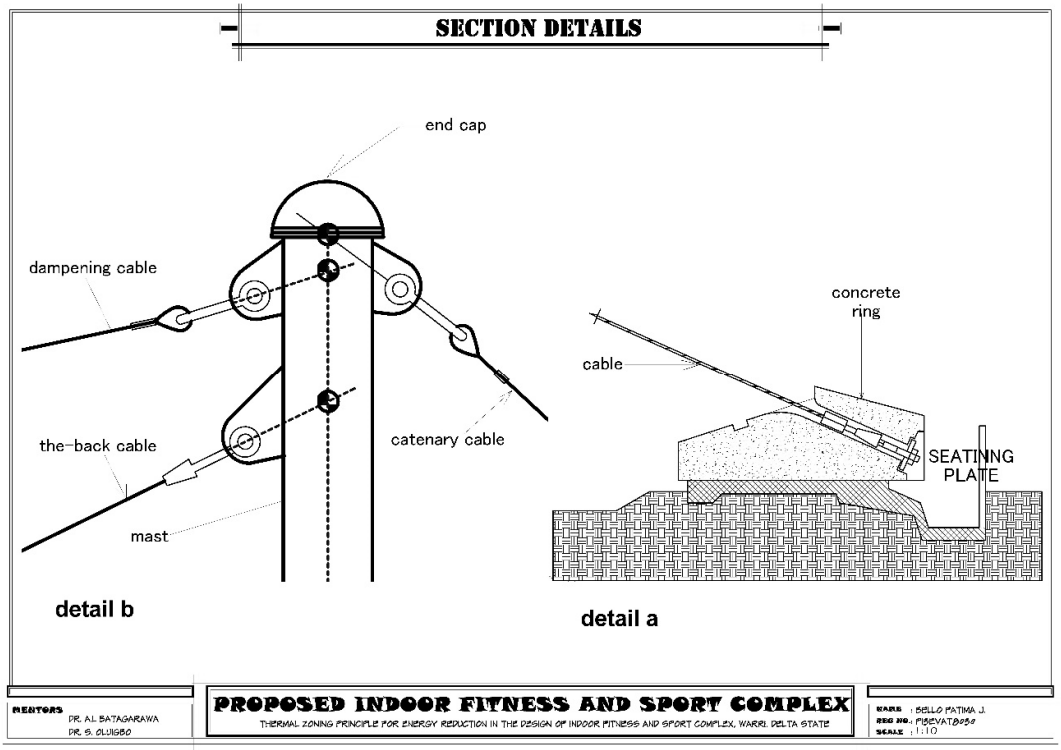
APPENDIX XVII

Proposed East and West Elevations



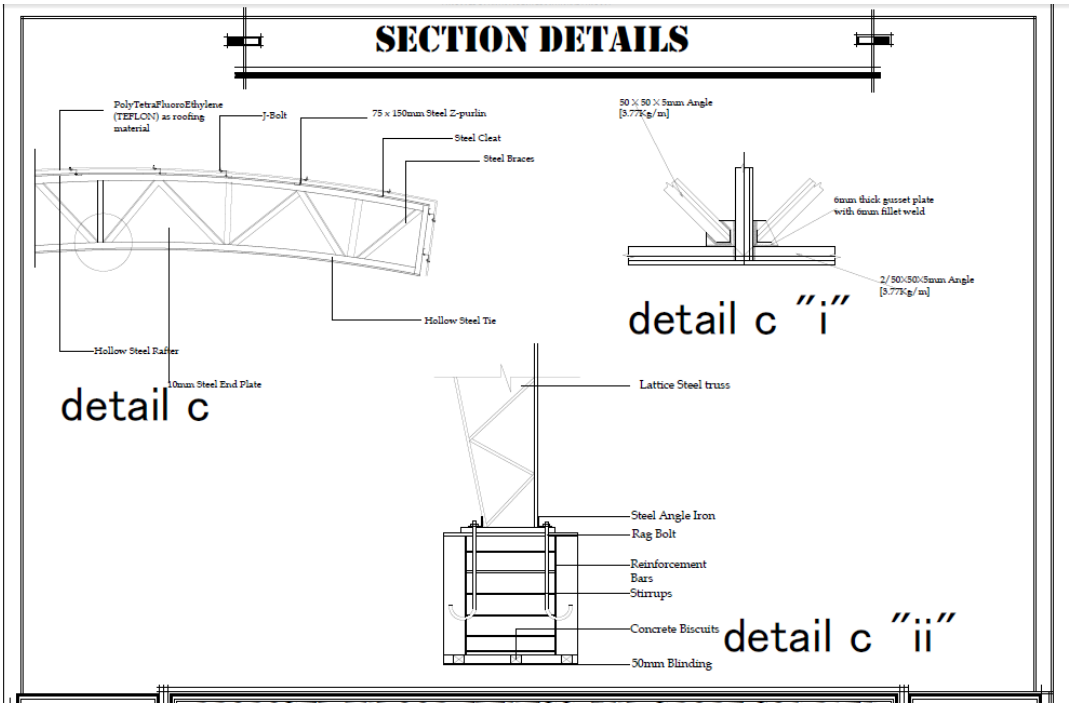
APPENDIX XVIII

Details



APPENDIX XIX

Details



APPENDIX XX

Perspectives



APPENDIX XXI

Perspectives

