AN EVALUATION OF SUSTAINABLE DESIGN STRATEGIES TO IMPROVE ENERGY EFFICIENCY OF SHOPPING MALLS IN ABUJA

By

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Declaration

I declare that the work in this thesis entitled "AN EVALUATION OF SUSTAINABLE DESIGN STRATEGIES TO IMPROVE ENERGY EFFICIENCY OF SHOPPING MALLS IN ABUJA" has been carried out by me in the Department of Architecture. The information derived from the literature has been dully acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at this or any other Institution.

KAMAL MOHAMMED SANI_____ _____

Name of Student Signature Date

Certification

This thesis entitled "AN EVALUATION OF SUSTAINABLE DESIGN STRATEGIES TO IMPROVE ENERGY EFFICIENCY OF SHOPPING MALLS IN ABUJA" by KAMAL MOHAMMED SANI meets the regulations governing the award of the degree of Master of Science in Architecture of Ahmadu Bello University, Zaria, and it is approved for its contribution to knowledge and literary presentation.

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Prof. M. L. Sagada Member, Supervisory Committee	Date
Dr. A. S. Salisu Head of Department	Date
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Dedication

This thesis is dedicated to my family - for their love and trust in me, to all my friends, to lovers of architecture and mankind.

Acknowledgements

All praise is due to God who has given me the strength and wisdom to accommodate all the challenges faced during the cause of writing this research thesis.

I would like to extend my profound gratitude to my humble supervisors Dr. H. T Kimeng and Prof. M. L. Sagada for their roles in guiding me during the course of this research. In addition, my regards goes to all my lecturers who gave their time to go through my work and for their valued contributions in the form of constructive criticism that made the research work better.

My Grandparents, parents, Uncles and Aunties, I feel blessed to be your son, brothers, and sisters, thanks for your support.

My acknowledgement will be incomplete without the mentioning of my friends, colleagues and relatives for their understanding and moral support. Thank you all. My immense appreciation also goes to my good Friends and well-wishers many of which space will not allow mentioning their names, whose words of encouragement and valuable suggestions that made Architecture and whole life interesting.

Abstract

The major source of energy used in existing shopping malls in Nigeria is generated via electricity, but due to epileptic power supply, high cost of energy and high carbon emission, there is a need to minimize energy demand in the facility. This research evaluated sustainable design strategies and their effects on energy efficiency in shopping malls in Nigeria. The research was based on case study approach and data was collected through visual survey, check-list ,computer simulation using "Ecotect Analysis, 2011" and interview of Architects/ designers of shopping malls in the field of energy as well as analysis of the environmental climate data of the proposed site. The case study revealed that the shopping malls as at the time of their construction did not consider sustainable design strategies in terms of materials of the building envelope, wall and window shading as well as natural means of cooling and lighting while the computer simulation gave a significant reduction of 38% when sustainable building materials where used for the envelope instead of contemporary building materials. In order to apply and achieve a sustainable design, effort was put into understanding the local climate and integrating appropriate strategies such as appropriate orientation, landscaping, fenestration, shading devices and appropriate use of materials into the architecture. The key factors which are local climate, building envelope, lighting, and cooling systems affecting the energy efficiency of the building were analysed and the strategies to improve its sustainability were examined. Innovative building materials and technology such as clay bricks in concrete render, precast concrete panels and solar tube day lighting system effectively utilized on a model in managing the problem of lighting and cooling energy loads were carefully investigated and these were used to overcome the energy efficiency challenges in the study area.

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1.0 INTRODUCTION

1.1 Background of Study

Sustainability in Architecture is a concept that is gaining a wide momentum. Several researchers define sustainability in Architecture in several ways. According to Ghani (2012), sustainable architecture involves a combination of aesthetic, environmental, social, political and moral values. It refers to the ability of a society, ecosystem or any such ongoing system, to continue functioning into the indefinite future (without being forced into decline through exhaustion of key resources. While Sassi (2006), sees it as a development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It involves addressing a wide spectrum of issues, sometimes, seemingly, conflicting ones. Acquiring a basic knowledge of these issues is the first step towards establishing or clarifying personal values and moving towards a more sustainable future (Sassi, 2006).

Benefits such as energy, water and operational cost savings, improved air quality, and increased productivity are drawing more attention to sustainable buildings (Nadel, 2006).The principles of sustainable design (economy of resources, life cycle design, and humane design) can provide a broad awareness of the environmental impact, both local and global, of architectural consumption (Kim,1998).

Shopping malls or shopping centres are 20th-century adaptation of the historical market place, with accommodation made for automobiles. A shopping centre is a collection of independent retail stores, services, and a parking area conceived, constructed, and maintained by a management firm as a unit. Shopping centres may also contain restaurants, banks, theatres, professional offices, service stations, and other establishments (Rouse, 1962).

Recent shopping mall designs favour large areas of glazing over common areas, with central voids allowing natural light to lower levels. This provides excessive day lighting and results in large solar gains which are typically offset by mechanical cooling. Controlling these gains can be very important towards reducing cooling usage and extending the envelope for natural ventilation and lighting (Fitzgerald & Woods, 2008).

Gruen & Smith (2006), opined that Current shopping centre projects should be focused on creating fresh indoor atmosphere, either using glass to allow plenty of light into the space or even melding the concepts of internal and external with schemes that flow effortlessly from inside to outside.

This thesis aims at solving the issue of energy efficiency, which poses as a challenge in shopping malls through the use of sustainable design strategies.

1.2 Problem Statement

In part, due to shopping malls being a relatively contemporary typology compared to markets in Nigeria, it is unclear which architectural strategies can be employed to improve energy efficiency in shopping malls in Abuja.

Challenges facing the realisation of sustainable development of shopping malls in Abuja are embedded in imported socio economic solutions based western paradigms. Consequently, this only results to poor outcomes due to poor or inappropriate comprehension of the African context in which it is applied (Ahmed, 2012).

In contrast to many developed countries where advances in regulatory instruments for energy use in buildings are evolving and enforced, Abuja (and Nigeria at large) is devoid of sufficient energy supply infrastructure let alone regulatory mechanism. Meanwhile, electricity supply has remained inadequate and unreliable in the past few decades (Bugaje, 2006).

Hence, to achieve an energy efficient shopping mall, there is a need for the search of sustainable alternative strategies to provide sustainable energy for shopping malls.

1.3 Justification of Study

The rate of energy consumed by shopping malls is very high. This is due to the large number of spaces required for lighting and thermal comfort. The poor provision of electricity in the country, which is the most consumed energy and conventional building materials used have affected the cost of running shopping malls.

The provision of electricity in shopping malls in Nigeria is mostly by burning fossil fuels, this process affects the climate leading to global warming and also proves to be very expensive thereby causing inflation of commodities in shopping malls. With this situation on ground, there is an urgent need to lay much emphases on possible sustainable ways to achieve energy efficiency in shopping malls so as to help protect the environment from global warming and to enhance the economic growth of the country as a whole.

1.4 Aim and Objectives

1.4.1 Aim

The Aim of this study is to explore the strategies of sustainable design in an attempt to achieve energy efficient Shopping Malls in Abuja, Nigeria.

1.4.2 Objectives

The objectives include:

i. To investigate factors affecting energy efficiency from literature.

ii. To investigate factors affecting energy efficiency of shopping malls in Abuja.

iii. To determine sustainable design principles concerning energy efficiency of shopping malls in Abuja.

iv. To demonstrate sustainable architectural design strategies to improve energy efficiency of shopping malls in Abuja.

1.5 Research Questions

i. What are the factors affecting energy efficiency of shopping malls in Abuja?

ii. What are the sustainable design principles concerning energy efficiency of shopping malls in Abuja?

iii. What are the sustainable architectural strategies to improve energy efficiency of shopping malls in Abuja?

1.6 Scope and Limitation of the Study

1.6.1 Scope

This research aims at studying issues concerning existing shopping malls in Abuja. Regional Shopping malls with a minimum 74,000sqm of gross leasable area were considered for the purpose of this study. This is necessary to help achieve improvement in the existing ones. Information was gathered through case studies of similar buildings with comparison between sustainability and energy efficiency in shopping malls.

1.6.2 Limitation

Snapping of pictures in certain areas of the shopping malls were restricted due to security challenges at the time of conducting case studies.

Computer softwares for simulating the effect of trees, hedges, grasses and water bodies were not accessible at the time of conducting this research.

2.0 LITERATURE REVIEW

The environmental impact of the energy industry is diverse. Energy has been harnessed by human beings for millennia. Initially it was with the use of fire for light, heat, cooking and for safety, and its use can be traced back at least 1.9 million years. Consumption of fossil fuel resources leads to global warming and climate change. In most parts of the world little change is being made to slow these changes. If the peak oil theory proves true, and more explorations of viable alternative energy sources are made, our impact could be less hostile to our environment (Subramanian, 2007).

Since the United Nations World Commission on Environment and Development (WCED) commonly referred to as Brundtland Report of 1987 (Our Common Future) the world's attention has been drawn unto two important issues. The first draws attention to concerns on resource depletion at a rate beyond its natural recovery. The second, asserts that greenhouse gas emissions resulting from human activities particularly those associated with the use and manufacture of high quality energy is increasing in such a way that it adversely affects the climate (Stern, 2008). The Report calls for responsible human activities that will ensure the survivability of present and future generations in which two main lines of action were identified – sustainable development and reduction in greenhouse gas (GHG) emissions (Nordhaus, 2007). The scientific consensus on global warming and climate change is that it is caused by anthropogenic greenhouse gas emissions, the majority of which comes from burning fossil fuels with deforestation and some agricultural practices being also major contributors.

There is no doubt that Africa's position will be further complicated due to the recent oil reserve discoveries in Ghana, Angola, Sudan, Cameroon, Nigeria, Libya, Sao Tome and Principe which seem plausible in terms of energy supply security for the continent as

well as the potentials for "transformational development" as experienced in the Gulf states due to oil wealth. This can undermine the efforts towards energy conservation and renewable energy exploration (Schwarz, 2009).

Furthermore, it has been reported that the magnitude of fuel-wood demand in Africa is responsible for significant deforestation and desertification (Bugaje, 2006). Evidently, this adversely contributes in the depletion of carbon sinks required to reduce Green House Gas emission levels through natural cycles of carbon capture. Congruently, this supports assertions in the Stern Review that developing countries will account for increases in Green House Gas emissions in the near future. As such, they are positioned as contributors to the global challenge and not mere victims or spectators anymore (Smith, 2003).

Ozone shields the Earth from ultraviolet (UV) radiation and its depletion is caused by emissions of chlorofluorocarbons (CFCs) and other ozone depleting substances into the atmosphere. Increases in UV radiation are thought to be linked to a rise in skin cancers, damage to the human immune system, and altered crop yields (Wilson, 2002).

2.1 Energy and Electricity

The environmental impact of electricity generation is significant because modern society uses large amounts of electrical power. This power is normally generated at power plants that convert some other kind of energy into electrical power. Each of such system has advantages and disadvantages, but many of them pose environmental concerns. Examples of such include but not limited to; Hydroelectric power, nuclear power and wind power (Agboola, 2011).

2.1.1 Hydroelectric power

The environmental impact of reservoirs is coming under ever-increasing scrutiny as the world demand for water and energy increases and the number and size of reservoirs increases. Dams and the reservoirs can be used to supply drinking water, generate hydroelectric power, increasing the water supply for irrigation, provide recreational opportunities and to improve certain aspects of the environment. However, adverse environmental and sociological impacts have also been identified during and after many reservoir constructions (Smith, 2003).

2.1.2 Nuclear power

The routine health risks and greenhouse gas emissions from nuclear fission power are smaller than those associated with coal, oil and gas. However, there is a "catastrophic risk" potential if containment fails (international panel on fission materials, 2010), in which nuclear reactors can be brought about by over-heated fuels melting and releasing large quantities of fission products into the environment. The most long-lived radioactive wastes, including spent nuclear fuel, must be contained and isolated from humans and the environment for hundreds of thousands of years. The public is sensitive to these risks and there has been considerable public opposition to nuclear power (Bugaje, 2006).

2.1.3 Wind power

The environmental impact of wind power when compared to the environmental impacts of fossil fuels is relatively minor. According to the Intergovernmental Panel on Climate Change **(**IPCC), in assessments of the life-cycle global warming potential of energy sources, wind turbines have a median value of between 12 and 11 (gCO_2eq/kWh) depending, respectively, on if offshore or onshore turbines are being assessed. Compared with other low carbon power sources, wind turbines have some of

the lowest global warming potential per unit of electrical energy generated (Pershing, 2005).

Research undertaken from 1995 to 2005 found that the cost of producing electricity from coal or oil would double over its present value, and the cost of electricity production from gas would increase by 30% if external costs such as damage to the environment and to human health, from the airborne particulate matter, nitrogen oxides, chromium VI and arsenic emissions produced by these sources, were taken into account (Buck & Young, 2006).

Challenges of poverty, healthcare, poor infrastructure and political instability as emphasised in agendas of the UN's Millennium Development Goals (MDGs) and the New Partnership for Africa's Development (NEPAD). Essentially, these are proposed frameworks targeted to deliver development and environmental sustainability to developing countries. Unless these goals are achieved, perhaps the reliance on electricity and other forms of high quality energy to alleviate poverty and ensure economic development in the developing countries will remain a rhetoric (Omar,2013).

According (Bureau of energy efficiency, 2013), hydroelectric electricity produces the lowest CO2 emissions, wind produces the second-lowest, nuclear energy produces the third-lowest and solar photovoltaic produces the fourth-lowest. There are reports of bird and bat mortality at wind turbines as there are around other artificial structures. The scale of the ecological impact may or may not be significant, depending on specific circumstances. Prevention and mitigation of wildlife fatalities, and protection of peat bogs, affect the siting and operation of wind turbines.

2.2 Energy and Buildings

Buildings have an average lifespan ranging from 50 to 100 years. Recent studies indicate that buildings are the biggest source of energy use and greenhouse gas emissions, which in turn impact the world's climate changes. Most Architects know that buildings can be designed to operate with far less energy than many buildings are currently consuming (Ahmed, 2012).

Design professionals and the building industry are developing innovative approaches to improve energy efficiency and reduce annual operating costs to building owners through advanced technology and a variety of sustainable design practices (Nadel, 2006).

According to Nordhaus (2007), benefits such as energy, water and operational cost savings, improved air quality, and increased productivity are drawing more attention to green building issues. Congressional leaders are discussing how to best support sustainability initiatives through legislation. Architects are well positioned to educate the public, facility managers, building owners, and elected officials about the clear economic benefits of sustainable design.

During a building's existence, it affects the local and global environments via a series of interconnected human activities and natural processes. At the early stage, site development and construction influence indigenous ecological characteristics. Though temporary, the influx of construction equipment and personnel onto a building site and process of construction itself disrupt the local ecology. The procurement and manufacturing of materials impact the global environment. Once built, building operation inflicts long-lasting impact on the environment. For instance, the energy and water used by its inhabitants produce toxic gases and sewage; the process of extracting,

refining, and transporting all the resources used in building operation and maintenance also have numerous effects on the environment (Kim, 1998).

Indoor thermal comfort is essential for occupants' well-being, productivity and efficiency. The hot-dry climate with its extremely high temperatures and intense solar radiation is becoming hotter and drier in this era of climate change and global warming. Thus providing for indoor thermal comfort and reducing energy use in buildings is becoming increasingly difficult. This has called for new ways of thinking and re-evaluation of the existing methods of tackling this problem (Oluwafemi, 2010). Figure 2.1 shows the relationship between external factors as it affects thermal comfort.

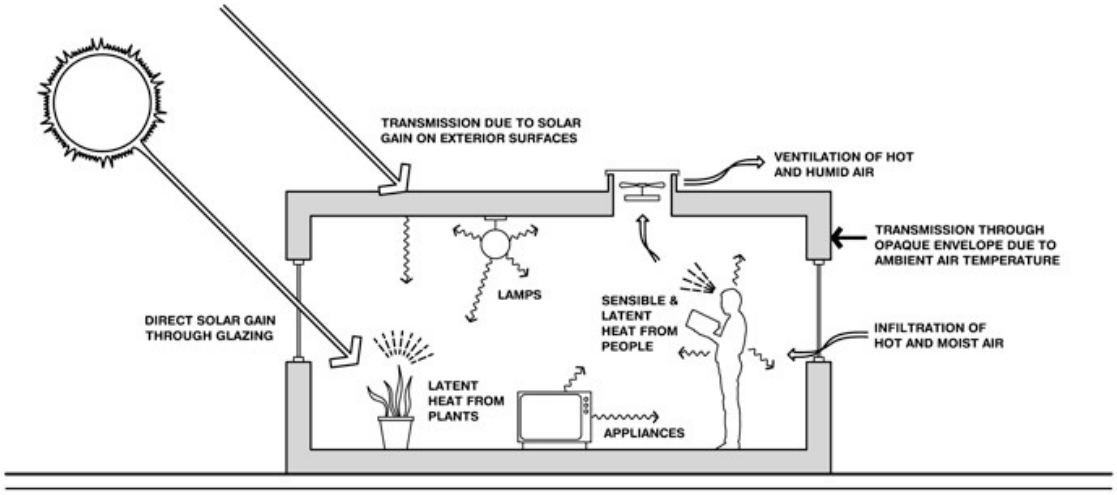


Figure 2.1: External Factors and Thermal Comfort
Source: Nordhaus (2007)

Sassi (2006) observes that conservation of natural resources is an imperative for the socially responsible architect. Addressing sustainability requires that we redefine boundaries of traditional practice. The idea of an isolated building on a site is no longer acceptable. Buildings belong to a larger community and must begin to support and sustain our environment.

2.3 Energy Efficiency

Efficient energy use, sometimes simply called energy efficiency, is the goal to reduce the amount of energy required to provide products and services. For example, insulating a home allows a building to use less heating and cooling energy to achieve and maintain a comfortable temperature. Installing fluorescent lights, LED lights or natural skylights reduces the amount of energy required to attain the same level of illumination compared with using traditional incandescent light bulbs. Compact fluorescent lights use one-third the energy of incandescent lights and may last from 6 to 10 times longer (Humphreys, 2009).

Improvements in energy efficiency are generally achieved by adopting a more efficient technology or production processes or by application of commonly accepted methods to reduce energy losses (Diesendorf, 2007).

The energy efficiency of a building is the extent to which the energy consumption per square metre of floor area of the building measures up to established energy consumption benchmarks for that particular type of building under defined climatic conditions (Pershing, 2005).

Energy efficiency and renewable energy are said to be the *twin pillars* of sustainable energy policy and are high priorities in the sustainable energy hierarchy. In many countries, energy efficiency is also seen to have a national security benefit because it can be used to reduce the level of energy imports from foreign countries and may slow down the rate at which domestic energy resources are depleted. Energy efficiency has proved to be a cost-effective strategy for building economies without necessarily increasing energy consumption (Smith, 2003).

The Energy Hierarchy is a classification of energy options, prioritised to assist progress towards a more sustainable energy system. It is a similar approach to the waste hierarchy for minimising resource depletion, and adopts a parallel sequence.

The highest priorities cover the prevention of unnecessary energy usage both through eliminating waste and improving energy efficiency. The sustainable production of energy resources is the next priority. Depletive and waste-producing energy generation options are the lowest priority (Agboola, 2011).

For an energy system to be sustainable: the resources applied to producing the energy must be capable of lasting indefinitely; energy conversion should produce no harmful by-products, including net emissions, nor wastes which cannot be fully recycled; and it must be capable of meeting reasonable energy demands. The top priority under the Energy Hierarchy is energy conservation or the prevention of unnecessary use of energy. This category includes eliminating waste by turning off unneeded lights and appliances and by avoiding unnecessary journeys. Heat loss from buildings is a major source of energy wastage (Buck & Young, 2006).

Improvements to building insulation and air-tightness can make a significant contribution to energy conservation (IEA, 2013).

Energy hierarchy in figure 2.2 shows in order of priority how best to save energy.

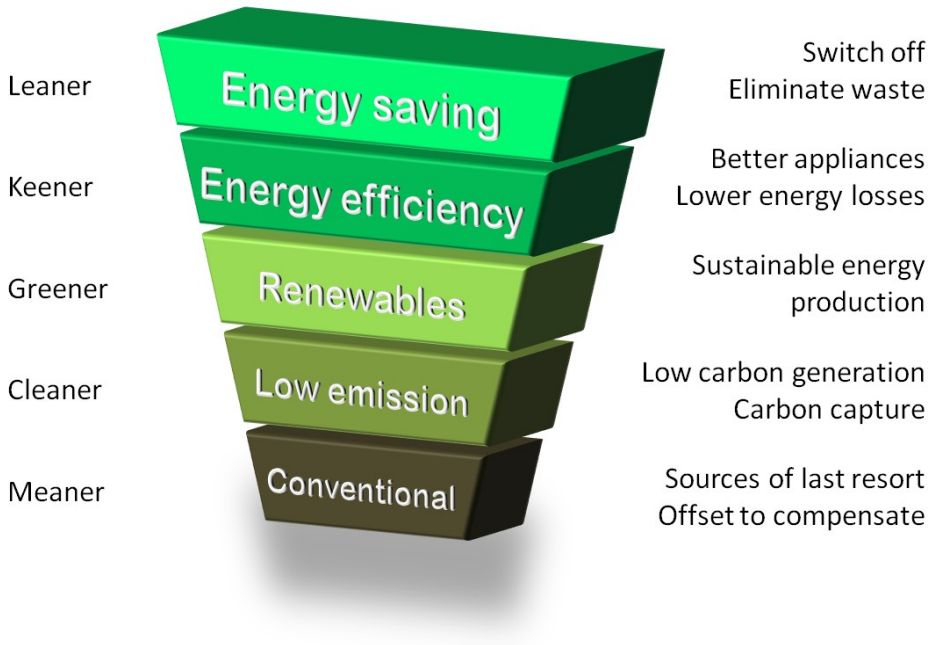


Figure 2.2: Energy Hierarchy
Source: Omar (2013).

Renewable energy is generally defined as energy that comes from resources which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat (Omar,2013).

According to Renewable Global Status (2010), Renewable energy replaces conventional fuels in four distinct areas: electricity generation, air and water heating/cooling, motor fuels, and rural (off-grid) energy services. Renewables contributed 19 percent to our global energy consumption and 22 percent to our electricity generation in 2012 and 2013, respectively. This energy consumption is divided as 9% coming from traditional biomass, 4.2% as heat energy (non-biomass), 3.8% hydroelectricity and 2% is electricity from wind, solar, geothermal, and biomass.

Renewable energy resources exist over wide geographical areas, in contrast to other energy sources, which are concentrated in a limited number of countries. Rapid

deployment of renewable energy and energy efficiency is resulting in significant energy security, climate change mitigation, and economic benefits (IEA, 2012).

Sustainable energy, which is the provision of energy that meets the needs of the present without compromising the ability of future generations to meet their needs. Sustainable energy sources are most often regarded as including all renewable energy sources, such as hydroelectricity, solar energy, wind energy, wave power, geothermal energy, bioenergy, and tidal power. It usually also includes technologies that improve energy efficiency (Omar, 2013).

According to Janda (2009), an approach for quantifying optimized energy performance is to set 'goals and to compare measured energy consumption to the predicted consumption had the building's energy design not been optimized. Aggressive energy efficient designs have used 70% less energy than standard buildings. Designers must rely on computer simulations to identify the set of energy efficiency strategies that can be applied to meet and exceed these goals.

2.4 Factors Affecting Energy Consumption in Buildings

Factors that affect energy efficiency in buildings include; day lighting, natural ventilation, building envelope, internal load, site and external space, orientation and planning, building shape and form, wall shading, as well as local climate amongst others (Subramanian, 2007).

According to Kim (1998), important factors related to energy consumption of buildings that need to be considered include: heat loss or heat gain, lighting, Impact of the occupants, climatic factors and the most effective overall means to reduce energy consumption, however, is to influence the occupants to save energy.

According to IEA (2013), the building envelope's impact on energy consumption should not be underestimated: globally, space heating and cooling account for over one-

third of all energy consumed in buildings, rising to as much as 50% in cold climates and over 60% in the residential sub-sector in cold climate countries. Buildings lose sensible heat to the environment (or gain sensible heat from it) in three principal ways:

i. **Conduction**: The transfer of heat between substances, which are in direct contact with each other. Conduction occurs when heat flows through a solid.

ii. **Convection:** The movement of gases and liquids caused by heat transfer. As a gas or liquid is heated, it warms, expands and rises because it is less dense resulting in natural convection.

iii. **Radiation:** When electromagnetic waves travel through space, it is called radiation. When these waves (from the sun, for example) hit an object, they transfer their heat to that object.

Figure 2.3 below shows how heat is being transferred from the source to the body in form of convection, conduction and radiation.

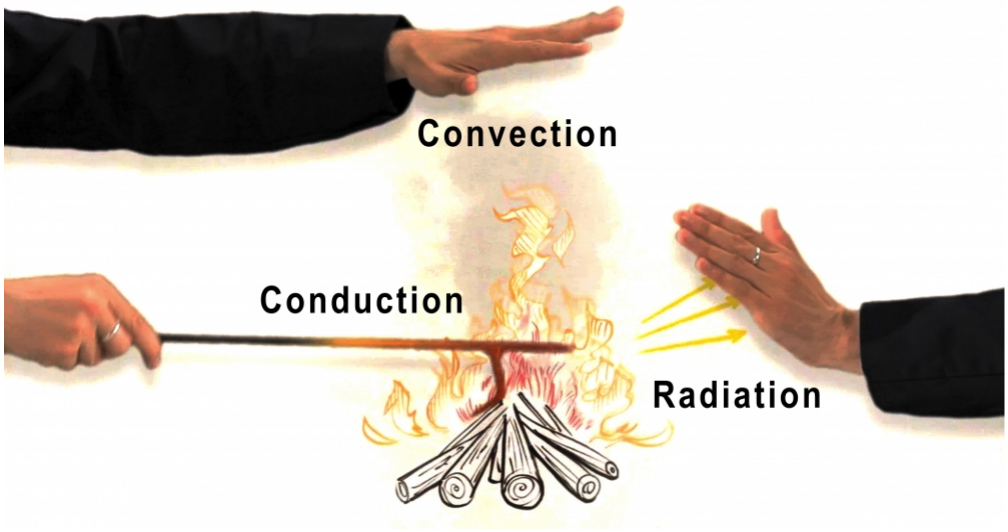


Figure 2.3: Heat Transfer through Conduction, Convection, and Radiation
Source: Autodesk sustainability workshop, (2003).

Conduction, convection, and radiation heat transfer take place almost everywhere we look. In a building envelope, conduction primarily takes place through opaque envelope assemblies, convection is usually the result of wind or pressure-driven air movement, and radiant heat transfer is primarily from the sun through fenestrations. Building HVAC systems are typically designed to provide comfort using convective or radiant modes of heat transfer (Sustainability workshop, 2003).

The reason that light-coloured materials reflect more light than darker materials is actually rather complex but basically comes down to the number and type of chemical bonds in a material, these bonds affect what kind of light (specifically what wavelength) it absorbs. Some people and companies have also started adopting white roofs, which reflect much more heat than darker-coloured roofs (Canbay, 2004).

The factors affecting energy efficiency of buildings are classified into the following categories:

i. Building envelope design
ii. Building materials
iii. Day lighting
iv. Building energy Loads
v. Climatic factors
vi. Occupants' factor

2.4.1 Building envelope

The building envelope refers to the exterior interface, and is comprised of opaque components and fenestration systems. Opaque components include walls, roofs, slabs on grade (in touch with ground), basement walls, and opaque doors. Fenestration systems include windows, skylights, ventilators, and doors that are more than one-half

glazed. The envelope protects the building‘s interiors and occupants from the weather conditions and shields them from other external factors (Samuel, 2011).

The building envelope also known as the building shell, fabric or enclosure is the boundary between the conditioned interior of a building and the outdoors. The energy performance of building envelope components, including external walls, floors, roofs, ceilings, windows and doors, is critical in determining how much energy is required for heating and cooling (Kim, 1998).

According to Autodesk sustainability workshop (2013), thermally insulated materials block or slow the flow of heat through the building envelope. Insulation is vital to most green building designs because it allows spaces to retain what heat they have, while avoid gaining excess heat from outside. Insulation primarily is designed to prevent heat transfer from conduction and radiation.

Resistance to conduction is measured by R-value (high thermal resistance = high R-value); Resistance to radiative heat transfer is measured by emissivity (high resistance = low emissivity and high reflectance). Conduction is the dominant factor when materials are touching each other; when there is an air gap between materials, radiation becomes important. Convection usually only becomes an issue when significant air pockets are involved (Autodesk Sustainability Workshop, 2013).

According to Janda (2009), Materials used for insulation fall into two broad categories:

i. Fibrous or cellular products include glass, rock wool, slag wool, perlite, cotton, synthetic fibers, cork, foamed rubber, or polystyrene.

ii. Metallic or metalized organic reflective membranes - These block radiation heat transfer and must face an air space to be effective.

Table 2.1 shows the thermal resistance (R-value) of some common building materials with thickness of 2.5cm (1").

Table 2.1 : R-values for 1" thickness of common building materials.

Material (2.5cm) thickness	m^2•K/W	ft^2•°F•h/BTU
Vacuum insulated panel	5.28 - 8.8	R-30 - R-50
Polyisocyanurate spray foam	0.76 - 1.46	R-4.3 - R-8.3
Polyurethane rigid panel	0.97 - 1.2	R-5.5 - R-6.8
Closed-cell polyurethane spray foam	0.97 - 1.14	R-5.5 - R-6.5
Extruded polystyrene (XPS), low-density	0.63 - 0.82	R-3.6 - R-4.7
Expanded polystyrene (EPS) high-density	0.65 - 0.7	R-3.85 - R-4.2
Air-entrained concrete	0.69	R-3.90
Fiberglass batts	0.55 - 0.76	R-3.1 - R-4.3
Cotton batts (Blue Jean insulation)	0.65	R-3.7
Open-cell polyurethane spray foam	0.63	R-3.6
Cardboard	0.52 - 0.7	R-3 - R-4
Rock and slag wool batts	0.52 - 0.68	R-3 - R-3.85
Cellulose wet-spray	0.52 - 0.67	R-3 - R-3.8
Straw bale	0.26	R-1.45
Softwood (most)	0.25	R-1.41
Hardwood (most)	0.12	R-0.71
Brick	0.03	R-0.2
Glass	0.025	R-0.14
Poured concrete	0.014	R-0.08
Steel stud	5.3x10-4	R-0.003

Source: Autodesk Sustainability workshop (2013)

2.4.2 Day lighting

Heat transfer through a window involves all three modes of heat transfer; conduction, convection, and radiation. The dominant mode of heat transfer is always changing and depends on the time, the ambient and interior temperatures, the exterior wind speed, and the amount and angle of solar radiation that strikes the window (Nadel, 2006).

Bugaje (2006) argued that windows ("glazing") let light and radiation through, there are a host of properties that must be considered to optimize their thermal and visual performance. For example, a simplified metric used to specify radiant heat transfer through the window when solar energy strikes the window is called the solar heat gain coefficient (SHGC). The **SHGC** is a value between 0 – 1.0 and is a measure of how much radiant heat transfer will occur relative to an unglazed opening. Three of the most important properties of the materials, coatings, and constructions that make up windows, skylights, translucent panels, or other products used to let sunlight into a building include:

i. Thermal conductance (U-value)

ii. Solar Heat Gain Coefficient (SHGC)

iii. Visible Light Transmittance (Tvis)

i. Thermal conductance (U-value):

The rate of heat transfer per unit area, per unit temperature difference from the hotter side to the colder side. This is W/(m²K) in SI units, BTU/(h°F ft²) in Imperial units. The size of the air gap between glazing's, the coatings on the glazing's, the gas fill between glazings, and the frame construction all influence the U-factor (Nadel, 2006).

ii. **Solar Heat Gain Coefficient (SHGC):**

Solar Heat Gain Coefficient (SHGC) measures how much of the incoming heat from sunlight gets transmitted into the building, versus how much is reflected away. Heat from the sun is long-wave radiation (infrared and other non-visible light). The SHGC depends upon the type of glass and the number of panes, as well as tinting, reflective coatings, and shading by the window or skylight frame (Diesendorf, 2007).

The SHGC is a dimensionless number between zero and one. SHGC can theoretically range from 0 to 1, with 1 representing no resistance (all of the heat from the incoming sunlight comes through) and 0 representing total resistance (none of the sun's heat reaches the inside). SHGC values for real products typically range from about 0.9 to 0.2 (Humphreys, 2009).

According to Buck & Young (2006), Choosing the right SHGC depends on the size and placement of the apertures as well as climate and other design factors. The SHGC is especially important in hot sunny climates (where cooling is the dominant thermal issue), and you should generally use glazing with lower SHGC (below ~0.4). Buildings in cold climates should generally have higher SHGC to enable passive solar heating and to reduce heating loads.

The SHGC for ordinary uncoated, un-tinted glass can be 0.9, while values can be as low as 0.25 or even 0.15 for some specialized glazing units. In spectrally selective glazing, the SHGC can be independent of visible light transmission. The Light to Solar Gain ratio is used to measure the effectiveness of spectrally selective glazing and is visible light transmittance divided by solar heat gain coefficient (Nadel, 2006).

iii. **Visible Light Transmittance (VT)**

The percentage of visible light that passes through a window or other glazing unit is called the Visible Light Transmittance (Tvis or VLT). An opaque wall would have a Tvis of 0%, while an empty opening would have 100%; many un-tinted glass and plastic materials have a Tvis of 90% or more. Tvis does not measure shorter-wavelength light like UV or longer-wavelength light like infrared--only visible light.

More light is often not better, as it can cause glare and overheating. Tints, frits, and coatings can be chosen to produce any Tvis; common values are often 30 - 80%.

Tvis is influenced by the colour of the glass (clear glass has the highest Tvis) as well as by coatings and the number of glazing (Autodesk Sustainability Workshop, 2013).

2.4.3 Building energy load

Energy load is the amount of energy a building needs. These demands can be provided by electricity, fuel, or by passive means (Bugaje, 2006).

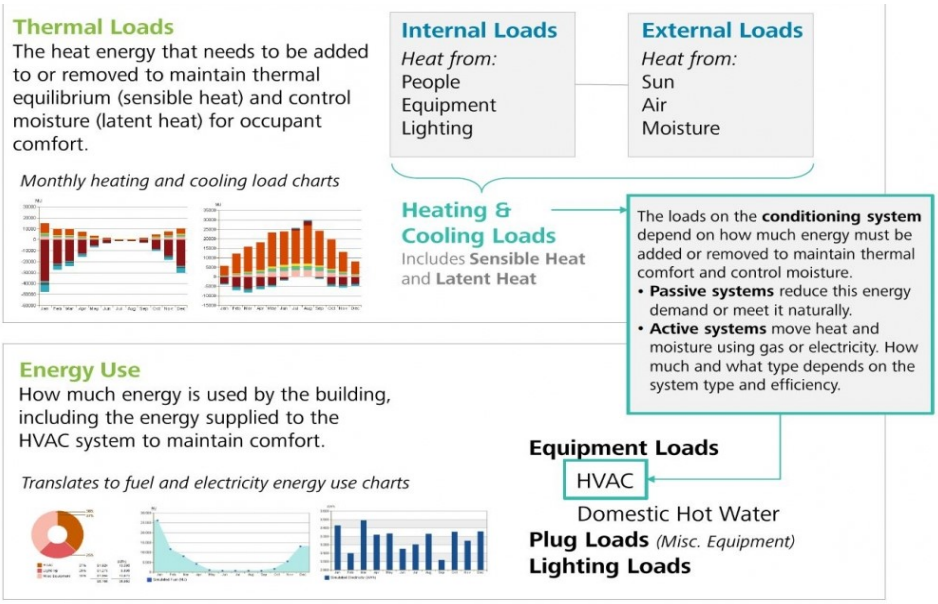


Fig 2.4: Building energy and thermal loads
Source: Autodesk sustainability workshop, (2003).

Fig 2.4 identifies and categorises the different kinds energy used in a building and the energy which is also used by the building. Heating and cooling loads are met by the building's HVAC system, which uses energy to add or remove heat and condition the space. This energy use translates to the HVAC component of a building's equipment loads (met by fuel or electricity).

Other building loads include plug loads (electricity used for computers and appliances) and lighting loads (electricity used for lights).

Most energy intensive buildings are hospitals and retail stores due to their high process/plug loads and their end use service. The next range belongs to residential sector including high-rise, mid-rise and mixed use (commercial/residential) buildings. The relatively high portion of gas consumption in high-rise buildings is comparable to gas consumption in hospital/health care applications whereas the total energies are not analogous (Pershing, 2005).

The International energy agency (2013), estimated that as much as 30% of the energy consumed in buildings is wasted. This suggests a significant opportunity for energy use reduction, cost savings, and the mitigation of greenhouse gas emissions through cost-effective energy efficiency opportunities. To help identify the best opportunities, both from the perspective of the building owner and the utility, it is important to examine how, where, and when energy is used and the savings likely to occur.

2.4.4 Climatic factors

Climate is a re-occurring pattern of generalities and averages that relate to temperature, humidity, precipitation, and air movement. It can be defined as how hot or cold it is in a certain place over a long period of time. It is specific to conditions driven by solar and lunar cycles in concert with water, soils, and geology. Its location is affected by its latitude, terrain, altitude, ice or snow cover, as well as nearby water bodies and their

currents. Within any climate, there are times when human comfort can be achieved without mechanical intervention and times when it cannot (Smith, 2003).

According to Nordhaus (2007), there are different climate factors that must be considered in civil operations, building constructions and building designs. The most significant climate factors are as follows: weather temperature, soil temperature, angle and intensity of sunlight, relative humidity, direction and wind speed, rainfall and sunlight.

2.4.5 Occupants' factor

Janda (2009) argued that, buildings do not consume energy, it is people that consume energy particularly in the demand for comfort.

Occupant comfort in buildings is primarily an embodiment of thermal, visual and indoor air quality (Dawson, 1982). Occupants comfort has a wide variance globally, owing to climate, individual preferences, age, gender, activity (metabolic rate) and duration of occupancy. That is, depending on the building's purpose and climatic location, the energy demand may vary in the fulfilment of the three comfort components named above and other associated energy requirements (Humphreys, 2009).

Achieving occupant comfort is a priority that has a great effect on energy demand, particularly in cold climate zones. Maintaining a proper interior environment involves contrasting heat gain and loss. This gain and loss can vary broadly among building types. For instance, buildings with a high electrical load, such as data centres, will have a high heat gain and an emphasized strategy for the removal of heat. However,

Table 2.3 : Effects of Clothing and different behaviours on thermal comfort

BEHAVIOR	EFFECT	OFFSET
Jumper/Jacket on or off	Changes Clo by ± 0.35	± 2.2K
Tight fit/Loose fit clothing	Changes Clo by ± 0.26	± 1.7K
Collar and tie on or off	Changes Clo by ± 0.13	± 0.8K
Office chair type	Changes Clo by ± 0.05	± 0.3K
Seated or walking around	Varies Met by ± 0.4	± 3.4K
Stress level	Varies Met by ± 0.3	± 2.6K
Vigour of activity	Varies Met by ± 0.1	± 0.9K
Different postures	Varies Met by ± 10%	± 0.9K
Consume cold drink	Varies Met by -0.12	+ 0.9K
Consume hot drink/food	Varies Met by +0.12	- 0.9K
Operate desk fan	Varies Vel by +2.0m/s	+ 2.8K
Operate ceiling fan	Varies Vel by +1.0m/s	+ 2.2K
Open window	Varies Vel by +0.5m/s	+ 1.1K

Source: Humphreys (2009)

Table 2.3 shows how clothing and different behaviours affect individual's thermal comfort . Residential buildings tend to have less internal heat gains, and the enclosure is more important in maintaining the internal environment temperature efficiently (Straube, 2005).

Also, occupants have the option of adding or removing clothing to adapt to the thermal conditions.

According to the ANSI/ASHRAE Standard 55-2010, thermal comfort is define as "that condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation. Also known as human comfort, thermal comfort is the occupants' satisfaction with the surrounding thermal conditions and is essential to consider when designing a structure that will be occupied by people.

A cold sensation will be pleasing when the body is overheated, but unpleasant when the core is already cold. At the same time, the temperature of the skin is not uniform on all areas of the body. There are variations in different parts of the body that reflect the

variations in blood flow and subcutaneous fat. The insulative quality of clothing also has a marked effect on the level and distribution of skin temperature. Thus, sensation from any particular part of the skin will depend on time, location and clothing, as well as the temperature of the surroundings.

According to Fanger (1970), there are six factors to take into consideration when designing for thermal comfort. Its determining factors include the following:

i. **Metabolic rate** : The energy generated from the human body
ii. **Clothing insulation** : The amount of thermal insulation the person is wearing
iii. **Air temperature**: Temperature of the air surrounding the occupant
iv. **Radiant temperature**: The weighted average of all the temperatures from surfaces surrounding an occupant
v. **Air velocity**: Rate of air movement given distance over time
vi. **Relative humidity**: Percentage of water vapour in the air

Thermal comfort is calculated as a heat transfer energy balance. Heat transfer through radiation, convection, and conduction are balanced against the occupant's metabolic rate. The heat transfer occurs between the environment and the human body, which has an area of 19 ft^2. If the heat leaving the occupant is greater than the heat entering the occupant, the thermal perception is "cold." If the heat entering the occupant is greater than the heat leaving the occupant, the thermal perception is "warm" or "hot."

A method of describing thermal comfort was developed by Ole Fanger and is referred to as Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD) (Bureau of Energy Efficiency, 2013).

Predicted Mean Vote

The Predicted Mean Vote (PMV) refers to a thermal scale that runs from Cold (-3) to Hot (+3), originally developed by Fanger and later adopted as an ISO standard. The original data was collected by subjecting a large number of people (reputedly many thousands of Israeli soldiers) to different conditions within a climate chamber and having them select a position on the scale; the best described their comfort sensation. A mathematical model of the relationship between all the environmental and physiological factors considered was then derived from the data (Bureau of Energy Efficiency, 2013).

Table 2.4 relates the size thermal comfort factors to each other through heat balance principles and produces a sensation scale ranging from -3 to 3.

Table 2.4: Predicted Mean Vote Sensation Scale

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

Predicted Mean Vote sensation scale

Source: Bureau of Energy Efficiency (2013)

The recommended acceptable PMV range for thermal comfort from ASHRAE 55 is between **-0.5 and +0.5** for an interior space.

Predicted Percentage of Dissatisfied

Predicted Percentage of Dissatisfied (PPD) predicts the percentage of occupants that will be dissatisfied with the thermal conditions. It is a function of PMV, given that as PMV moves further from 0, or neutral, PPD increases. The maximum number of people

dissatisfied with their comfort conditions is 100% and, as you can never please all of the people all of the time, the recommended acceptable PPD range for thermal comfort from ASHRAE 55 is **less than 10% persons dissatisfied** for an interior space (Bureau of Energy Efficiency, 2013).

2.5 Energy Demand in Shopping Malls

There are differences in energy use and system solutions due to local outdoor climate, available energy resources, prices, national building regulations, and traditions (Stensson, 2009).

Shopping malls overall tends to have large lighting loads, high population density and, hence, a large air conditioning demand. There is also an apparent trend towards increasing glass surfaces and such design feature affects the energy balance of the building. For those interested in the energy efficiency of the building and its installations, it is interesting to know how different system solutions affect the energy use (Gruen & Smith, 2006).

Previous studies have shown that much of the energy used in malls and shopping centres is dedicated to the provision of light and temperature control. In a study of four recently constructed fully air-conditioned malls in Hong Kong, ranging from 2 to 4 storeys, with floor space ranging from 6,550 to 29,900 m3, it was found that 85% of energy use was dedicated to the provision of lighting and air-conditioning. With a large percentage of energy use in these buildings devoted to temperature control, usage exhibited seasonal fluctuations (Howell, 1981).

An energy audit study of a 16,000 m3 Turkish shopping centre housing a restaurant, a hypermarket, a playground, other retail outlets, and offices, notes that energy requirements are not constant from day to day, due to varying occupancy patterns and to seasonal fluctuations. The occupancy patterns impact energy usage as they determine

the demand for the provision of occupant comfort via the heating, ventilation and air-conditioning (HVAC) systems. It was determined that HVAC and lighting systems accounted for approximately 50% of total electricity use, and that fuel use was distributed unevenly across the various tenants, with the restaurant and the heating system accounting for almost equal proportions of approximately 15% each. The authors conclude that the most cost effective way of increasing energy efficiency for this particular shopping centre would be through improvements in HVAC controls (Canbay , 2004).

In shopping malls, energy purchased for the shopping mall corresponds to the building service energy and it is mainly used for the heating, ventilation and air-conditioning (HVAC) system. Even though the tenant electricity (electricity purchased by the tenants and used for lighting and other installations in the shops) is not considered in the energy declaration, it still highly affects the total energy use and the energy balance of the building (Stensson, 2009).

Supermarkets, which are often major tenants of malls or shopping centres, are relatively intense energy users, largely due to their refrigeration needs. A study conducted in California, that examines five available thermal distribution systems that are appropriate for use in large (> 2000 m3) commercial buildings in California (one supermarket and 3 office buildings), finds that air leakage and conduction losses vary with the choice of distribution system (Xu *et al*., 2002). Another study posits that refrigeration equipment accounts for approximately one half of the energy use in supermarkets (Ducoulumbier , 2006).

2.6 Shopping Malls

A shopping mall is a modern, chiefly North American, term for a form of shopping precinct or shopping centre, in which one or more buildings form a complex of shop representing merchandisers with interconnecting walkways that enable customers to walk from unit to unit (Ballard, 1981).

Shopping malls didn't just happen. They are not the result of wise planners deciding that suburban people, having no social life and stimulation, needed a place to go (Bombeck, 1985). The mall was originally conceived of as a community centre where people would converge for shopping, cultural activity, and social interaction (Gruen & Smith, 1960).

According to Samuel Feinberg (1960) shopping centres got their start a bit earlier, in 1907, in a Baltimore neighbourhood where a group of stores established off-street parking. Malls are now the retail, social and community centres of their communities. Indeed, shopping malls are the centre pieces for rejuvenation of urban centres. The largest mall in the world, has over 800 stores, ice skating, 24 movie screens.

One of the earliest examples of public shopping malls comes from ancient Rome, in forums where shopping markets were located. One of the earliest public shopping centres is Trajan's Market in Rome located in Trajan's Forum. Trajan's Market was probably built around 100-110 CE by Apollodorus of Damascus, and it is thought to be the world's oldest shopping centre (Burstiner, 1986).

The competitive environment that a mall faces is considerably different from that faced in their early days when their primary competition was a downtown business district. Many of the best "locations" are gone so that a mall's primary competition is now likely to be another mall (Jacobs, 1986).

The enviable success and impact of the shopping mall may have something to do with the potential of shopping malls to enhance community life, there is no conflict between shopping malls, profits, and people. The basis for a shopping mall is to make it an "indispensable servant of the community" (Rouse, 1962).

2.6.1 Types of shopping malls.

The International Council of Shopping Centres (2013), classifies shopping malls into eight basic types:

i. **Neighbourhood Centre:**

Neighbourhood centres are small-scale malls serving the local neighbourhood. They typically have a supermarket or a drugstore as an anchor, and are commonly arranged in a strip mall format. Neighbourhood centres usually have a retail area of 30,000 to 150,000 square feet (2,800 to 13,900 m2), and serve a primary area in a 3-mile (4.8 km) radius. They are sometimes known as convenience centres (International Council of Shopping Centres, 2013).

ii. **Community Centre :**

Community malls are larger than neighbourhood centres, and offer a wider range of goods. They usually feature two anchor stores which are larger than that of a neighbourhood centre's, e.g. a discount department store. They may also follow a strip configuration, or may be L- or U-shaped. Community centres usually feature a retail area of 100,000 to 350,000 square feet (9,300 to 32,500 m2) and serve a primary area of 3 to 6 miles (4.8 to 9.7 km) (International Council of Shopping Centres, 2013).

iii. **Regional Centre:**

According to the International Council of Shopping Centres (2013), A regional mall is a shopping mall which is designed to service a larger area than a conventional shopping mall. As such, it is typically larger with 1,000 sq ft

(93 m^2) to 800,000 sq ft (74,000 m^2) gross leasable area with at least two anchor stores and offers a wider selection of stores. Given their wider service area, these malls tend to have higher-end stores that need a larger area in order for their services to be profitable but may have discount department stores. Regional malls are also found as tourist attractions in vacation areas.

iv. Superregional Centre:

mall with over 800,000 sq ft (74,000 m^2) of gross leasable area, three or more anchors, mass merchant, more variety, fashion apparel, and serves as the dominant shopping venue for the region (25 miles) in which it is located.

v. Fashion/Specialty Centre:

Fashion or specialty centres feature upscale apparel shops and boutiques and cater to customers with higher incomes. They usually have a retail area ranging from 80,000 to 250,000 square feet (7,400 to 23,200 m^2) and serve an area of 5 to 15 miles (8.0 to 24.1 km).

vi. Power Centre:

Power centres are large shopping centres that almost exclusively feature several big-box retailers as their anchors. They usually have a retail area of 250,000 to 600,000 square feet (23,000 to 56,000 m^2) and a primary trade area of 5 to 10 miles (8.0 to 16.1 km).

vii. Theme/Festival Centre:

Theme or festival centres have distinct unifying themes that are followed by their individual shops as well as their architecture. They are usually located in urban areas and cater to tourists. They typically feature a retail area of 80,000 to 250,000 square feet (7,400 to 23,200 m^2).

viii. Outlet Centre:

An outlet mall (or outlet centre) is a type of shopping mall in which manufacturers sell their products directly to the public through their own stores. Other stores in outlet malls are operated by retailers selling returned goods and discontinued products, often at heavily reduced prices.

2.6.2 Shopping mall facilities

Shopping malls house a variety of commercial activity types such as medical clinics, retail stores, supermarkets, food services, hotels, swimming pools, hair salons, offices, etc. In order to house a large set of tenants, these buildings have design characteristics that are different from most other commercial buildings. These design characteristics, along with tenancy characteristics, location, and the extent of energy conservation measures that have been adopted, are expected to play an important role in the patterns of energy utilization of different shopping centres and malls (Young and Buck, 2006).

Shopping malls are one of the largest contributors to the stock of parking spaces. A typical shopping mall has 4-6 parking spaces per 1,000 sq. ft. of gross leasable area (International Council of Shopping Centres and Urban Land Institute, 2003).

2.6.3 Current trends in shopping malls

The trends helping to create change include changing demographics, such as an aging population and increased urbanization, which means more people living in smaller spaces and a greater need for public spaces in which to socialize and congregate. In this environment, malls offer a welcome watering hole, especially in cities where other public spaces are not safe (Ahmed, 2012).

Sustainability concerns are causing some consumers to prefer mixed use developments where they can live, shop and work all within walking distance instead of having to get into a car and drive to a crowded suburban mall (Stensson, 2009).

The e-commerce revolution and the rise of digital technologies are fundamentally reshaping consumer expectations and shifting the function of stores toward useful and entertaining customer experiences. Innovative malls are incorporating value added elements that attempt to recast the mall as the new downtown, including concerts, arts centres, spas, fitness clubs, and farmer's markets. These services provide a level of leisure and entertainment that can never be satisfied online (Janda, 2009).

Malls are using technology to transform mall usability as a means of improving customer satisfaction. There is many opportunities for malls to decrease customer pain points, while simultaneously creating entirely new delight points. Technology, for instance, can be used to address one of the biggest challenges shoppers face at the mall i.e. finding parking, Sensors located in parking lots detect how many spots are available and give visual indicators to drivers. Once within the mall, mobile apps can offer quick, easy guides to help shoppers find what they are looking for at today's increasingly large and multi-level malls (Ahmed, 2012).

High land prices in populous cities have led to the concept of the "vertical mall," in which space allocated to retail is configured over a number of stories accessible by elevators and/or escalators (usually both) linking the different levels of the mall. The challenge of this type of mall is to overcome the natural tendency of shoppers to move horizontally and encourage shoppers to move upwards and downwards (Kim, 1998).

2.6.4 Spatial organization of a shopping mall

This has to do with the general planning of the site and facilities in such a way that the activity relationship are well co-ordinated to create a harmonious grouping and ease of circulation. In a shopping mall, there are wide ranges of activities taking place. Hence, it is important to have a good circulation pattern to ease movement within the facility and avoid rowdiness (Bombeck, 1985).

Isfahan City Centre

This a large commercial and entertainment complex in Isfahan, Iran.It is the largest shopping mall in Iranand one of the largest shopping malls containing a museum in the world. Built in four phases, the Centre covers approximately 465,500 square metres and includes a 5 star hotel, a general shopping mall with more than 750 retail outlets, a museum, a hypermarket, restaurants, airline offices, an international financial centre (IFC) and a World trade centre (WTC), and an entertainment centre with seven cinema screens and a fair complex. The mall is developed by Prestige Land Iran Co. and was designed by the architect Medardo Cadiz of Cadiz International, Inc.

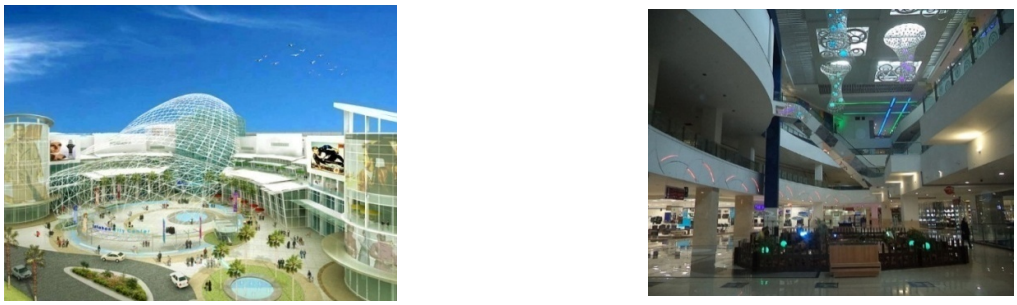


Figure 2.5: Views Of Isfahan City Centre

Source: Haidar (2013)

West Edmonton Mall

It is located in Edmonton, Alberta, Canada, is the largest shopping mall in North America and the tenth largest in the world (along with The Dubai Mall) by gross

leasable area. The mall was founded by the Ghermezian brothers, who emigrated from Iran in 1959. It was the world's largest mall until 2004.

West Edmonton Mall covers a gross area of about 490,000 m^2. There are over 800 stores and services in the compound, and parking for more than 20,000 vehicles.More than 24,000 people are employed at the property. The mall receives 32.2 million visitors per year; it also attracts between 90,000 and 200,000 shoppers daily, depending on the day and season. Fig 2.6 is the floor plan of West Edmonton Mall and shows the bay, world water park and galaxy amusement park amongst others.

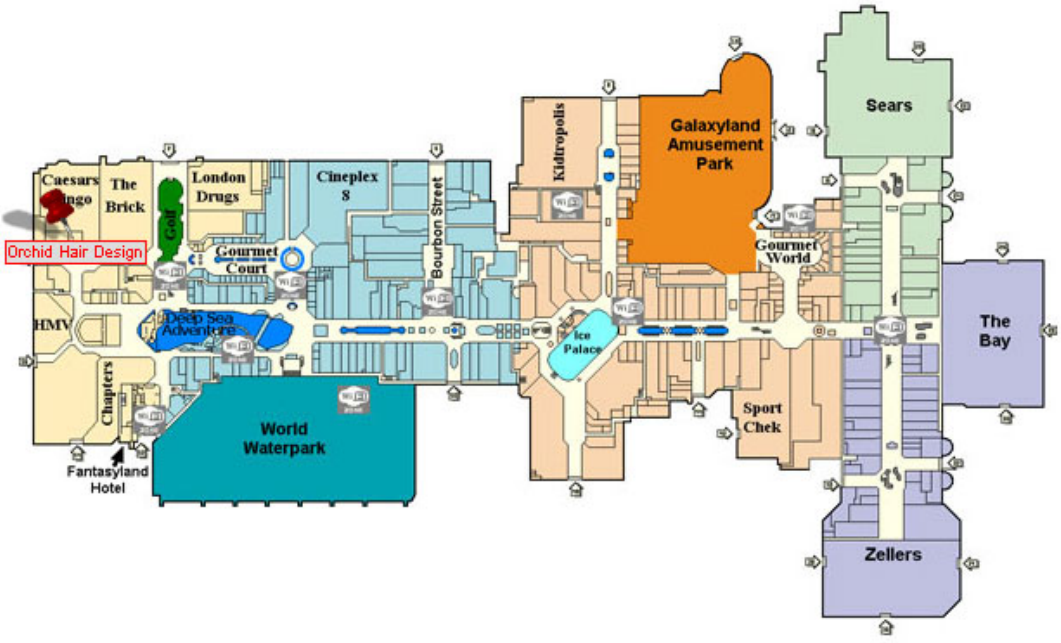


Figure 2.6: Floor Plan of West Edmonton Mall
Source: International Council of Shopping Centres (2013)

2.7 Sustainable Design

Sustainable design process is driven by a number of factors, with the goal of providing a functional, cost-effective, and healthy living environment. It governs all attributes, such as the geometry, orientation, materials and construction methods.

According to Kim (1998), Sustainable design is the thoughtful integration of architecture with electrical, mechanical, and structural engineering. In addition to concern for the traditional aesthetics of massing, proportion, scale, texture, shadow, and light, the facility design team needs to be concerned with long term costs: environmental, economic, and human.

"Choosing a good building shape and orientation are two of the most critical elements of sustainable architectural design" (Ghani, 2012).

Environmental design best practices and goals are achieved through attention to proper siting, building form, glass properties and location, material selection, heating, cooling, ventilation, day-lighting, and increasingly, water conservation through efficient plumbing fixtures(Nadel, 2006).

Building footprint must be decided upon early in the planning stages and has a profound impact on energy consumption. Thus, selecting the optimal building geometry is a critical early step in the design of sustainable buildings (Canbay, 2004).

In Architecture, there are many ways a building may be "green" and respond to the growing environmental problems of our planet. Sustainable architecture can be practiced still maintaining efficiency, beauty, layouts and cost effectiveness. There are five basic areas of an environmentally oriented design. They are Healthy Interior Environment, Energy Efficiency, Ecological Building Materials, Building Form and Good Design (Ghani, 2012).

2.7.1 Principles of sustainable design

Economy of resources, life cycle design and humane design are principles that serve as a guide for architects to formulate concepts and strategies in designing sustainable buildings.

The principles of environmentally oriented design comprise yet another meaningful and environmental building approach called Green or Sustainable design. Architects should use their creativity and perception to correlate principles to generate locally appropriate strategies, materials and methods keeping in mind that every region should employ different green strategies (Ghani, 2012).

Kim(1998) proposes three principles of sustainability in architecture, namely;Economy of Resources, Life Cycle Design, and Humane Design.

Economy of Resources is concerned with the reduction, reuse, and recycling of the natural resources that are input to a building.

2.7.1.1 Life cycle design

Life cycle design provides a methodology for analysing the building process and its impact on the environment (Kim, 1998).

2.7.1.2 Humane design

Humane design focuses on the interactions between humans and the natural world. These principles can provide a broad awareness of the environmental impact, both local and global, of architectural consumption (Kim, 1998).

2.7.2 Sustainable architectural design strategies to improve energy efficiency in shopping malls.

There are many motivations to improve energy efficiency. Reducing energy used in buildings helps in reducing the amount of carbon dioxide emissions and control global emissions of greenhouse gases to the atmosphere. It also reduces energy costs and may result in a financial cost saving to consumers if the energy savings offset any additional costs of implementing an energy efficient technology.According to the International Energy Agency, improved energy efficiency in buildings, industrial processes

and transportation could reduce the world's energy needs in 2050 by one third. (Nadel, 2006).

Sustainable building envelope design, Ecological building materials, sustainable mechanical and electrical appliances, and sustainable construction are key strategies to consider in this study.

2.7.2.1 Building envelope design

Building envelope improvements can improve occupant comfort and the quality of life to millions of people, while offering significant benefits such as reduced health care costs and reduced mortality of "at risk" populations. The building form should respond to the site, region, climate and the materials available thereby generating a harmony between the inhabitants and the surroundings (Ducoulombier, 2006).

The optimization of the efficiency of the building envelope can be achieved by adequate insulation, air-tightness and optimized glazing, which allows the passive use of solar gains in cold climates or limiting solar impact in hot climates. The top priority is reduction of energy losses in cold regions or control of energy gains in hot regions. Only if the building itself is energy efficient advanced technologies using renewable energy sources work efficiently as well (Ghani, 2012).

Design strategies such as building orientation and architectural features to minimize solar gains in dry season and maximize the availability of usable day lighting combined with properly controlling the heating, ventilating, air-conditioning, and lighting systems are an example of an integrated design approach to optimize the building's energy performance (Agboola, 2011).

According to Samuel (2011) passive design strategies should be used to produce ambient energy sources instead of purchased energy like electricity or natural gas. These strategies include daylighting, natural ventilation, and solar energy.

To determine appropriate building form to maximise natural lighting and ventilation for specific climate and location, window sizes, spacing, courtyards to optimise natural lighting, building depth and location, and operation of openings in external walls to optimise natural ventilation must be considered (Sustainable design strategies, 2001).

Design considerations

i. Use high levels of well-insulated thermal mass.
ii. Select site for exposure to cooling breezes; design for cross-ventilation and night purging.
iii. Use north-facing, high thermal mass living areas with passive solar access (see Passive solar heating).
iv. Limit external wall area.
v. Consider compact floor plans with central, closable stack ventilation shafts or solar chimneys.
vi. Consider mechanical ventilation of ceiling spaces to ensure high level flows of cooler (south-side) air in summer and a complete seal in winter.
vii. Provide screened, shaded outdoor living areas that allow winter sun penetration.
viii. Use garden ponds and water features to provide evaporative cooling.

Designing basic elements of the building envelope (roofs, walls, windows and skylight) properly can improve energy efficiency of the building. For example:

i. Wall

Decisions regarding the appropriate material can be more complicated because the energy properties of the entire wall are affected by the design. Importantly, material selection and wall insulation can both affect the building's thermal properties.

In warm climates, the interior surface temperature is also close to the indoor air temperature which means that it is lower than that of poorly insulated components which allow heat to be transported from the outside towards the inside. Highly insulated constructions have a high temperature amplitude attenuation reducing the temperature fluctuation of external building components, even with very small masses (e.g. double plaster board) (Ahmed, 2012).

ii. Roof

Roof design and materials can reduce the amount of air conditioning required in hot climates by increasing the amount of solar heat that is reflected, rather than absorbed, by the roof. In addition, roofs also offer several opportunities for installing on-site generation systems. Solar photovoltaic (PV) systems can either be installed as a rooftop array on top of the building or a building-integrated photovoltaic system can be integrated into the building as roofing tiles or shingles (Sassi, 2006).

A roofing system through shading, insulation, evapo-transpiration and thermal mass, thus reducing a building‘s energy demands for space conditioning. The green roof moderates the heat flow through the roofing system and helps in reducing the temperature fluctuations due to changing outside environment (Ghani, 2012).

Light coloured roofs should be used instead of dark roofs, this is because bright colours reflect heat while dark colours absorb and transfer the heat to the interior space.

Another roofing material well suited to warm climates is flat concrete tiling, and as mentioned earlier, it is available in cool colours. A close, but lighter-weight version is the bright white flat tile made of ceramic, elastomeric material or combinations of fibers and cement. These white flat tiles rank high in testing as both very heat-reflective and long lasting. Flat white cement tiles reflect as much as 77 percent of the sun's rays (Better Homes and Gardens, 2011). As with the white barrel type, white flat tiles keep

heat from filtering down into buildings. Some upkeep comes with white roofing, as with most roof types, and power-washing helps to keep the surface from becoming dingy and losing its reflective edge over more traditional shingles (Samuel, 2011).

Basic clay roofing is light in colour and does not retain as much heat as a darker roof. Modern clay tiles have paint treatments to make them look like more expensive slate or traditional terra cotta and to add weatherproofing and reflective capabilities. Traditional rust or sienna-colored terra cotta tiles keep buildings cool through their shape as much as their composition. Terra cotta tiles go through a baking process in ovens, or kilns, which makes them harder and less porous in terms of holding lots of heat. Most often,they are molded into a half-barrel or "S" shape, forming interlocking arches across a roof. Space beneath the arch of each tile allows for air and water circulation and runoff, which prevents heat capture and keeps the home below cooler (Ghani, 2012).

Many clay and terra cotta roofs sit on top of concrete and stucco homes, and with good reason. These materials are heavy and need solid foundations for load bearing and wind and earthquake resistance. Another consideration with terra cotta roofing is that cold and wet weather often make tiles snap. Newer processes and treatments prevent this from happening, but checking for durability and temperature (Janda, 2009).

Sub-roof system called a radiant barrier application involves installing a reflective material, such as aluminium, or even a specialized reflective spray treatment that is installed into an attic or space between a home's interior and the roof. These act as barriers to keep heat up and out of a home (OAK ridge laboratory,2011).

According to Nadel (2006), roofing with slate tiles is a centuries-old European tradition that made its way to the Americas in the early 17th century Slate is durable and

beautiful, with a natural color range, and it lasts a long time with little maintenance. Light colored and earth-toned slate help in reducing the heat absorbed by a building because it has natural reflective properties. It also wears to a nice finish over time. Some downsides to using slate are its upscale price and heavy weight. While slate is among the most beautiful roofing treatments, Its extensive use worldwide is due to its popularity as a cool roofing material for hot climates and its widespread availability. In areas without natural slate reserves, it is an expensive option. Reclaimed or salvage slate is available in some areas, but installation and transport costs still add up.

Green roof is a roof of a building that is partially or completely covered with vegetation and soil that is planted over waterproofing membrane. If widely used green roofs can also reduce the problem of urban heat island that would further reduce the energy consumption in urban areas (EFCB).

iii. Windows, Doors, and Skylights

Collectively known as *fenestration*, windows, exterior doors, and skylights influence both the lighting and the HVAC requirements of a building.

In residential buildings, using optimum window design and glazing specification is estimated to reduce energy consumption from 10 to 50 percent below accepted practice in most climates; in commercial buildings, an estimated 10 to 40 percent reduction in lighting and HVAC costs is attainable through improved fenestration (Canbay, 2004).

According to centre for sustainable building research (2013), The energy impact due to windows in a building depends on climate, window orientation, window area, shading conditions, and window (frame and glazing) type.

Orientation: Homes with windows facing predominately north use less energy than homes facing east, south, or west. With high-performance windows and shading strategies, these differences can be considerably less (Kim, 1998).

Window Area: Energy use increases with window area using windows with clear and high-solar-gain glazing. With high-performance windows, energy use may not increase at all when using a larger window area (Kim, 1998).

Shading Condition: On north-facing buildings, shading devices will have little impact. On south-facing buildings, overhangs can be effective to block the hot summer sun. Shading devices have less impact when using high performance windows with low-solar-gain glazing (Dawson, 1982).

Low-E coating glass works like a thermal mirror with the low-E material on the back of the pane that reflects the heat radiation. The surface that is treated by the low-E coating material is selected based on the climate.

In multi-pane windows, thermal radiation from warmer pane to other pane is the main mechanism of heat flow. By applying low-emmitance material to the interior or exterior pane, depending on side that heat is meant to be kept, a significant amount of radiant heat transfer is blocked (Ghani, 2012). Table 2.5 shows different types of glazings and their respective U-values.

Table 2.5: U-values of some Glazing types

Glazing type	u-value(W/m^2k)	BTU/($h^oF\ ft^2$)
Single pane	4.8	0.85
Double pane, air filled	2.5	0.49
Double pane, low-E	2.1	0.37
Triple pane	2.1	0.37
Triple pane, low-E	1.4	0.25

Source : Ghani (2012)

Samuel (2011), argued that buildings with larger window areas use more energy than homes with smaller window areas. This may be true for windows with conventional clear glazing, however, with high performance windows, a home with a large window area can use the same amount of energy or even less energy than a space with a small window area.

Glazing design considerations:

i. Avoid overuse of glazing.
ii. Use low U-value glazing in all cases.
iii. Use double-glazing in regions with cooler winters.
iv. Use low SHGC glazing in regions with hot summers and mild winters.
v. Shade all east and west-facing glass in summer.
vi. Shade south-facing glass north of the tropic of Capricorn.

2.7.2.2 E*cological building materials*

Buildings use a lot of resources and materials so it's important to select materials with consideration to durability, thermal comfort, health effects on occupants, availability and impact to the global environment. This reduces the amount of energy consumed by

buildings, manufacture of building materials and amount of materials going to landfill as waste.

Design specifications should recommend bio-based building materials rather than building materials with too much embodied energy. Embodied energy refers to the energy required to extract, manufacture, transport, install, and dispose building materials (Ahmed, 2012).

Selecting adequate building materials can also make a big difference to the amount of resources used, pollution generated, and waste sent to landfill by re-using, recycling and buying recycled building materials for your home or renovation. These can be cheaper than new building materials (Department of industry, innovation and science, Australia).

Careful selection of environmentally sustainable building materials is the easiest way for architects to begin incorporating sustainable design principles in buildings. Traditionally, price has been the foremost consideration when comparing similar materials or materials designated for the same function. However, the "off-the-shelf" price of a building component represents only the manufacturing and transportation costs, not social or environmental costs (Kim, 1998). As far as possible, the use of building materials should be from renewable sources having relatively safe sources of production (Ghani, 2012).

2.7.2.3. Natural ventilation

Natural ventilation can save significant amounts of fossil fuel based energy by reducing the need for mechanical ventilation and air conditioning. Reduced use of air conditioning reduces greenhouse gases released into the atmosphere from electricity generating plant that produces the energy used for cooling buildings (Nadel, 2006).

In many design situations, boundaries and constraints limit the application of innovative actions. In these circumstances, designers should at least consider the following:

i. Take advantage of wind in the design of the site layout and building form.
ii. Orient buildings to maximise their exposure to the prevailing wind direction.
iii. Design buildings with a relatively narrow plan form across the prevailing wind direction, to facilitate the passage of air through the building.
iv. Locate wall openings to facilitate the passage of air through the building.
v. Use passive evaporative cooling methods in hot dry climates, by passing incoming air over or through wetted surfaces.
vi. Utilise ceiling fans where appropriate to minimise the need for refrigerated air conditioning.
vii. Horizontal openings near floor level are more effective than vertical openings, for ventilation purposes.
viii. Elevate rooms above the ground to catch stronger winds (Ghani, 2012).

2.7.2.4 Sustainable mechanical and electrical appliances

A sustainable mechanical and electrical design should aim at reducing energy consumptions in mechanisms for heating, cooling, ventilation, lighting, and other electricity consumed appliances. Computer applications can be used to switch on or off appliances when not in use. Renewable sources of energy should also be provided.

It has to be well ensured that the building's use of energy is minimized. The various HVAC systems and methods of construction etc. should be so designed that energy consumption is minimal (Ghani, 2012).

Pershing (2005) argued that benchmarks should be applied mainly to heating, cooling, air-conditioning, ventilation, lighting, fans, pumps and controls, office or other

electrical equipment, and electricity consumption for external lighting. The benchmarks used vary with the country and type of building.

Recent attempts to improve energy efficiency in supermarkets often exploit a set of related features that create synergies. Careful design planning can allow the lighting system to optimize energy use when used in conjunction with skylights and windows. Air systems can be designed to optimize energy usage in conjunction with insulation features, and heat can be reclaimed from equipment used in the supermarket in order to reduce the use of heating fuels (Diesendorf, 2007).

When selecting energy efficient appliances and operating systems, the following should be considered:

i. Efficiency of lights, sensor systems, cooling and heating
ii. Zone equipment systems for appropriate settings and more responsive occupation usage.
iii. Select energy efficient appliances and operating systems.
iv. Employ smart building management systems to minimise energy requirements.
v. Encourage inclusion of appropriate renewable energy forms (Sustainable design strategies, 2001).

2.7.2.5 Local climate

The local climate of a place dictates the nature of design, building materials and nature of energy required for operation in buildings. It is very important and wise to design with climate as an unfriendly climate can cause an alarming increase in the energy consumption of a building (Nordhaus, 2007).

Local climate is an important determinant for identifying the design features that will result in the greatest reductions of energy needs. These may include such things as

south-facing windows in cool climates and shading to avoid summer sun in hot climates (IEA, 2013).

Approximately 40% of household energy is used for heating and cooling to achieve thermal comfort. This rate could be cut to almost zero in new housing through sound climate responsive design and, indeed, should be our aspirational goal. Taking into account current consumer preferences and industry practices, halving the rate to 20% is a highly achievable in the short term.

Ahmed (2012) argues that to succeed in designing an optimized building, understanding of climate specific design principles. This means the overall concept of the construction has to respond to the local environment as well as to the intended use of the building. The main construction features for energy efficient residential or office buildings depend on the outdoor climate and can be summarized as follows:

i. **Cold climate**: Compact building design with very well insulated building envelope components; total fenestration area should be limited with very low U-value and high SHGC (solar heat gain coefficient); mechanical ventilation with heat recovery is essential.

ii. **Moderate climate**: Well-insulated building envelope with energy efficient fenestration (very low to low U-value, moderate to high SHGC depends on glazing area); operable shading systems required to prevent summer overheating; thermal mass and mechanical ventilation with heat recovery is beneficial (Ghani, 2012).

iii. **Hot and dry climate**: Well-insulated building envelope with limited fenestration area; glazing with very low SHGC and shading from direct sunlight in summer; reflective exterior envelope surfaces essential; solar powered AC equipment can provide day time cooling; thermal mass and lower night-time

temperatures provide comfortable indoor conditions after sunset (Humphreys, 2009).

iv. **Warm and humid climate**: Moderately insulated building envelope with limited fenestration area having low SHGC and effective shading devices; green (vegetated) roofs and/or reflective exterior envelope surfaces are beneficial; since the removal of latent heat (water vapour) matches the energy required for sensible cooling, investing in sophisticated ventilation and AC systems is essential to provide healthy and comfortable indoor air conditions without wasting energy (Ducoulombier, 2006).

2.7.2.6 *Site landscape elements*

i. Use water features in, or near a building to engender a sense of coolness.

ii. Use vegetation to modify the external wind direction, to enhance ventilation and cool incoming air.

2.7.2.7 *Sustainable construction*

Sustainable construction is defined as the creation and responsible management of a healthy built environment based on resource efficient and ecological principles. Sustainable designed buildings aim to lessen their impact on our

environment through energy and resource efficiency. Sustainable building involves considering the entire life cycle of buildings, taking environmental quality, functional quality and future values into account.

According to Stensson (2009), the demand for green, clean technology has become forefront in the construction trades as focus on the environment has trickled down to even the smallest decisions. New green technologies can be applied from the very beginning design and sitting process to the finishing touches of construction, satisfying the client's needs and using resources more efficiently. The concept of sustainable

building incorporates and integrates a variety of strategies during the design, construction and operation of building projects. The use of green building materials and products represents one important strategy in the design of a building. Green building materials offer specific benefits to the building owner and building occupants. Building and construction activities worldwide consume 3 billion tons of raw materials each year or 40 percent of total global use.

Use high thermal mass construction.

i. Where summer ground temperatures exceed 19°C at 3m depth, use insulated concrete slabs or insulated elevated lightweight floors with high thermal mass walls.
ii. Consider using earth-coupled slabs in all areas where deep ground temperatures are less than 19°C.
iii. Choose light coloured roof materials.

3.0 RESEARCH METHODOLOGY

3.1 Introduction

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). This approach was adopted for this study. It requires basic tools for data collection and analysis which include interview, visual survey which is incorporated into case studies in order to provide the researcher with information on the subject matter, secondary data from the cases visited and calculations/simulation. This is necessary in order to deduce the appropriate and practicable guideline needed in the design of the proposed facility.

The case study method ensures an accurate description on similar problems stated in the research and the existing solutions applied.

3.2 The Case Study Approach

Case study is a dominant approach in architectural research. 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 being researched (Veal, 2006).

According to Adeniyi (2001), case study can be seen as an empirical inquiry that investigates a contemporary phenomenon within its real life context using multiple source of evidence.

Sourcing information is an invaluable task and difficult in the context of most developing countries (Aina, 2002). The case study carried out on this research was documented based on the following headings: history and background; site planning and landscaping; spatial organization of buildings; structure and materials; and building services. This was then followed by the application of general data collection techniques.

3.3 Case Study Selection

Although a case study approach is not the same as sampling technique used in social science research (Akinwumiju, 2000), selective or purposive method was applied in selection of the buildings for the case study. Since the selected buildings constitute the unit of assessment, it is essential that they are similar in all respect as much as possible (Ahmed, 2012).

The population must have an anchor store and a cinema which is the state of the way of combining both entertainment and leisure facilities.

To properly select case studies best suited for this research, the following criteria were considered:

i. Its function
ii. The climatic zone to which the case belongs
iii. The scope of facility provided: this is to check the services, facilities, climatic zone, architectural characteristics, etc. provided and its correlation to the proposed facility.
iv. Their adaptation to sustainable design strategies: this is to check its success as it relates to energy conservation/efficiency (in materials used, energy sources, passive design application, etc.). Hence, the selected case studies were required to strongly satisfy the listed criteria.

From the listed criteria above, the following cases were selected due to their inherent qualities, they are all regional centre shopping malls which were in consonance with the phenomenon under investigation;

i. Silverbird Galleria, Abuja
ii. Ceddi Plaza, Abuja
iii. 2xL Mall, Abuja

The above case studies were also chosen deliberately to increase the likelihood of showing or expressing important variations of several features of the facility. This type of case study is illustrative. It is information-rich and can be used to illustrate an architectural style or issue.

3.4 Instrument of Data Collection

The instrument used for data collection in this research include;

3.4.1 Visual survey

This is a method of data collection in which the eyes is used to study and observe. This survey was guided by critical literature review guidelines. E.g. checklist. Visual survey was documented through tabulation, sketches, plates, figures, written reports, etc.

3.4.2 Secondary data

This involves data gotten from the management such as electrical design drawings and records of energy consumption. This helped to carry out statistical analysis on the cases.

3.4.3 Computer simulation

This involves the use of computer to test mathematically parameters such as lighting, ventilation etc. on a given model. Ecotect Analysis (2011) was used to compare the effects of different wall, roofing and window materials, to test the effect of buiding orientation and wall to window ratio . The results were used to determine the best building materials and strategies with respect to the least energy consumption.

3.5 Procedure of Data Collection

Visitations was made to each of the cases selected, visual survey inform of walking tours made around the site observing and identifying architectural features was made taking note of materials, finishes and spatial arrangements of their floor plans in order to analyse the collected data. Documentation will be made on;

i. Sustainable design features of the centres;

ii. Energy efficiency strategies applied in the design;

iii. Architectural design requirement used to achieve energy efficiency and

iv. Facilities provided and spatial organization of the design.

Visual survey was reflected using photographs which were taken of relevant case studies to ascertain the features of sustainable design, sketches was also made of some parts of the selected cases. These sketches show the spatial organization of the facilities.

3.6 Variables of the Case Study

From literature, the variables to be considered for this study are design dependent variables which pointed out the elements of sustainable design applied in the cases and their effect in energy reduction. They are;

i. The building envelope

ii. Natural lighting

iii. Natural ventilation

iv. Wall and window shading

v. Mechanical and electrical appliances

vi. Landscape elements

vii. Existing source of energy

3.7 Data Analysis

Data analysis was based on descriptive, visual and ranking system. A checklist was also employed to assess and record the extent to which sustainable design strategies were employed in the three centres based on Shape and form of the building envelope, orientation of the building, thermal heat capacity of the building materials, solar heat gain, passive means of ventilation, wall and window shading, water and electricity

consumption . A 5-point scale ranking system ranging from very inadequate-1point to very adequate-5point was used for scoring.

Using computer simulation to determine the factors affecting energy efficiency of shopping malls in Abuja, Ecotect Analysis, 2011 was used. The thermal properties of the contemporary design strategies of the shopping mall in question and other design strategies were used to analyse the lighting and cooling energy required per day.

4.0 RESULTS PRESENTATION AND DISCUSSION

4.1 Introduction

In this chapter, extent to which sustainable design strategies were applied in the design of shopping malls was carried out. The data gotten from the cases studied are described and a checklist was employed to access and record the level of application based on a 5-point scale ranking system ranging from Very Inadequate-1 Point, Inadequate-2 Points, Average-3 Points, Adequate-4 Points to Very Adequate-5 Points.

Computer based building energy simulation software have become increasingly popular in the past three decades (Agboola, 2012). These programs incorporate sets of mathematical models that seek to explain quantitatively how each component of a building behaves under given circumstances (Ahmed, 2012). This enables designer to evaluate appropriate design options and building performance based on a prototypical model.

4.2 Case Study One: Findings from Silver Bird Galleria

4.2.1 Background

The Silver-bird Galleria building is located in Abuja municipal area. This building is a High-rise structure, and was constructed in 2009. It is a six-storey building having total site area of 35,000sqm, the area of theatre complex is 3,700sqm, office tower is 296sqm, generator is 186sqm, security is 195sqm, landscaped area is 17% and paved area is 57.5%. It includes:

i. 12no.Screen multiplex cinemas
ii. 8no. VIP lounges
iii. Game arcade
iv. Retail shops
v. Stores

vi. Administrative offices

vii. Restaurants

viii. Parking spaces

ix. Outdoor retail stands

4.2.2 Findings from visual survey

At the silver bird galleria, it was observed that the source of energy consumption within the building are:

i. Lighting fixtures

ii. HVAC systems

iii. Cinema screens

iv. Escalators

v. Printers

vi. Television and sound systems

vii. Refrigerator

viii. Elevators.

Plate I represents the Aerial view of Silver bird Galleria Abuja showing the features of the site and the neighbouring environment.



Plate I: Aerial View of Silver Bird Galleria
Source: Author's case study research (2015)

4.2.3 Building envelope

The building envelope and its components are key determinants of the amount of heat gain/ loss and wind that enters into a building. The building form is rectangular elongated on the north-south axis It has concrete curtain walls having 225 mm thickness with extensive use of steel and glass material. All the windows are made of tampered glass which is reflective and double glazed. The roof is partly decked and drained with pipes at the exterior, while other areas are covered with fibreboards to serve as atriums and its interior floors are covered with decorative hardware tiling. The external finish of a surface determines the amount of heat absorbed or reflected by it, as shown in plate II. Also, Table 4.1 shows the thermal properties of the building envelope materials used.



Plate II: Perspective view of Silver Bird Galleria
Source: Author's case study research (2015)

Table 4.1: Thermal Properties of Materials at Silver Bird Galleria

Elements	Materials	Thermal Properties						
		Colour	U-value (W/m^2k)	Admittance	Solar absorption.	Emissivity	Reflectivity	Conductivity
Wall	Concrete block wall	Cream	1.800	3.360	0.506	0.90	0.549	0.431
Floors	Glazed Tiles	Grey	0.880	6.100	0.47520	0	0.573	0.837
Roof	Corrugated Aluminium roofing sheet	Red	7.140	7.100	1.000	0.89	0.624	0.075
Ceiling	Suspended ceiling	White	0.500	0.900	0.368	0.90	0.702	0.431
Doors	Glass door	Trans-parent	5.356	5.360	1.000	0.86	0.967	1.046
Windows	Single glazed all. win.	Tinted blue	6.000	6.000	SHGC 0.94	VT 0.753	0.725	1.046 RI=1.74

Source: Author's case study research (2015)

4.2.4 Natural lighting

Natural lighting through the use of windows and glazed reflective walls and covered atrium were introduced as seen in plates III and IV.



Plate III: Clear Glass Windows



Plate IV: Glazed Reflective Walls

source: Author's case study research (2015)

Occupants' choice of demarcating retail shops have succeeded in obstructing sources of daylighting and are using artificial lighting as alternative due to the lack of originally designed office spaces as seen in plates V and VI.



Plate V: Artificial Lighting



Plate VI :obstructed source of daylighting

source: Author's case study research (2015)

4.2.5 Natural ventilation

The windows used are fixed, despite the good orientation of the building, it cannot be naturally ventilated. Hence, artificial means of ventilation is being used.

4.2.6 Wall and window shading

Use of reflective glass for window without shading device and wall shading is prone to direct solar radiation.

4.2.7 Mechanical and electrical appliances

Energy saving bulbs, solar powered security lights and sustainable toilet wares to conserve energy are in place as shown in plates VII and VIII.



Plate VII: Energy saving bulbs



Plate VIII: solar powered security lights

source: Author's case study research (2015)

4.2.8 Landscape elements

The parking space can accommodate an average of 350 cars at a time. Plants are scanty and still growing on site. Concrete was used for parking lots and pavements. Presence of water fountains provided a means of sustainable cooling. Plates, IX, X and XI show the parking and landscape elements of the site.





Plate IX: landscape elements on the site



Plate X: Water Fountains on the Site



Plate XI: Parking Space at the Mall

Source: Author's case study research (2015)

4.2.9 Existing source of energy

An average of 280,000kwhof electricity is consumed monthly from PHCN and back-up generators of 1000kva, 1500kva and 2000kva . Water is supplied through the national grid by water board and presence of two boreholes as backup. Plate XII shows the three generators used as backup for the facility.



Plate XII: Generators Used As Backup for the Facility
Source: Author's case study research (2015)

4.2.10 Sustainable design strategies applied on the building elements

This section will evaluate the extent to which sustainable design strategies were applied on building elements. Details are seen on Table 4.2 using a 5-point scale ranking system ranging from very inadequate-1point, inadequate-2points, average-3points, adequate-4points to very adequate-5points.

Table 4.2: Sustainable Design Strategies Applied at Silver Bird Galleria

S/N	Variables	Checklist	Level of application					Remark
			1	2	3	4	5	
1	Building envelope	Sustainable building materials				✓		The building form is rectangular in shape and elongated on the north-south axis
		External insulation		✓				
		Use of bright colours for walls				✓		
		Use of bright colours for roofing sheet.		✓				
		Low embodied energy materials			✓			
		Sun orientation; E-W				✓		
		Wind orientation; SW-NE			✓			
2	Daylighting	Wall to window ratio (40%)				✓		The glasses used do not allow for heat gain in the interior
		Use of spectrally selected glasses				✓		
		Use of atriums or courtyard		✓				
3	Natural ventilation	Use of openable windows	✓					In flow of air from the exterior to the interior was not allowed into the building.
		Use of passive ventilation		✓				
4	Wall and window shading	Use of win. shading devices	✓					
		Use of interior blinds		✓				
		Use of recessed walls		✓				
		Use of roof overhangs		✓				
		Use of plants for shading		✓				
5	Mechanical and electrical appliances	Use of energy saving bulbs				✓		Incandescent bulbs were used in the cinemas
		Use of energy saving toilet wares			✓			
6	Parking and landscape elements	Thermal reflective parking spaces	✓					Materials used for parking and paving contributed immensely to the structure
		planting and Waterbodies		✓				
7	Existing Energy	Use of renewable energy for electricity		✓				Solar powered street lights were used for external lighting
		Use of natural gas	✓					

Source: Author's Case Study Research (2015)

4.3 Case Study Two: Findings From Ceddi Plaza

4.3.1 Background

The Ceddi Plaza building is situated in the central business district of the Abuja municipal area. This building is a High-rise structure, and was constructed in 2007. It is a six-storey building having total site area of 28,000sqm. Facilities in the building include:

i. 8no. Screen multiplex cinemas
ii. Game arcade
iii. Retail shops
iv. Stores
v. Administrative offices
vi. Restaurants
vii. Parking spaces
viii. Outdoor retail stands
ix. Basement floor for parking and shopping

4.3.2 Findings from visual survey

At the Ceddi Plaza, it was observed that the source of energy consumption within the building are:

i. Lighting fixtures
ii. HVAC systems
iii. Cinema screens
iv. Printers
v. Televisions and sound systems
vi. Refrigerators
vii. Elevators.

viii. Cooking equipment

ix. Ice cream machines

x. Popcorn machines

xi. Automated Teller machine

xii. Automatic Sliding door

4.3.3 Building envelope

The dominant building materials used on the building envelope are concrete walls, Curtain walls, and glass windows, cream paint on the outside, white patterned suspended ceiling and vitrified glazed tiles for the floors as shown in plate XIII.



Plate XIII: Building Materials used in the shopping mall
Source: Author's case study research (2015)

Table 4.3 Thermal Properties of the Building Envelope Materials used.

Elements	Materials	Thermal Properties						
		Colour	**U-value (W/m^2k)**	**Admittance**	**Solar absorption.**	**Emissivity**	**Reflectivity**	**Conductivity**
Wall	Concrete block wall	Cream	1.800	3.360	0.506	0.90	0.549	0.431
Floors	Glazed Tiles	Grey	0.880	6.100	0.47520	0	0.573	0.837
Roof	Corrugated Aluminium roofing sheet	Blue	7.140	7.100	1.000	0.89	0.624	0.075
Ceiling	Suspended ceiling	White	0.500	0.900	0.368	0.90	0.702	0.431
Doors	Glass door	Trans-parent	5.356	5.360	1.000	0.86	0.967	1.046
Windows	Single glazed all. win.	Tinted blue	6.000	6.000	SHGC 0.94	VT 0.753	0.725	1.046 RI=1.74

Source: Author's case study research (2015)

Table 4.3 shows the basic values of contemporary building materials used at ceddi plaza as required by Ecotect analysis 2011 for running simulations.

4.3.4 Natural lighting

The excessive use of clear glass for windows, skylight, and atrium in some parts of the building as seen in plates has contributed immensely to the heat gained during the daytime. This heat gain requires large amount of energy for cooling. Natural lighting was utilized for lighting the basement as an alternative for lighting with the use of electricity as seen in Plates XIV and XV.

Perforated metal was used for the Retail shop doors to allow the penetration of lighting even when the doors are shut as seen in plate XVIII.



Plate XIV:Clear Glass Windows

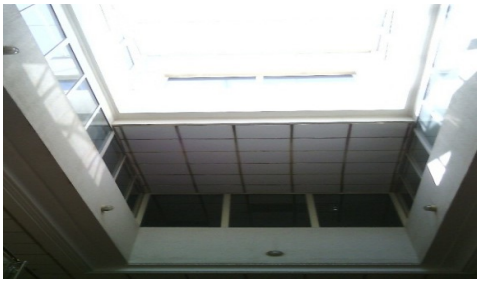


Plate XV: Atrium



Plate XVI: skylight



Plate XVII: Basement Lighting



Plate XVIII: Perforated metal used for the Retail shop doors
source: Author's case study research (2015)

4.3.5 Natural ventilation

Fixed windows that do not allow in flow of air into the interior spaces where used. As a result, artificial means of ventilation was employed. Plate XVIX below shows the picture of units of the air-conditioning system at the shopping mall.



Plate XVIX: Units of Air-Conditioning System at the Shopping Mall
Source: Author's case study research (2015)

4.3.6 Wall and window shading

The corridor at the west elevation gives shading to the first two floors of the building leaving the remaining four storey without shade. Plate XX below shows the only shading device used.



Plate XX: Corridor at the West Elevation
source: Author's case study research (2015)

4.3.7 Mechanical and electrical appliances

Energy saving bulbs were used adequately in retail shops while incandescent bulbs were used in the cinemas. Toilet fittings were designed in such a way that water is conserved. Plate XXI shows the picture of energy saving bulbs used.



Plate XXI: Energy Saving Bulbs Used In Shops Interior
source: Author's case study research (2015)

4.3.8 Landscape elements

The parking spaces are of two floors i.e. the ground floor and basement floor, each accommodating about sixty cars with 120 units of parking. Asphalt was used for parking floor. The entire landscape is more of a hard one than a soft one. Trees, shrubs and hedges were used both on the interior and exterior of the building. Plates XXII, XXIII, XXIV, and XXV show the parking spaces and plants used in the mall.



Plate XXII: Underground Parking



Plate XXIII: Drop-Off Area



Plate XXIV: Entrance Area



Plate XXV: Parking Area

source: Author's case study research (2015)

4.3.9 Existing source of energy

The major existing source of electricity is PHCN but two generators of 1000kva and 1500kva respectively are used as backup. It was gathered that an average of 260,000kwh of electricity is consumed monthly with more energy used on cooling the spaces for thermal comfort. Water is supplied by the water board and a borehole drilled as backup.

4.3.10 Sustainable design strategies applied on the building elements

This section will evaluate the extent to which sustainable design strategies were applied on building elements. Details are seen on table 4.4 using a 5-point scale ranking system ranging from very inadequate-1point, inadequate-2points, average-3points, adequate-4points to very adequate-5points.

Table 4.4: Sustainable Design Strategies Applied At Ceddi Plaza

S/N	Variables	Checklist	Level of application					Remark
			1	2	3	4	5	
1	Building envelope	Sustainable building materials				✓		
		External insulation		✓				
		Use of bright colours for walls				✓		
		Use of bright colours for roofing sheet.		✓				
		Low embodied energy materials			✓			
		Sun orientation; E-W				✓		
		Wind orientation; SW-NE			✓			
2	Daylighting	Wall to window ratio (40%)				✓		
		Use of spectrally selected glasses				✓		
		Use of atriums or courtyard		✓				
3	Natural ventilation	Use of openable windows	✓					In flow of air from the exterior to the interior was not allowed into the building.
		Use of passive ventilation		✓				
4	Wall and window shading	Use of win. shading devices	✓					
		Use of interior blinds		✓				
		Use of recessed walls		✓				
		Use of roof overhangs		✓				
		Use of plants for shading		✓				
5	Mechanical and electrical appliances	Use of energy saving bulbs				✓		
		Use of energy saving toilet wares			✓			
6	Parking and landscape elements	Thermal reflective parking spaces	✓					Concrete used for parking spaces conduct much heat to the underground parking space.
		planting and Waterbodies		✓				
7	Existing Energy	Use of renewable energy for electricity		✓				1000kva and 1500kva generators
		Use of natural gas	✓					

Source: Author's Case Study Research (2015)

Key : very inadequate-1point, inadequate-2points, average-3points, adequate-4points to very adequate-5points.

4.4 Case Study Three: Findings at 2xl Mall

4.4.1 Background

The 2xl mall building is located at Gwarimpa housing Estate. The building is a High-rise building having total site area of 30,000sqm. Facilities in the building include:

i. Retail shops
ii. Stores
iii. Administrative offices
iv. Restaurants
v. Parking spaces
vi. Outdoor retail stands
vii. Cinemas
viii. Toilets

4.4.2 Findings from visual survey

At the 2xl mall, it was observed that the source of energy consumption within the building are:

i. Lighting fixtures
ii. Air-condition
iii. Cinema screens
iv. Printers
v. Televisions and sound systems
vi. Refrigerators and cooking equipments

4.4.3 Building envelope.

The dominant building material used on the building envelope are concrete walls, glass windows as shown in Plate XXVI and a courtyard occupied by a building, while Table 4.5 shows the thermal properties of the building materials used for the building envelope of 2xL Mall.



Plate XXVI: Building Materials Used for the shopping Mall
Source: Author's case study research (2015)

Table 4.5 : Thermal properties of building materials used at 2xL Mall

Elements	Materials	Thermal Properties						
		Colour	**U-value (W/m^2k)**	**Admittance**	**Solar absorbtion.**	**Emissivity**	**Reflectivity**	**Conductivity**
Wall	Concrete block wall	Dove grey	1.800	3.360	0.506	0.90	0.549	0.431
Floors	Glazed Tiles	Grey	0.880	6.100	0.47520	0	0.573	0.837
Roof	Corrugated Aluminium roofing sheet	Blue	7.140	7.100	1.000	0.89	0.624	0.075
Ceiling	Suspended ceiling	White	0.500	0.900	0.368	0.90	0.702	0.431
Doors	Glass door	Trans-parent	5.356	5.360	1.000	0.86	0.967	1.046
Windows	Single glazed all. win.	Tinted blue	6.000	6.000	SHGC 0.94	VT 0.753	0.725	1.046 RI=1.74

Source: Author's case study research (2015)

4.4.4 Natural lighting

The use of clear glass for windows, and open courtyard contributed to the heat gained. Plate XXVII shows the kind of window used for lighting.



Plate XXVII: Sunrays from clear glass glazing
Source: Author's case study research (2015)

4.4.5 Natural ventilation

Openable windows that allow in flow of air into the interior spaces were used. The building in the courtyard do not allow for proper in flow of air due to wind shadow effect as seen in plate XXVIII.



Plate XXVIII: Wind shadow effect at 2xL mall
Source: Author's case study research (2015)

4.4.6 Wall and window shading

Shading devices were not used to shade windows. Corridor was used on the inside to shade the sun coming from the courtyard. This can be seen in in plate XXIX.



Plate XXIX: View of Corridor and Courtyard at 2xL Mall
Source: Author's case study research (2015)

4.4.7 Mechanical and electrical appliances

Energy saving bulbs were used adequately in retail shops while incandescent bulbs were used in the cinemas. Plumbing fittings were designed to reduce water consumption in the Toilets.

4.4.8 Landscape elements

There are about 200 parking units present in the mall. The trees planted have not grown to serve as shading elements. Plate XXX shows a perspective view of the parking space and other soft landscape elements on the site.



Plate XXX: Perspective view of Landscape elements on the site.
Source: Author's case study research (2015)

4.4.9 Existing source of energy

The major existing source of electricity is PHCN. Shop owners were left to get alternative electricity backups. It was gathered that an average of 210,000kwh of electricity is consumed monthly with more energy used on cooling the spaces for thermal comfort and lighting. Water is supplied through water board and there was no borehole drilled as backup.

4.4.10 Sustainable design strategies applied on the building elements

This section will evaluate the extent to which sustainable design strategies were applied on building elements. Details are seen on table 4.6 using a 5-point scale ranking system ranging from very inadequate-1point, inadequate-2points, average-3points, adequate-4points to very adequate-5points.

Table 4.6: Sustainable design strategies applied at 2XL Mall

S/N	Variables	Checklist	Level of application					Remark
			1	2	3	4	5	
1	Building envelope	Sustainable building materials				✓		Poor solar orientation causes heat gain and glare. The dark dove grey colour conducts much heat.
		External insulation		✓				
		Use of bright colours for walls				✓		
		Use of bright colours for roofing sheet.		✓				
		Low embodied energy materials			✓			
		Sun orientation; E-W				✓		
		Wind orientation; SW-NE			✓			
2	Daylighting	Wall to window ratio (40%)				✓		Too much glazing on the west direction improve heat gain and causes glare
		Use of spectrally selected glasses				✓		
		Use of atriums or courtyard		✓				
3	Natural ventilation	Use of openable windows	✓					
		Use of passive ventilation		✓				
4	Wall and window shading	Use of win. shading devices	✓					Recessed walls and corridors aided the shading of some parts of the structure
		Use of interior blinds		✓				
		Use of recessed walls		✓				
		Use of roof overhangs		✓				
		Use of plants for shading		✓				
5	Mechanical and electrical appliances	Use of energy saving bulbs				✓		Incandescent bulbs were used in the cinemas
		Use of energy saving toilet wares			✓			
6	Parking and landscape elements	Thermal reflective parking spaces	✓					
		planting and Waterbodies		✓				
7	Existing Energy	Use of renewable energy for electricity		✓				
		Use of natural gas	✓					

Source: Author's case study research (2015)

Key : very inadequate-1point, inadequate-2points, average-3points, adequate-4points to very adequate-5points.

Table 4.7 shows the total scores of all variables used on the checklists for Silver Bird Galleria, Ceddi Plaza, and 2xL Mall. Fig 4.1 graphically represent the scores of the case studies with respect to their building envelopes, Fig 4.2 represent result of scores from daylighting, Fig 4.3 represent result of scores from natural ventilation, Fig 4.4 represent result of scores from wall and window shading, Fig 4.5 represent result of scores from mechanical and electrical appliances, Fig 4.6 represent result of scores from parking and landscape elements, while Fig 4.7 represent result of scores from existing energy.

Table 4.7:Summary of findings on case study (Checklist)

		Silverbird	Ceddi	2XL mall	
1	Building Envelope	22	23	19	35
2	Daylighting	10	09	10	15
3	Natural Ventilation	03	04	06	10
4	Wall and window shading	09	10	12	25
5	Mechanical and electrical appliances	07	10	06	10
6	Parking and landscape elements	05	03	03	10
7	Existing energy	03	02	02	10
	TOTAL	59	61	58	115

Source: Author's case study research (2015)

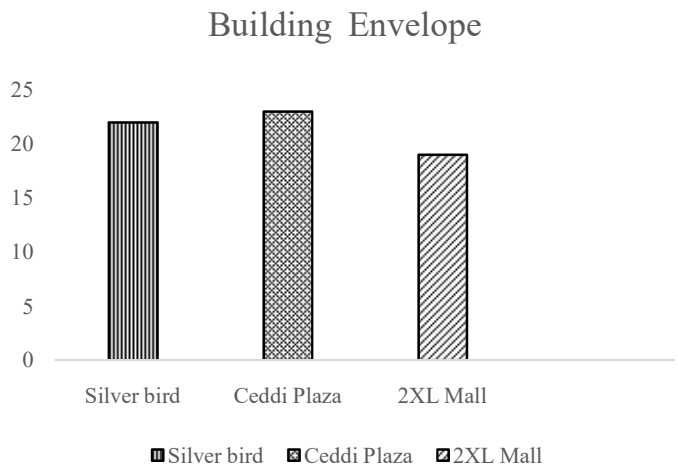


Figure 4.1: Comparison of the Findings from Building Envelope

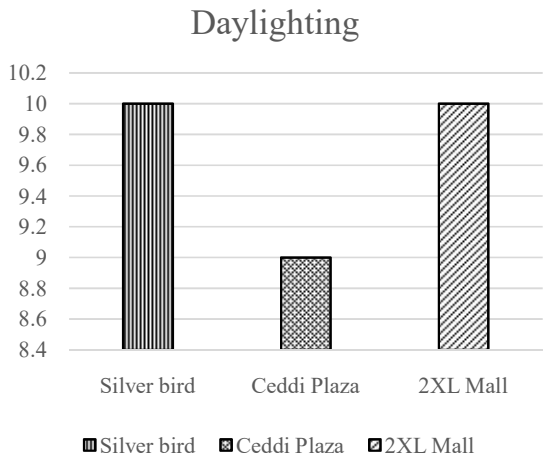


Figure 4.2: Comparison of the Findings from Day lighting

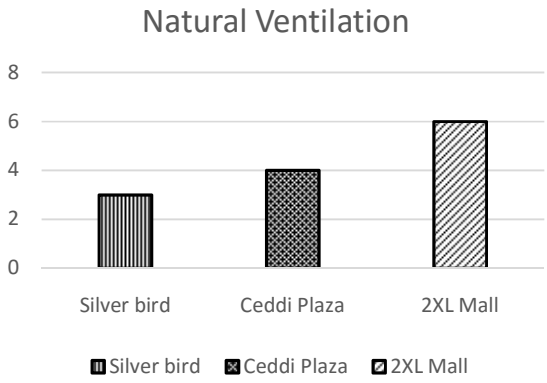


Figure 4.3: Comparison of the Findings from Natural Ventilation

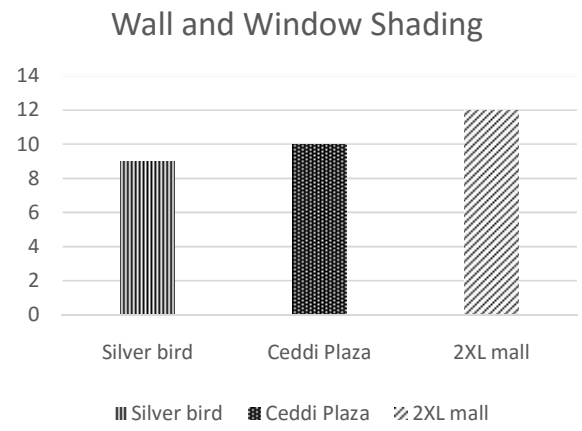


Figure 4.4: Comparison of the Findings from Wall and Window Shading

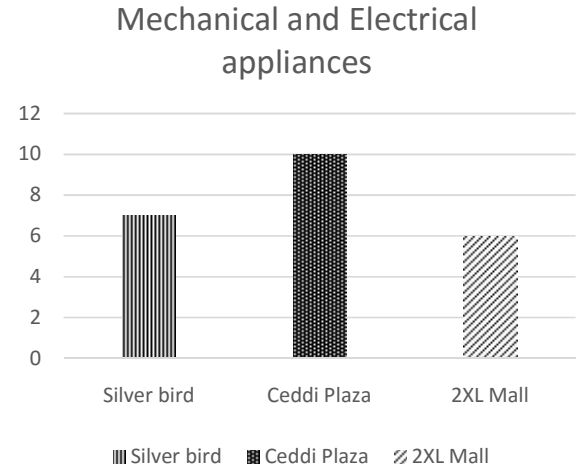


Figure 4.5: Comparison of the Findings from Mechanical and Electrical Appliances

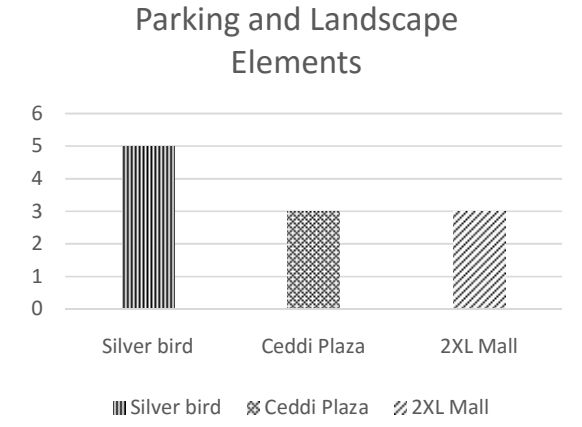


Figure 4.6: Comparison of the Findings from Parking and Landscape Elements

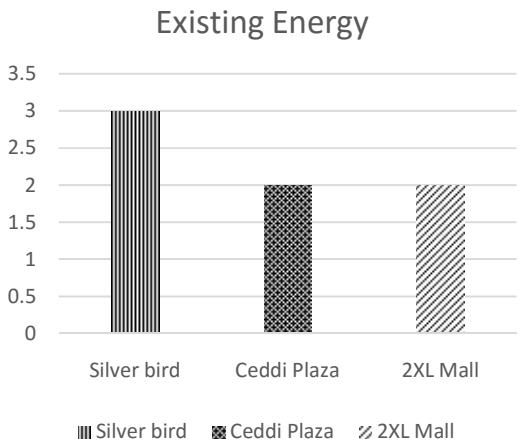


Figure 4.7: Comparison of the Findings from Existing Energy

4.5 Findings from Computer Simulation

Computer simulation programs incorporate sets of mathematical models that seek to explain quantitatively how each component of a building behaves under given circumstances (Aina, 2002).

A typical space of a supermarket and Gymnasium under the climatic conditions of Abuja was considered for analysis using a simulation software called "Ecotect analysis 2011". The analysis was based on orientation, wall to window ratio, and choice of building materials.

4.5.1 Analysis based on orientation of building

The parametric definitions for building orientation included four of the main geographical cardinal points and four of their central mid-point sub divisions as identified in the literature review. Hence the building's main axial directions lay within North/South, East/West, North-East/South-West and North-West/South East.

Using Ecotect analysis 2011, the amount of solar radiation and energy used for cooling will be calculated. Table 4.8 below shows the amount of energy required for cooling throughout the year considering the longer side of facing respective possible orientation.

Fig. 4.8 represents a bar chart showing the energy required with respect to the four different orientations using computer simulation.

Table 4.8: Energy required based on orientation.

S/N	Orientation of main axis	Energy Required for cooling (kwh) per yr
1	East-West	78541.938
2	North-South	82253.922
3	Northwest-Southeast	80168.906
4	Northeast-Southwest	80386.094

Source: Author's research work (2015)

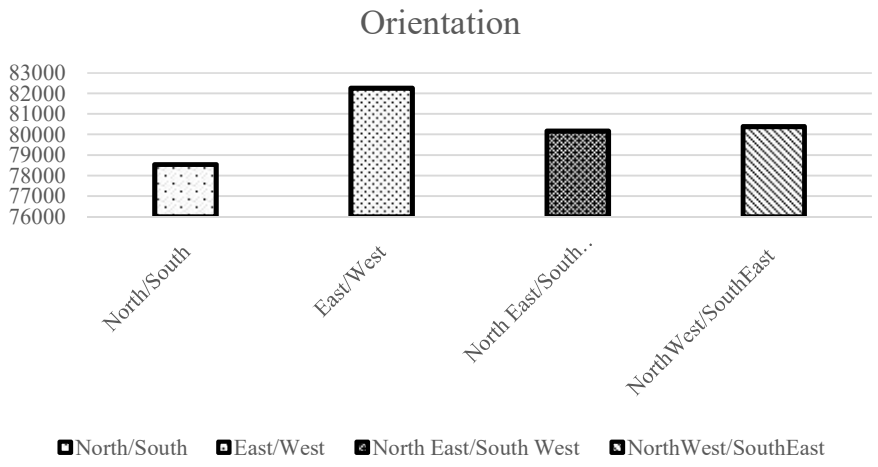


Figure 4.8: Energy required for four different orientations

4.5.2 Analysis based on window to wall ratio

Considering the best orientation, which is the longer side facing North-South direction and using the same building materials, three different models were used to test for impact of window to wall ratio. Table 4.9 shows the values deduced from the analysis in kwhr per year.

Table 4.9: Result for Wall to Window Ratio.

S/N	Window to wall ratio	Energy Required for cooling (kwh)per yr
1	40%	35896.879
2	60%	88058.844
3	80%	114045.297

Source: Author's research work (2015)

4.5.3 Analysis based on building elements

Three major elements of the building envelope were considered for comparison. These include the wall, roof and window. Three sample materials for each basic element will be used for analysis using ecotect analysis 2011.

4.5.3.1 Wall analysis

Table 4.10 shows the energy required by the model for three different wall building materials used for three different models.

Table 4.10: Energy Required For Different Wall Types.

Wall type	Energy required (kwh)per yr	U-value (W/m^2k)	Admittance	Solar absorption.	Visible transmittanc	Thermal decrement	Thermal Lag(hrs)
Concrete block wall	95794.695	1.830	3.340	0.6	0	0.79	5.0
Double brick cavity wall	85806.742	1.740	4.590	0.4	0	0.35	7.8
Rammed Earth	84239.992	3.020	5.850	1.0	0	0.18	12.1

Source: Author's research work (2015)

4.5.3.2 Window analysis

Different kinds of windows with different U-values were used to test for energy requirement using "Ecotect Analysis, 2011" as seen in Table 4.11.

Table 4.11: Shows The Energy Required For Different Window Types.

Window type	**Energy required (kwh) per yr**	U-value (W/m^2k)	Admittance	Solar Heat gain coefficient	Visible transmittance	Refractive index of	Solar Gain
Single glazed aluminium frame	87707.477	6.000	6.000	0.94	0.753	1.74	0.64
Double glazed aluminium frame	68073.523	2.700	2.800	0.81	0.639	1.74	0.56
Double glazed low-E aluminium frame	58609.355	2.410	2.380	0.75	0.611	1.74	0.29

Source: Author's case study research (2015)

4.5.3.3 Roof analysis

Different kinds of Roofs with different U-values were used to test for energy requirement using "Ecotect Analysis, 2011" as seen in Table 4.12.

Table 4.12: Shows The Energy Required For Different Roof Types.

Roof type	**Energy required (kwh)yr**	U-value (W/m^2k)	Admittance	Solar absorption.	Visible transmittanc	Thermal decrement	Thermal Lag(hrs)
Corrugated Metal Roof	201642.281	7.140	7.100	1.0	0	1.0	0
Clay Tiled roof	109996.312	3.100	3.100	0.6	0	1.0	0.2
Concrete roof with Asphalt	73100.508	0.896	2.300	0.9	0	0.58	7

Source: Author's case study research (2015)

4.6 Discussion of Findings

Reasearch has shown that design of the building envelope can help determine the amount of lighting, heating, and cooling a building will require. Orientation, site and external spaces, natural ventilation, wall to window ratio, thermal properties of building materials, wall and window shading are all factors to be considered in order to achieve an energy efficient design.

From the case studies conducted, it was observed that all the buildings selected are oriented in relation to the main access route into the site such that the building's main entrance is always in the line of vision as the building is approached. The buildings therefore are oriented with the longer sides facing east/west direction (North-South orientation) giving room for unnecessary heat gain from solar radiation.

Using computer simulation, it was proved that the buildings' main axis running from east to west is the best building orientation for the climate of Abuja. After running tests based on four orientations with main axis running from east-west, north-south, northeast-southwest, and northwest-southeast, the result showed that east-west orientation requires the least energy to maintain thermal comfort, followed by northeast-southwest, northwest-southeast and north-south orientation requiring more energy for thermal comfort as seen in Table 4.8. The best orientation was able to save energy by 7%.

Choice of building materials is a very important factor for achieving energy efficiency, hence a designer should be aware of the basic thermal properties, embodied energy, and health effect of building materials to be specified. Thermal properties of building materials have adverse effect on heating or cooling requirement of an interior space with respect to the climatic factors of the region. The sun path direction of a region determines the major building element that conducts the most heat to the building

interior. In Abuja, it was noted that the sun heats the roof more than any other building element. The colour and thermal properties of the roof can significantly improve the energy efficiency of the building.

With the aid of Ecotect analysis 2011, three models named X, Y and Z with diiferent roofs and of different thermal properties were tested to determine the energy required for cooling throughout the year. Corrugated metal roof, Clay tiled roof, and concrete roof with asphalt were used for model X, Y an Z respectively. model Z required the least energy followed by model Y and model X requiring the most energy as seen in Table 4.12.

Using the same roof for the three models, and changing the wall properties toConcrete block wall, Double brick cavity wall, and Rammed Earth for the three respective models. Rammed earth required the least energy, followed by the double brick cavity wall and concrete block wall requiring the most energy as seen Table 4.10.

Finally, using the same roof and wall properties and changing the window types for each model. Model X with single glazed aluminium frame requires the most energy for cooling, followed by model Y with double glazed aluminium frame, and model Z with double-glazed low e aluminium frame requiring the least energy for cooling as seen in Table 4.11.

According to centre for sustainable building research (2013), the energy impact due to windows in a building depends on climate, window orientation, wall to window ratio, shading conditions, and window (frame and glazing) type. Samuel (2011) argued that buildings with larger window areas use more energy than buildings with smaller window areas.

Previous studies indicate that improved fenestration (collective name for windows, glazed exterior doors, and skylights) using optimum window design and glazing

specification is estimated to reduce energy consumption from 10 to 50 percent below accepted practice in most climates (Nadel,2006).

Based on visual survey, it was noted that two buildings with large amount of glazing were having higher internal temperature when compared to the one building with lesser glazing. A thermometer was used to measure the interior temperature of the three building at 13:00hrs for three consecutive days respectively.

Computer analysis confirmed that the higher the window to wall ratio, the higher the energy required for thermal comfort. Three models named as model A, B and C with 40%, 60% and 80% glazing respectively were used to compare the amount of energy required for thermal comfort. Model A required the least energy, model B required 140% more energy with respect to model A and model C required 220% more energy with respect to model A as seen in Table 4.9.

Hence it can be deduced that the lower the amount of glazing the better as the amount of energy required for thermal comfort is much higher than the amount required for lighting the same space.

It was also observed from the case studies that in an attempt to modify the interior of the retail stores, the tenants tend to obstruct the inflow of day lighting by using shelves to cover the windows provided. In this case, the window meant to serve for lighting fails and only contributes to the heat gained in the interior space. It is therefore advised to reduce the large glazing and provide lighting by sustainable means that do not contribute to heat gain.

Natural ventilation has to do with harnessing useful velocity of the wind into the interior space to purposely create a thermally comfortable interior space. From literature, it was seen that buildings with openings require lesser energy for cooling than buildings without openings at all.

Architects should design buildings with relatively narrow plan form across the prevailing wind direction, to facilitate the passage of air through the building, and also use passive evaporative cooling methods in hot dry climates, by passing incoming air over or through wetted surfaces (Janda, 2009).

Sustainable mechanical and electrical appliances can help improve the energy efficiency of a building. This can be achieved by using renewable energy as well as energy saving appliances. Renewable energy such as solar energy and natural gas exist in abundance in buildings located at Abuja. Photovoltaic cells with the aid of an inverter can solely provide sufficient electricity for buildings thereby eliminating use of turbines and diesel engine generators used conventionally in Nigeria. This scenario can help against the global climate change.

Sustainable appliances used for lighting and ventilating the interior space can drastically reduce energy consumption. For example, energy saving bulbs are much more efficient than incandescent bulbs as it saves over 900% energy as compared to the incandescent bulbs.

Parking and landscape elements can contribute immensely to the heat gained in an interior space the building envelope. From literature, it was confirmed that the conventional cement used for concrete paving and parking is unsustainable as it conducts more heat, which in turn is released to the building. The use of asphalt or concrete made out of green cement proves to be more efficient as it does not conduct much heat and emits less greenhouse gas.

Plants provide a means of sustainable cooling called adiabatic cooling. This process involves planting along the windward path to serve as windbreak and cool the prevailing air for thermal comfort. Water bodies when placed along prevailing wind

paths provide sustainable means of cooling called evaporative cooling. It was noticed that the fountain used in landscaping silver bird galleria aided in cooling the building by the means of evaporative cooling.

Shading devices partly shield the building envelope from direct solar radiation. Shading devices are designed in consideration to the sun path of a geographical location. In Abuja, the sun rises in the east and follows a straight path to the west without diverting to the north or the south. As such, buildings in this region should be provided with horizontal shading devices on the north and south directions while east and west directions should be provided with vertical shading devices or blinds.

A typical model of a shopping mall with two different categories of materials and techniques were tested to compare the percentage difference between the sustainable strategies used. the first category consisted of ; North-South orientation, concrete block wall, corrugated metal roof, single glazed aluminium frame window with no recess for roof, wall and window and the energy required was 7,068kwhr of electricity daily. while the second category consisted of; East-West orientation, double brick cavity wall, concrete roof with asphalt, double glazed low E aluminium window, with roof, wall, and window recess and the energy required daily was 4,340kwhr. The difference between the two models is 2,728kwhr. Hence the percentage difference daily is approximately 38%.

5.0 DESIGN PRELIMINARIES

5.1 Introduction

This chapter and the subsequent chapters deal with the application of the research findings into the design aspect of the thesis. This chapter discusses the preliminary study on the design and it is arranged under the following headings: the brief; design case study; schedule of accommodation; spatial arrangement; site location and selection; site analysis; and conclusions.

5.2 The Brief of Proposed Shopping Mall

The proposed shopping mall shall be viewed as a design thesis proposal for the design of a shopping complex, which would house facilities to cater for all categories of shopping

The proposed building shall be a single unit of integrated complex functions, which aims at being the manifestation of design strategies to improve energy efficiency of shopping malls.

The general objectives of the proposal are:

i. To incorporate the findings of the research thesis in the proposed design.
ii. To provide spatial arrangements to house various retail services and other relevant services.
iii. To provide sustainable design strategies to improve energy efficiency of shopping malls

5.2.1 Clients brief

SPAR supermarket is a multi-national company that seek to empower young and growing business owners acquire shops contrary to the current trend of renting shops at a very expensive rate so it has decided to expand its business by providing an avenue for

buying and selling to help build the economy of Nigeria. The company has decided to build a new shopping mall in the Federal Capital Territory Abuja.

The clients list basic requirements or clients' wish list include:

i. Accessories and Luggage
ii. Managers office
iii. Electrical and communication
iv. Security office
v. Restaurant
vi. Fashion Stores
vii. Footwear
viii. Health and Beauty
ix. Jewelry and watches
x. Pharmaceutical Stores
xi. Photography and art
xii. Anchor Store
xiii. Internet cafe

5.3 The Study Area

The site for the proposed project is located in the Federal Capital Territory, which is centrally located, lying above the hot humid lowlands of Niger/Benue trough but below the hot dry parts of the savannah to the north. Abuja is located in the park savannah region of Nigeria between latitudes 8°25" and 9°20' north of the equator and longitudes 6°45" and 7°30" east of the Greenwich meridian.

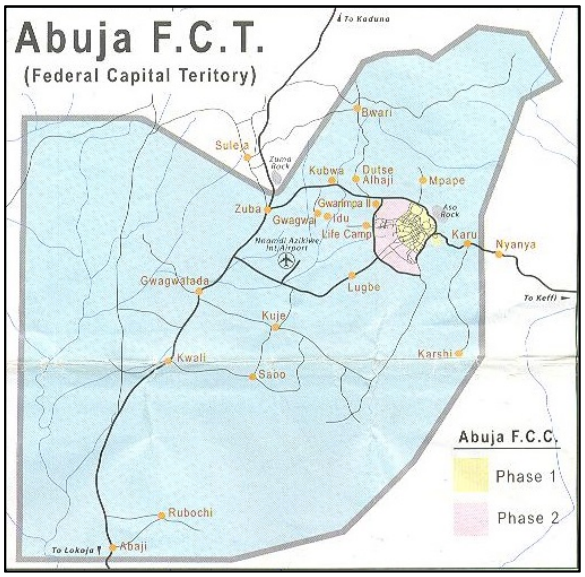


Figure 5.1: Map of Abuja

Source: (Abuja Geographical Institute, 2010)

The total area of Abuja is 8000 square kilometres as shown in Figure 5.1. It is bounded by Kaduna state to the north, Nassarawa state to the East and south east, Kogi state to the south west and Niger state to the west. The Federal Capital Territory itself consists of a tilted plain rising from an elevation of 300ft in the southwest corner to above 2000ft of the northeast corner. Rising out of this tilted plain are numerous rocky knobs and inselbergs. The most famous being the Zuma rock, and several mountains of low range.

5.4 Shopping Mall Location Selection

Shopping malls are one of the major ingredients of an urban city. The continuous sophistication of the city dwellers and the need for a comfortable space to shop and relax after work or a busy week is paramount with respect to time.

Developers make decision in selecting the site for their next development. This decision affects which tenant will be interested in locating in the mall, which consumer will frequent the mall and the sales volume of all the tenants who chose to locate in the mall. In short, the decision will largely determine the success or failure of the project and will

determine whether the developer or investor in the project will infact realize negative, average or superior return in their investment (Brubaker, 2004).

For the purpose of this study, Three locations were chosen. These three locations are within the area of study (FCT) as shown in Plate XXXI. They are:

- Location A (Gwagwalada Phase I)
- Location B (Gwagwalada Phase II)
- Location C (Gwagwalada Phase III)



Plate XXXI: Proposed Location from Gwagwalada Satellite Settlement

(Source: Google Earth, 2015)

i. Location A (Gwagwalada Phase I)

Gwagwalada is one of the six local Government Area Councils of The Federal Capital Territory, together with Abaji, Kuje, Bwari and Kwali and Abuja Municipal Area Council. Gwagwalada is also the name of the main town in the Local Government Area, which has a population of 157,770 as at 2006 with a land area of 1,043 km². The site is in gwagwalada Phase I as shown in Plate XXXIIbelow.



Plate XXXII: Proposed Location A From Gwagwalada

(Source: Google Earth, 2015)

ii. Location B (Gwagwalada Phase II)

Gwagwalada is one of the six local Government Area Councils of The Federal Capital Territory, together with Abaji, Kuje, Bwari and Kwali and Abuja Municipal Area Council. Gwagwalada is also the name of the main town in the Local Government Area, which has a population of 157,770 as at 2006 with a land area of 1,043 km².The site is located along the Gwagwalada – Paiko road on the western axis after Phase III as shown in Plate XXXIII below.



Plate XXXIII: Proposed Location B from Gwagwalada

(Source: Google Earth, 2015)

iii. Location C (Gwagwalada Phase III)

Gwagwalada is one of the six local Government Area Councils of The Federal Capital Territory, together with Abaji, Kuje, Bwari and Kwali and Abuja Municipal Area Council. Gwagwalada is also the name of the main town in the Local Government Area, which has a population of 157,770 as at 2006 with a land area of 1,043 km². The site is located along the Gwagwalada – Paiko road on the western axis as shown in Plate XXXIV below.



Plate XXXIV: Proposed Location C from Gwagwalada

(Source: Google Earth, 2015)

5.4.1 Site selection criteria

According to Khan (1999) selection of shopping mall location depends on depends on a range of factors that include the physical characteristics of the site, the demographical data of the locations and so on. These factors have been established to compare the locations and check the viability of each site with regard to those criteria. One of the major considerations given for design for the disabled is that the site should be relatively as flat as possible.

Below are the criteria outlined by Khan (1999), along with specific questions that were considered when evaluating the locations.

i. Proximity to residential areas;

ii. Location/Accessibility: traffic issues (Pedestrian, Passenger vehicles);

iii. Size of site, Possibility for expansion, suitability and availability;

iv. Commercial potential of surrounding area;

v. Land-use compliance;

vi. Visual and aesthetic potential.

vii. Proximity to national landmarks

Table 5.1: Site Selection

	CRITERIA	SITE A	SITE B	SITE C	REMARKS
i.	Proximity to residential areas	3	4	2	All the sites are not too far to residential areas but Site B has the closest distance
ii.	Location/Accessibility	3	5	3	Site B has the best location because of the three roads that goes to the site
iii.	Size of site	4	3	4	Site A and Site C have ample space for expansion with Site B having the least
iv.	Commercial potential of surrounding area	4	5	3	Site B have the best potential for commercial activities
v.	Land-use compliance	4	4	4	All the three sites are compliant with the land use policy of the F.C.D.A
vi.	Visual and aesthetic potential	4	4	3	Site A and Site B have the best Visual and aesthetic potential for commercial facility
vii.	Proximity to national landmarks	2	3	3	All the three sites are not too close to national landmarks with Site A being the farthest.
	TOTAL	**24**	**28**	**22**	Site B possess better characteristics and thus is the most suitable for the Shopping Mall

Weighing scale: Excellent 5, Very good 4, Good 3, Fair 2, Poor 1, Very poor 0.

Based on the above analysis site B has been chosen.

Table 5.1 describes the criteria used for the site selection and possible remarks were given for each criteria.

5.4.2 The proposed site

The proposed site is located in Gwagwalada Local Government Area within the Federal Capital Territory. The site is located in Phase 1. To the north-west, part of the site is the Gwagwalada Phase 3.To western and eastern part of the site are residential settlements as seen in Plate XXXV.



Plate XXXV: Selected Site for Proposed Design

(Source: Google Earth, 2015)

5.5 Characteristics and Analysis of Proposed Site

The site characteristics and analysis shall be based on the following factors and their associated to the basement complex geology of central Nigeria. The basement complex is dominantly granite but consist of same gneiss, schist and quartzite. The top soil is rich and good judging from the thieving nature of the plants and trees growing on it. It is classified under the undifferentiated older alluvium and younger laterite.

5.5.1 Noise

The site has some form of noisy environment towards the Southern, Western and Eastern part of the site judging from the high amount of traffic and movement and other activities around it that could generate noise. However, the thickness of trees and vegetative covering around the site help serve as buffer to noise.

5.5.2 Topography

The slope of the site is quite even and gentle. It is not completely flat so drainage of the site occurs quite well. However close to the east boundary is an ample undeveloped site which allows for future expansion as shown in Figure 5.2.

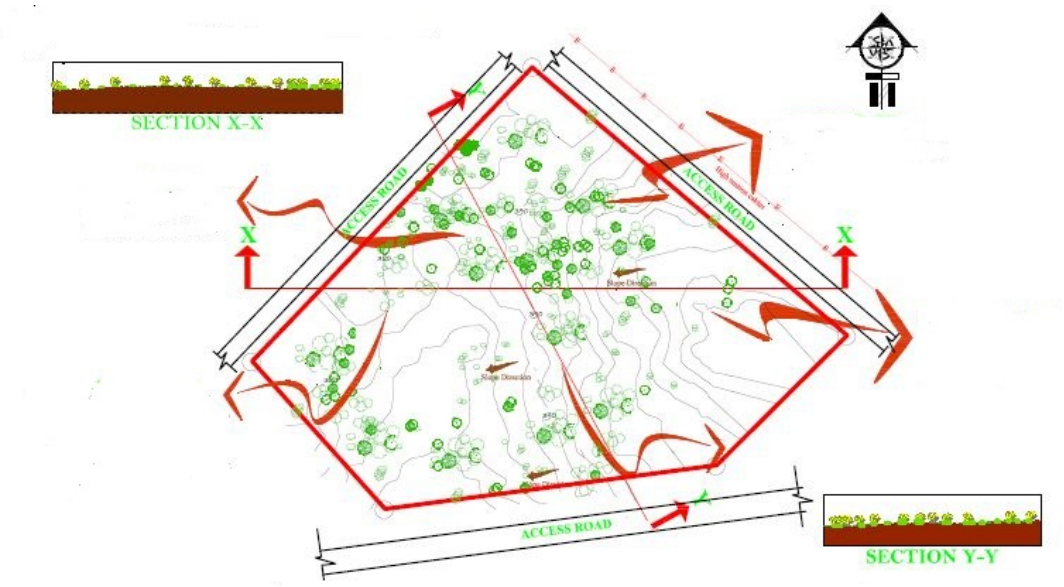


Figure 5.2: Site Topography
Source: Author's research work (2015)

5.5.3 Utilities

Electricity power lines run parallel to the access road bounding the site to the East. This power line supplies a three-phase line and could be tapped. Water supply mains could also be connected directly to the AMAC water board, which lies close to the neighboring site. Telecommunication lines could be drawn to the site via the already existing poles and all cellular networks are available.

5.5.4 Vegetation

The site is covered by much grasses and trees due to lack of human activities but generally the vegetation at Abuja is classified under the Southern Guinea savannah zone, which implies wood land vegetation as shown in Figure 5.3. The vegetation is classified by leaves that shed their leaves during the long dry season. The site is mostly covered by matured trees and some ornamented trees that beautify the access road.

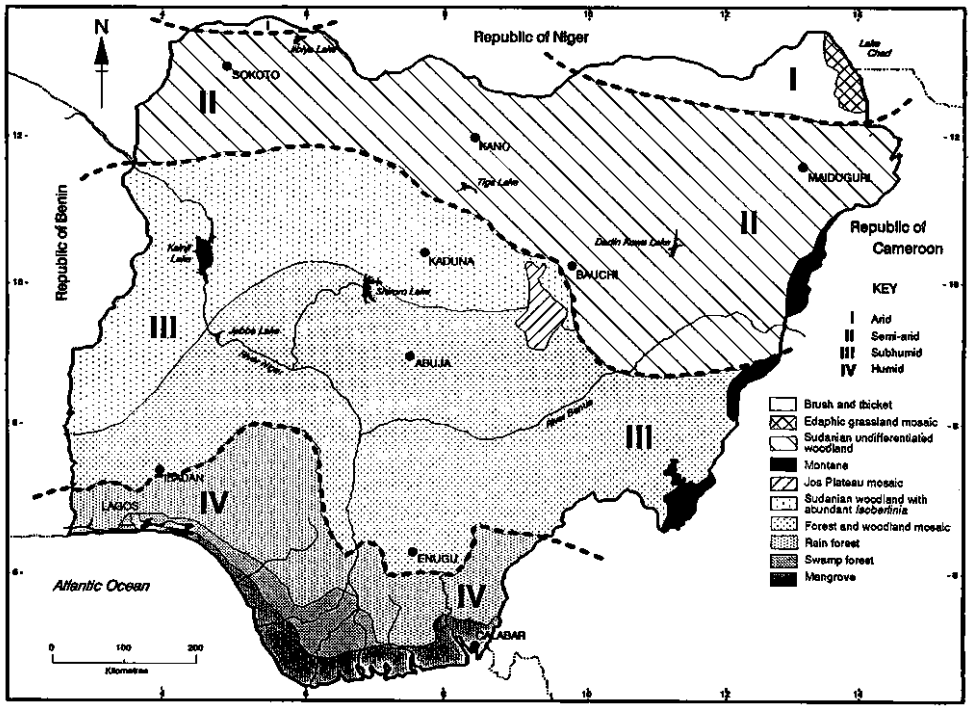


Figure 5.3: Map of Nigeria Showing Respective Vegetative Belts

Source: http://www.fao.org

5.5.5 Climate

Abuja is characterized by a distinct dry and wet season that lies within the tropical savannah climate. The seasons are as a result of the movement of Inter-Tropical discontinuity zone (ITD), which is directly by two dominant winds movement that affects the country as a whole. These are;

- The continual air masses from the ashore. This wind is a dry cold wind. It carries dust and blows from the northeast direction.
- The maritime air masses. It blows from the southwest direction. The wind is warm and carries moisture. This wind brings rainfall into the region.

Generally, the dry season in Abuja is from the month of November to March or April when the west season starts and last until October. This however depends on the movement of the ITD. The orientation of the surface position of the ITD over Nigeria generally is approximately from WNW to ESE. It reaches its peak in the North between latitude 19.6°-20.2°N in August and its peak in the south in between latitude 6.2°-8°N in February. The ITD crosses Abuja during its southward movement in movement and in later march or early April; it crosses the latitude of Kano on its north mud movement. This may vary from year to year.

5.5.6 Rainfall

The annual total rainfall is in the region of 1100 mm to 1600 mm in Abuja. However, a common feature of the rainfall in Abuja is its corrective nature and the occurrence of the associated thunderstorm usually with late afternoon maximum and with September seasonal maximum. The relative position of ITD over Abuja can be seen in Fig. 5.4 below.

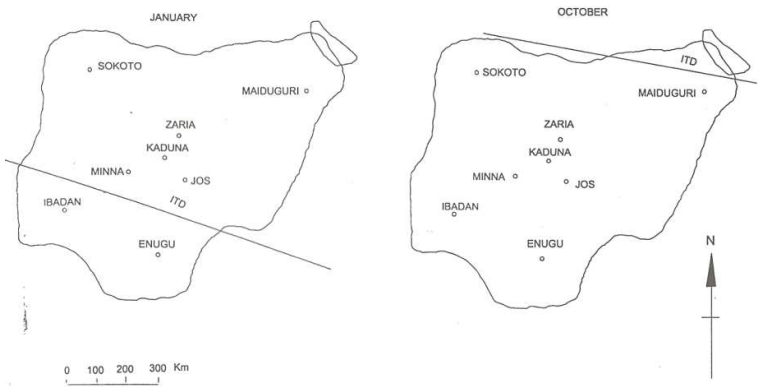


Figure 5.4: Relative Position of ITD over Abuja

Usually a dry season is practically rainless. Rainfall starts in May and increases from 63mm in May to 198mm in August, which is the maximum for the years as shown in Figure 5.5.

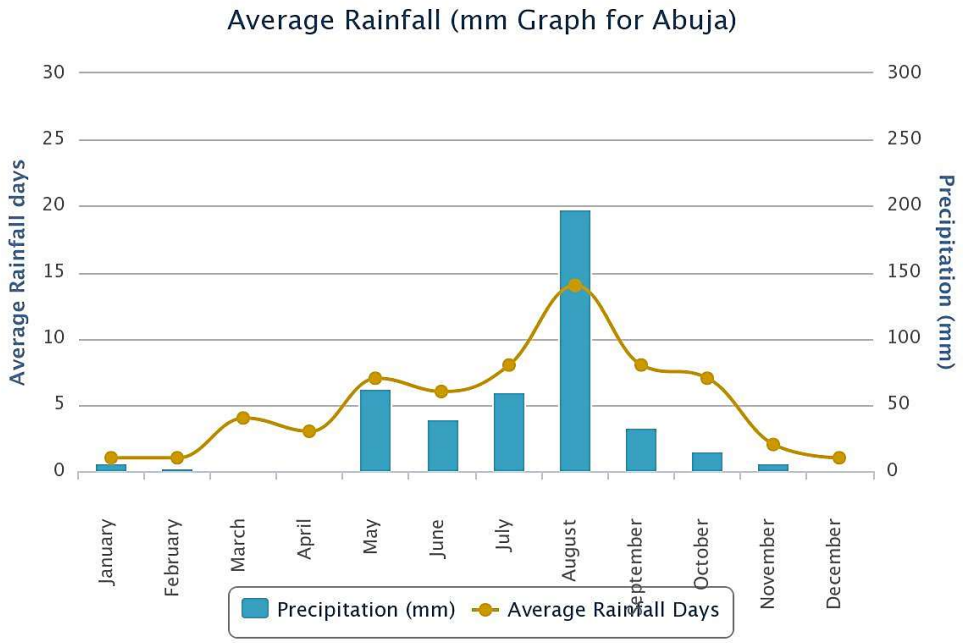


Figure 5.5: Mean Monthly Rainfall in Abuja
Source: http://www.worldweatheronline.com

5.5.7 Temperature

The temperature of the area is high throughout the year. The mean daily maximum temperature rises gradually from January 34^{0}C and shows a major maximum in March 37^{0}C before rainfall starts and minor one in October with its lowest figure in August 28^{o}C as shown in Figure 5.6. However, the mean daily maximum is about 34^{o}C while the mean daily minimum is between 17^{0}C in December with corresponding diurnal range during the wet season lowers than that of the day season as shown in Fig. 5.6.

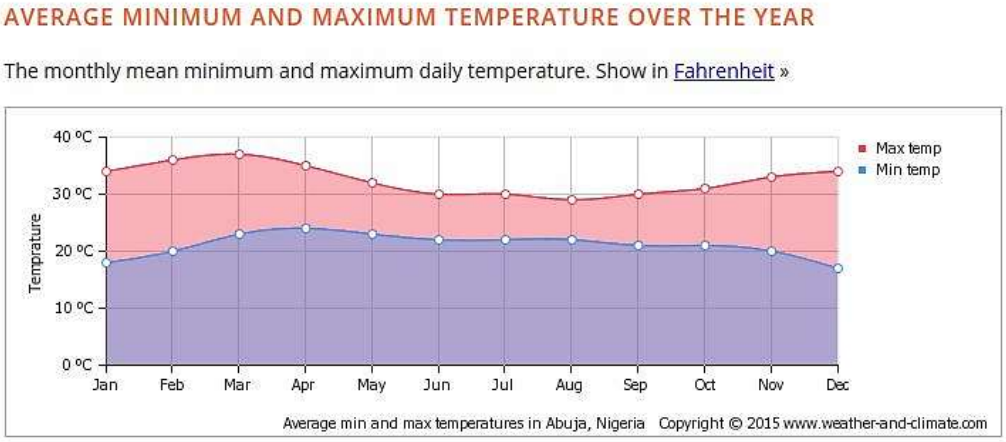


Figure 5.6: Mean Monthly Max. And Min. Temperatures
Source: http://www.worldweatheronline.com

5.5.8 Relative humidity

During the dry season, there is an abrupt drop in atmosphere humidity to about 25-30 percent in November; this may further fall to 10-15 percent as shown in Figure 5.7.

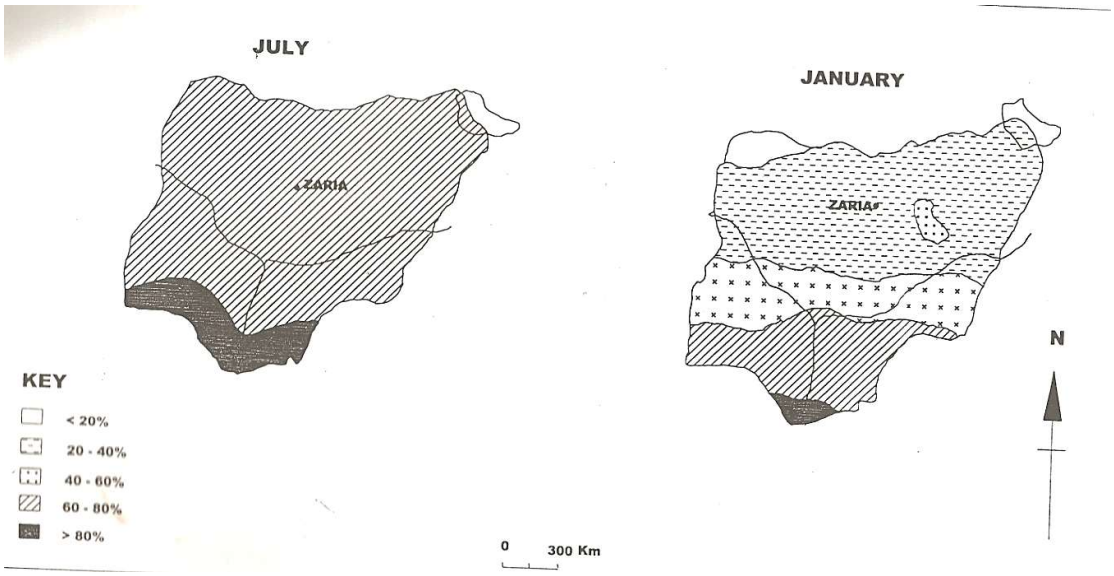


Figure 5.7: Relative Humidity in Abuja
Source: http://www.worldweatheronline.com

In January, northeastern winds becomes fully established. However, atmospheric humidity in the wet season as about 65-75 percent in June to about 80 percent in August. The humid southwestern becomes fully established. They rapidly transform

local cumulus clouds into cumulus nimbus clouds with the associated showers. The climate of Abuja and its environment is dry-sub humid, according to Thorn worthe's moisture index.

5.5.9 Sunshine

November sunshine hours vary from 8.9 to 9 hours per day. January sunshine hours are quite high, 8.7 to 9.5 hours. Minimum sunshine hours per day occur in August with as low as 5.1 hours per day as shown in Figure 5.8.

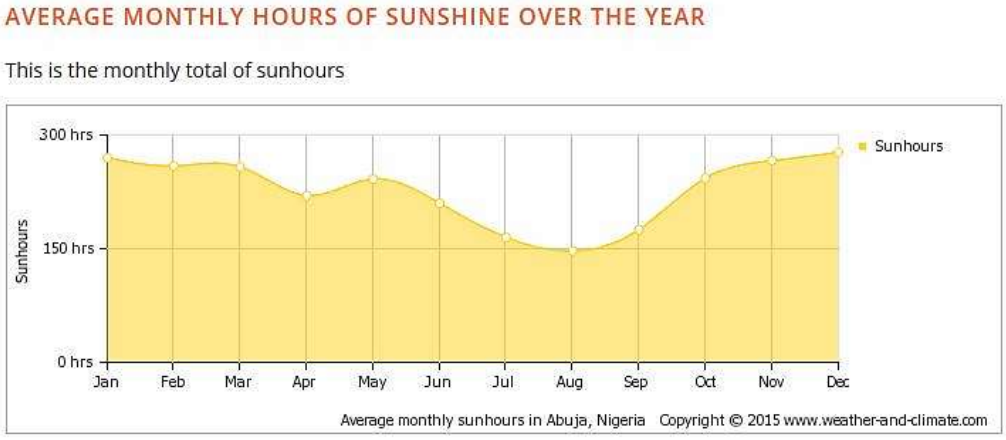


Figure 5.8: Average monthly sunshine in Abuja
Source: http://www.worldweatheronline.com

5.5.10 Visual quality

The site has a good visual quality especially to the northern and eastern part of the site due to the presence of trees and shrubs that serve to give good cooling effects. These effects of the trees and the microclimate provide a conducive and optimal restoring condition for the delinquents as well as the staffs. The trees can also serve as noise and sound barriers and acts as absorbent to direct solar radiation.

5.6 Site Climatic Implications on Design

Design parameter shall be drawn based on the effect of the above-analyzed site and climate factors to see how best they can be utilized to achieve required effects on the final design proposal.

5.6.1 Site plan

To reduce the effect of direct sunlight, the building orientation should be along east-North axis with the longer sides facing the North and south side.

5.6.2 Roofing

The volume of rain in Abuja is quite moderate but the winds are high. Roofs of relatively low pitch could be used or even flat roofs. However, parapet walls should be provided to prevent wind blowing off roofing materials.

Also, roofing materials with reflective properties should be used reduce effect of solar radiation penetrating the building

5.6.3 Foundation

Normal strip and pad foundation can be used since the soil is relatively stable. However, attention should be paid to prevention of rising water as soil has high water retaining ability, especially after heavy rain showers.

5.6.4 Finishing

The finishing should be bright and glossy to reflect direct solar radiation from building and air spread of natural lighting within.

5.6.5 Lighting

The abundance of sunlight hours should be maximized achieve maximum natural lighting. Fenestrations should be placed abundantly but with close attention to the sun path. This is to reduce direct sunlight from penetrating the interior of the building.

5.6.6 Ventilation

To achieve maximum natural thermal comfort, methods of ventilation applied in both hot humid and hot arid regions should be employed. This would mean providing large voluminous spaces with high head rooms to allow for stack effect. Cross ventilation should be provided were ever possible. The use of shaded courtyards should be employed to trap cool air and feed it into interior spaces.

6.0 DESIGN REPORT

6. 1 Introduction

This chapter encompasses the report of the architectural design of the proposed shopping mall. In this chapter key design requirements and how the research findings are been incorporated into the design are discussed. The chapter is arranged under the following headings: The Design Brief; Design Philosophy; Major Functional Divisions; Functional Organization: Design Consideration.

6.2 Design Brief

The different areas required for the different activities that take place in a shopping mall vary. The table below summarizes the areas that will be adopted for the different functional spaces in the mall. The Table 6.1 compares the space requirements as observed from the case studies; the standard requirements and that adopted for the design.

Table 6.1: Schedule Of Accommodation Table.

S/ no	Functional space	Unit area (m2)	No.	Total area (m2)
1.	Entrance Area	205	1	205
2.	Security Post	18	2	36
3.	A.T.M	20	2	40
4.	Luggage	25	2	50
5.	Bank	60	1	60
6.	Anchor Shop	560	2	1120
7.	Store	45	4	180
8.	Phone Shop	36	4	144
9.	Electronics	100	1	100
10.	Crèche	56	1	56
11.	Exhibition Stand	25	4	100
12.	Fashion Shop	38	8	288
13.	Arcade	300	1	300
14.	Restaurant	260	1	260
15.	Kitchen	48	1	480
16.	Multi-faith Room	26	2	52
17.	Food Court	100	1	100
18.	Confectionary	100	1	100
19.	Home ware	100	1	100
20.	Bookshop	56	2	102

Source: Author's case study research (2015)

6.3 Major Functional Divisions

The functional spaces in the shopping mall are grouped into various functional divisions based on the nature of the activities carried out in the spaces. All the related spaces are grouped together. The major functional divisions are four, namely: home accessories; entertainment and recreation; commercial and other activities. The divisions are arranged according to the floor levels. The division is done as follows:

i. On the ground floor is the anchor shops, maintenance room and electronics shop This was done in order to make the movement of goods and people in and out of such stores easier as shown in Figure 6.1

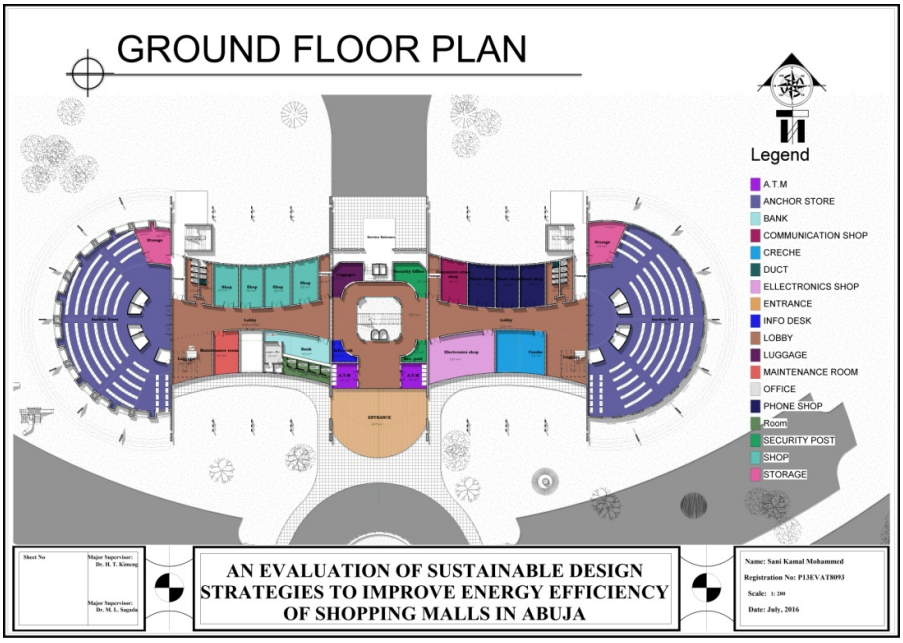


Figure 6.1: Ground Floor Plan
Source: Author's case study research (2015)

ii. The first floor is the consisting of sports equipment, Fashion shops and other related items. This was done in order to make the movement of goods in and out of such stores easier as shown in Figure 6.2

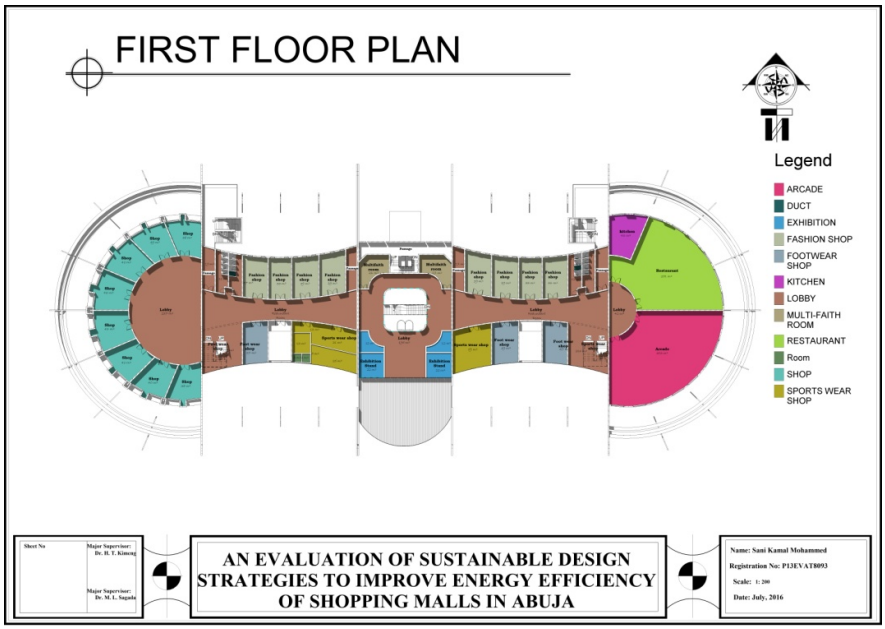


Figure 6.2: First Floor Plan
Source: Author's case study research (2015)

iii. On the second floor is the food court, beauty salon, barbers shop children's play area, arcade games, departmental stores. This is done in order to locate the food area midway the shopping mall to allow for equal distance to all customers and occupants as shown in Figure 6.3.

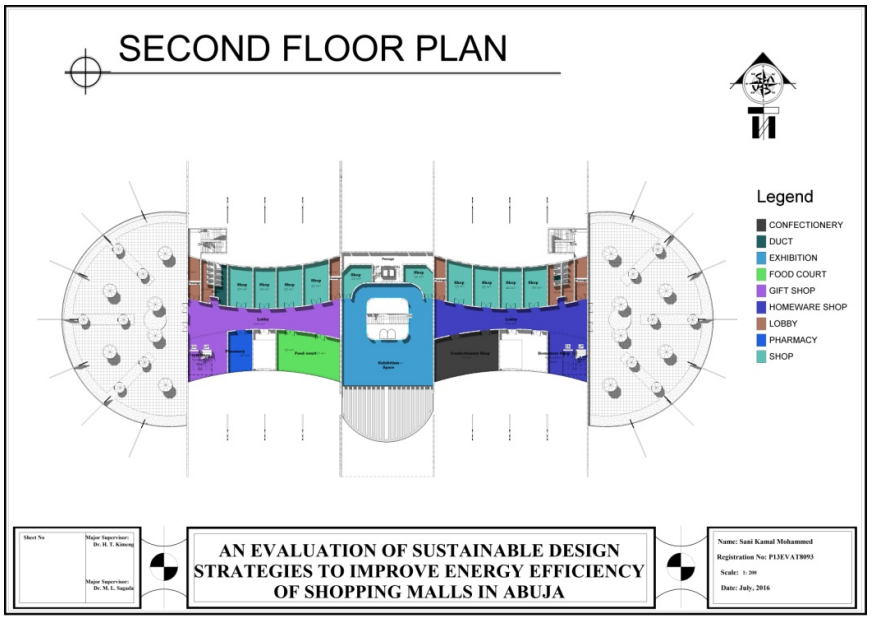


Figure 6.3: Second Floor Plan
Source: Author's case study research (2015)

iv. On the Third floor are the management activities like office, travel agency and let table office spaces. The volume of shoppers is much less on the last two floors which make them a good location for the offices as shown in Figure 6.4

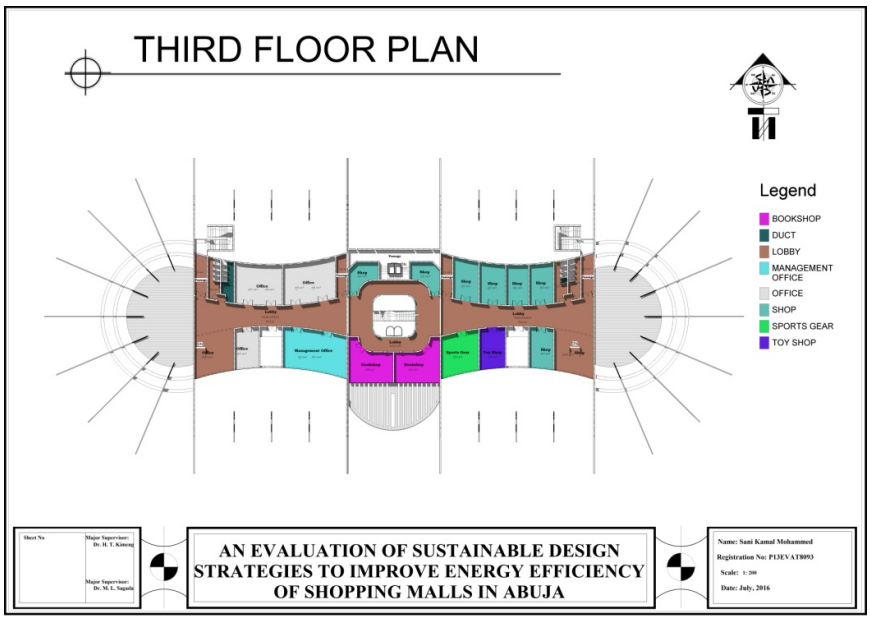


Figure 6.4: Third Floor Plan
Source: Author's case study research (2015)

6.4 Functional Organization

The design of shopping malls involves three basic concepts which are used to determine the organization of the functional spaces. These concepts are listed below:

i. Linear Concept: This concept is characterized by locating the display area at the façade of the building, and the service area at the rear end.

ii. Introverted Concept: The introverted concept has the shopping activities taking place at the core of the structure while service is carried out at its periphery.

iii. Extroverted Concept: In this arrangement, the main shopping activity takes place at the periphery of the structure while the services take place at the core. This concept is usually used in most western shopping areas where a covered street flanked by shops is the main shopping enclave.

For the purpose of this design, the Linear Concept shall be adopted. The purpose of this is to make access for maintenance easy and also to open up the interior space for more flexibility.

6.5 Design Considerations

This shopping mall is an environmentally friendly project, which has used technology and abundant natural resources to develop a model which show cases energy efficiency. The centre is dedicated and committed to sustainable design and the strategies employed based on the variables gotten from the literature review reflects this commitment. The proposed design will significantly reduce the energy it would originally consume; this will be achieved by in cooperating the sustainable strategies from the preliminary stages of the design to finish.

6.5.1 Climate

The climate of the site plays a significant role in the design of the proposed building. In a warm humid region such as F.C.T which is characterized by high humidity and hot discomfort, building materials, considerations and construction techniques are such that they should keep off heat rather than absorbing it thereby reducing the building interior temperature and running time of the air conditioning systems.

6.5.2 Site

Building orientation was with regards to solar radiation and wind, the longer sides of the building was oriented to face the south and the north direction on the east and west axis respectively. Openings on the east and west sides of the building were shaded with trees and horizontal and vertical shading devices. The proposed building was placed on the higher point of the site to avoid any form of wind shadow effect and drainages were placed on the lower points of the site, this will help for easy drainage during peak periods of rainfall. The site incorporated native plants and wild grasses to reduce direct sun from striking and heating up the building surfaces, this will prevent reflected light carrying heat into the building from the ground to other surfaces. Impervious landscaping surfaces was minimized to achieve maximum drainage.

Deciduous planting provided for shading during summer and allows desirable solar gains during winter and added aesthetic to the centre. The drought-tolerant Chitalpa tree (*Chitalpa x tashkentensis*) is recommended for this design, it grows several feet a year to a mature height of 25 to 30 feet. It has an open branching structure and casts a dappled shade. This heat-loving tree blooms with pink, white or lavender flowers all summer long. It requires low water usage after it is established within surrounding. Plate L illustrates this.

6.5.3 Building envelope

The roof receives significant solar radiation and plays an important role in heat gain/ losses and daylighting, hence light colours were used on the roof to reflect light that will heat up the surface from the roof. Atrium was introduced in order to allow adequate passage of sunlight and escape of hot air from the building.

Double glazing, low emittance coatings, blue/green tints have become very important means of energy conservation in modern construction to reduce both thermal losses and heat gain, hence it was used in this design.

6.5.4 Building shape and form

In warm humid climates, Forms with large surface areas facing North and South are preferred to reduce solar radiation. This influenced the shape and form of the proposed shopping mall. Figure 6.5 shows the massive nature of the proposed centre.

6.5.5 Spatial organization

The general planning of the site and facilities are such that the activity relationship are well co-ordinated to create a harmonious grouping and ease of circulation.

6.5.5.1 Accessibility

Accessibility to site is convenient and free from all obstruction. Two separate accesses were provided, the main access that is for staffs, users and visitors while the other for services. The main access is complimented with a pedestrian walkway.

6.5.5.2 Site drainage

The site drainage is positioned at the lowest point on the site, this is to allow easy flow and collection of running water during rainfall.

6.5.5.3 Main facilities

This centre consist of three floors, all floors are designed to have an open plan circulation in order to encourage free movement of air and users. The entrance of the building leads to the reception desk, which is directly before the central atrium. Staircases are also provided for vertical movement of user.

7.0 SUMMARY, CONCLUSION AND RECOMMENDATION

7.1 Summary

The aim of this research was to explore the concept of sustainable design strategies in an attempt to enhance energy efficiency in shopping malls, this was achieved by having an in-depth review of sustainable design strategies, energy efficiency factors and their application in shopping malls, investigating the extent to which these strategies were applied in shopping malls designs and finally, a demonstration showing the application of these sustainable design strategies on a shopping malls

The studies carried out in the course of this research have shown that buildings account for up to 50% of total energy consumption with heating and cooling accounting for most of the energy demands in buildings. The effect on shopping malls and other related facilities in Nigeria is that energy has to be generated privately to sufficiently cater for the energy demands of such institutions. Consequently, there is a corresponding increase in prices to consumers. Based on findings sustainable principles are not widely used in shopping mall designs in Nigeria. This is evident in the case study summary, where it shows that only one or two variables are applied.

The intent of the thesis was to examine sustainable design strategies, its level of applicability in architecture with particular reference to shopping malls. . This situation makes it imperative to consider the use of environmentally sensitive technologies in the provision of comfortable shopping environment for shoppers considering that so many people will pay for a good shopping, entertainment and relaxation experience. Another finding worthy of note is the fact that environmentally sensitive innovations in the areas of energy generation and management are not in application in Nigerian shopping malls even where the micro and macro climatic conditions of the site would have made it viable.

The inferences drawn from these findings are; perhaps with an insightful application of some of the mentioned sustainable design strategies in shopping mall designs in Nigeria, that the shopping environment will become more viable since it will enhance the shopping experience entertainment and relaxation, while not compromising the quality of the environment.

7.2 Conclusion

In conclusion, the research highlights two important contributions to knowledge:

Firstly, the use of sustainable design strategies is a preferred approach to the enhancement of human comfort, visual effect and shopper's experience within the shopping mall environment.

Secondly, there is the need for more enlightenment amongst shopping mall operators of the viability of sustainable shopping mall design. This enlightenment campaigns should inform such individuals of the financial profitability of environmental sustainability and the long-term gains of engaging in sustainable design.

Finally, this research has been able to apply various sustainable design strategies to achieve natural cooling and ventilation in shopping malls.

7.3 Recommendations

Based on the conclusions drawn, the following recommendations are made to ensure that sustainable design strategies aid energy efficient shopping mall.

i. Buildings should be made to maximize the site's potential and to achieve the best possible orientation for functional areas.
ii. Shading devices should be introduced to those areas that face severe heat collection from the sun path or such walls should be insulated to reduce heat emitted into the building.

iii. Issues of sustainable planting and landscaping should be considered by planting more trees and grasses to enhance the cooling of the immediate environment.

iv. Building materials should be of high thermal performance in order to reduce heat gain.

7.4 Contributions to Knowledge

i. The study established that the application of sustainable design strategies such as proper building orientation, appropriate building envelope materials, landscaping and shading can reduce the energy of cooling loads in shopping malls by 38%

ii. It identifies the impact buildings pose on the local energy supply which is vital in the protection and development of an informed energy policy.

References

Adeniyi, J. A. (2001) *Citation And Referencing In Adegboye A.O.* (Ed) Research Project Report: A Practical Guide. Ilorin: Kola Success Project.

Afolayan, M. O. {1999} *How To Write Thesis Or Technical Paper Quickly*: With Introduction On How To Research Information From The Library And The Internet. Zaria: Faith Printers And Computer Services.

Agboola, O. P. (2011). *Importance Of Climate To Architectural Designs In Nigeria*. Department Of Architecture Osun State College Of Technology, Esa - Oke, Osogbo, Osun-State .

Ahmed, M. O. (2012). *The Application Of Eco-Architecture To Enhance Energy Efficiency In The Design Of A Resort Hotel For Silverbird, Abuja*. Unpublished Msc Thesis, Department Of Architecture, A.B.U. Zaria.

Aina, L. O. (2002) *Research In Information Sciences:* An African Perspective. Ibadan: Stirling-Horden.

Akinwumiju, J. A. {2000} *Eme 409 Educational Research Methods:* External Studies Programme. Ibadan: The Centre For External Studies.

Autodesk Sustainability Workshop (2003*). List Of Partnerships For Sustainable Development And Summary* (Www.Un.Org Esa/Sustdev/Partnerships/List-Partnerships.Htm).

Ballard, C. (1981), '*Trends In Retail Development: 1980's And Beyond,"* In George Sternlieb And James Hughes (Eds), Shopping Centers: Usa, New Jersey: State University Of New Jersey, Center For Urban Policy Research.

Bombeck, E (1985), "Lost Forever In A Shopping Mall," *The Daily News*, Sunday-December 22, P. 16.

Bugaje, I. M. (2006). Renewable Energy For Sustainable Development In Aq Africa: A Review.*Renewable&Sustainableenergyreviews*10:603–612.

Buck, J. And D. Young (2006), "The Potential For Energy Efficiency Gains In The Canadian Commercial Building Sector: A Stochastic Frontier Study," *Energy - The International Journal*, 32: 1769-1780.

Bucklin, L. (1971), "*Retail Gravity Models And Consumer Choice: A Theoretical And Empirical Critique*," Economic Geography

Bureau Of Energy Efficiency. (2013). Energy Conservation Building Code.

Burstiner, I. (1986), "*Retailing For The Next Twenty Years: Looking Forward In Time*," Basic Retailing, Il: Irwin Publishing

Brunner, J., and Mason, J. (1968), "*The Influence Of Driving Time Upon Shopping Center Performance*," *Journal Of Marketing*, 32, 57-61.

Canbay, C. S., A. Hepbsali, G. Gokcen. 2004. Evaluating Performance Indices Of A Shopping Centre And Implementing Hvac Control Principles To Minimize Energy Usage. *Energy And Buildings*, Vol. 36, Issue 6, June2004 Pp. 587–598.

Crask, M. (1979), "A Simulation Model Of Patronage Behavior Within Shopping Centers," *Decision Sciences*, 10, 1 -15.

Dawson, J. (1982), Shopping Centers: A Bibliography, Il: Council Of Planning Librarians.

Diesendorf, M. (2007) Green House Solutions With Sustainable Energy, Sydney: Unsw Press.

Ducoulombier, M., A. Teyssedou, And M. Sorin (2006), "A Model For Energy Analysis In Supermarkets," *Energy And Buildings* 38: 349-356.

Fanger, P. O. (1970). *Thermal Comfort-Analysis And Applications In Environmental Engineering*. Danish Technical Press, Copenhagen

Feinberg, S. (1960), *What Makes Shopping Malls Tick*, New York: Fairchild Publications.

Fitzgerald, S. D., & Woods, A. W. (2008).The Influence Of Stackson Flooor Patterns and Stratification Associated With Natural Ventilation. *Building And Environment*, 43 (10),1719-1733

Gentry, J. (1977-1978), "How Important Are Evaluative Criteria In Shopping Center Patronage," *Journal Of Retailing,* 23(12), 45-47

Ghani, S. (2012). *Planning For Sustainable Housing Development*. In Ramli, M & Byrd, H. Towards A Sustainable Built Environment In Malaysia (107-120). Penang: Universiti Sains Malaysia.

Gruen, V., and Smith, L. (2006), *Shopping Towns, U.Sa.*: The Planning Of Shopping Centers. New York: Van Nostrand Reinhold.

Howell, R., and Rogers, J. (1981), "*Research Into Shopping Mall Choice Behavior*,", In K. Monroe (Ed.), Advances In Consumer Research, 8, Mi: Association For Consumer Research

Humphreys, M. A., Nicole, F., Rijal, H., and Clarke, J. (2009) Occupant Behaviour In Naturally Ventilated And Hybrid Buildings, *Ashrae Transactions* 115(1) Pp 16- 27

International Energy Agency (2013); Sustainable Design And Green Building Toolkit For Local Governments. Epa 904b10001 | June 2010

International Council of Shopping Centres (2013) New York. *A Brief History of Shopping Centres.* ICSC.

Jacobs, J. (1986), *The Mall: An Attempted Escape From Everyday Life, Il*: Waveland Press.

Janda (2009) World Status Of Energy Standard For Buildings Http://Www.Eci.Ox.Ac.Uk/Publications/Downloads/Janda09worldwidestatupdf

Kim, J. J. (1998). *Sustainable Architecture Module: Introduction To Sustainable Design*; National Pollution Prevention Centre For Higher Education

Martin, D. (1987), "Behemoth On The Prairie: In Edmonton The World's Largest Mall Mixes Shopping And Show Business," *The New York Times*, January 4, 19-20, 29.

Nadel, S. (2006). *Energy Efficiency Resource Standards: Experience And Recommendations (No. E063).* Washington, Dc: American Council For An Energy-Efficient Economy.

Nevin, J., and Houston, M. (1980), "Image As A Component Of Attraction To Intra-Urban Shopping Areas," *Journal Of Retailing*,3(10), 22-35

Nordhaus, W. D. (2007). Critical Assumptions In The Stern Review On Climate Change. *Science*, 317, 201-202.

Neufert, E., & Neufert, P. (2000). Architect's Data: Third Edition. Oxford, UK.

Nicklas, M. (2008). *Daylighting Strategies That Maximize Benefits.* The Following Article Was Published In High Performing Buildings, Spring 2008. American Society Of Heating, Refrigerating And Air-Conditioning Engineers, Inc.

Oluwafemi, S. O., Femi, J. A., & Oluwatosi, T. D. (2010), Time Series Analysis Of Rainfall And Temperature In South West Nigeria, *The Pacific Journal Of Science And Technology*, 11(2) , 552-564.

Omar. M. (2013). "Measures Of Sustainability: A Case Study Of Materials Selection For Eco-Lightweight Auto-Bodies." *Journal Of Cleaner Production* 40: 177-89.

Pershing, J. (2005). Climate Science 2005: Major New Discovering. Wri Issue Brief,

Washington Dc, U.S.A.

Rouse, J. (1962), "Must Shopping Centers Be Inhuman," *Architectural Forum*, 116, 105-119.

Samimi, A. (2013)," Preservation Ways And Energy Consumption In Oil Refinery", *International Journal Of Chemistry*; (Ijc), Austria, 41-47

Samuel (2011) Sustainable Design Principles For Every Architect

Sassi, P, (2006). *Strategies For Sustainable Architecture.* Taylor And Francis, Abingdon

Schwarz, V. (2009). *Environment And Energy: Promoting Energy Efficiency In Buildings*: Lessons Learned From International Experience. Copyright © Undp 2010

Smith, P. (2003). *Sustainability At The Cutting Edge*. Architectural Press, Oxford

Stern, N. (2008)."The Economics Of Climate Change."*American Economic Review*, 98(2): 1-37.

Straube, J., and Burnett, E. (2005). *Building Science For Building Enclosures*. Building Science Press, Westford, Ma.

Stensson, S., M. Axell, Et Al. (2009). *Specific Energy Use In Swedish And Norwegian Shopping Malls*. Eceee Summer Study.

Subramanian, N. (2007). Sustainability – Challenges And Solutions: *The Indian Concrete Journal*, 3(10), 55-60.

Turchiana, F. (1990), "*The Unmalling Of America*," American Demographics, April, 36-39.

U.S. Green Building Council. (2003). *An Introduction To The U.S. Green Building Council And The Leed Green Building Rating System*. Www.Usgbc.Org/Resources/Research.Asp

United Nation Environmental Programme (2009): Assessment Of Policy Instruments For Reducing Green House Gas Emissions. Http://Www.Unep.Org/Sbci/Pdfs/Sbci_Ceu_Policy_Tool_Report.Pdf /26thnov 2009

Veal, A. J. (2006). *Research Methods Or Leisure And Tourism*. Third Edition. London: Prentice Hall.

World Commission For Environment And Development Wced (1985). '*Mandate For Change, Key Issues, Strategy And Workplan*' (Geneva: Centre For Our Common Future)

World Commission For Environment And Development Wced (1987). 'Our Common Future' (Oxford: Oxforduniversity Press)

Wilson, E. O. (2002).The Future Of Life. Vintage

Williams, P. D., Guilyardi, E., Sutton, R.T., Gregory,J.M. And Madec, G. (2007) '*A New Feedback On Climate Change From The Hydrological Cycle'*, Geophysical Research Letters, 34, L08706, Doi: 10.1029/2007gl029275

Williams, E. D. (2007). Sustainable Design: Ecology, Architecture, And Planning. Donald Watson, Faia

APPENDICES

APPENDIX A

CASE STUDY CHECKLIST

S/N	Variables	Checklist	Level of application					Remark
			1	2	3	4	5	
1	Building envelope	Sustainable building materials External insulation Use of bright colours for walls Use of bright colours for roofing sheet. Low embodied energy materials Sun orientation; E-W Wind orientation; SW-NE						
2	Daylighting	Wall to window ratio (40%) Use of spectrally selected glasses Use of atriums or courtyard						
3	Natural ventilation	Use of openable windows Use of passive ventilation						
4	Wall and window shading	Use of win. shading devices Use of interior blinds Use of recessed walls Use of roof overhangs Use of plants for shading						
5	Mechanical and electrical appliances	Use of energy saving bulbs Use of energy saving toilet wares						
6	Parking and landscape elements	Thermal reflective parking spaces planting and Waterbodies						
7	Existing Energy	Use of renewable energy for electricity Use of natural gas						

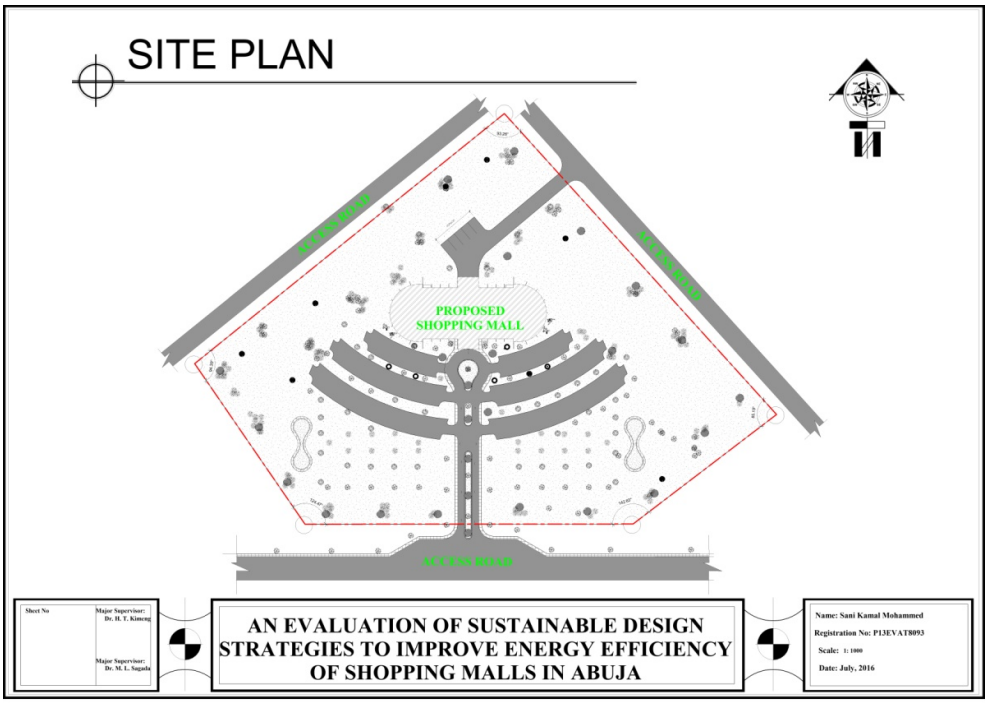
APPENDIX B

INTERVIEW SCHEDULE

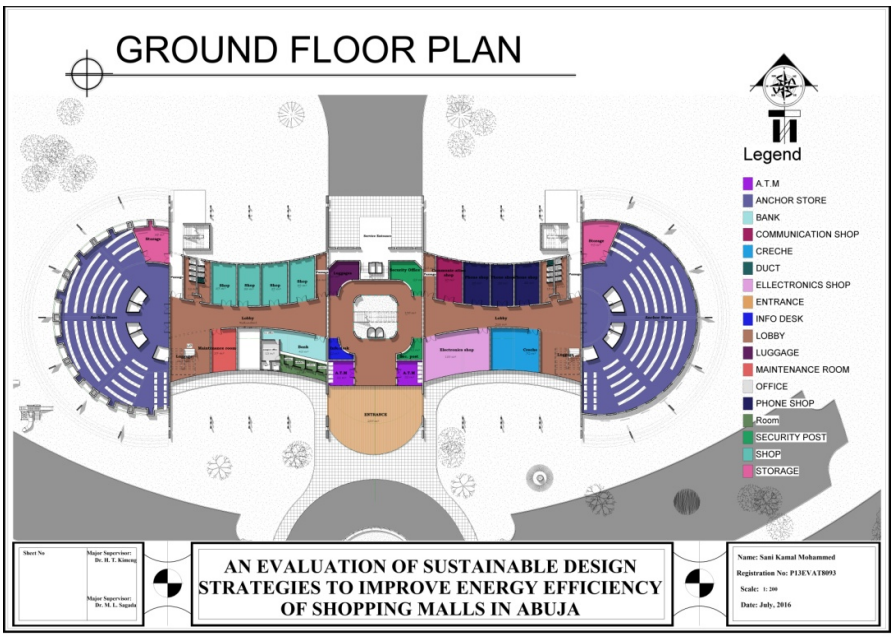
1. What is the energy source of this facility, the consumption rates and how sustainable is the current energy source of the facility?
2. Were there any considerations made to achieve adequate daylight and natural ventilation in the shopping mall?
3. What strategies were employed to minimize energy consumption considering the ratio of the built area to the open spaces?
4. What considerations were made during the orientation and planning of the building to help maximize energy efficiency?
5. Does the shape and form of the building help to minimize energy consumption?

APPENDIX C

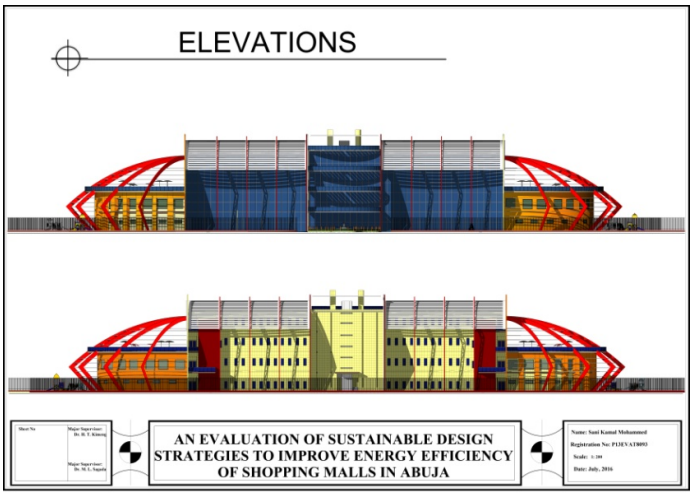
DESIGN



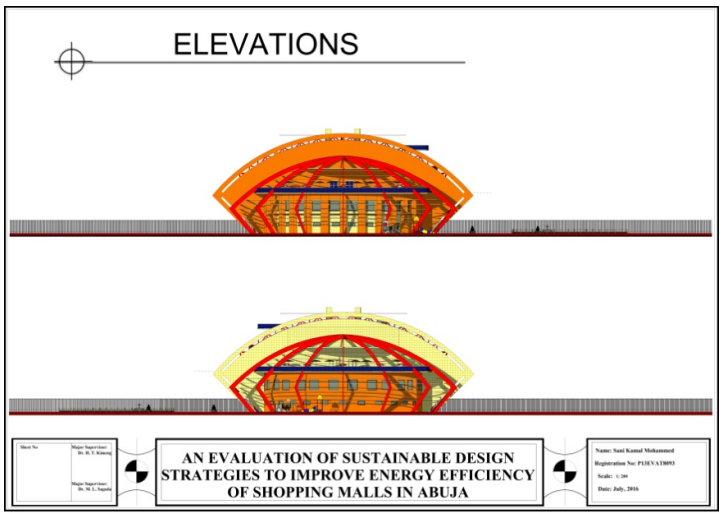
Appendix I: Site Plan of the proposed building



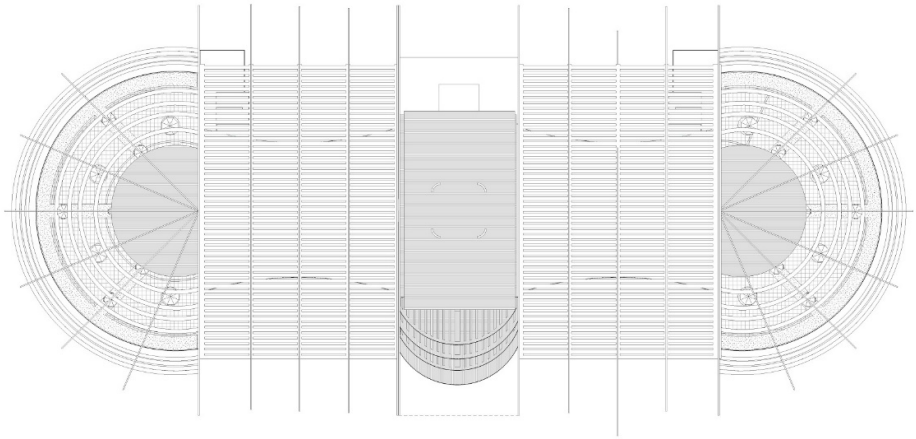
Appendix II: Ground Floor Plan of the proposed building



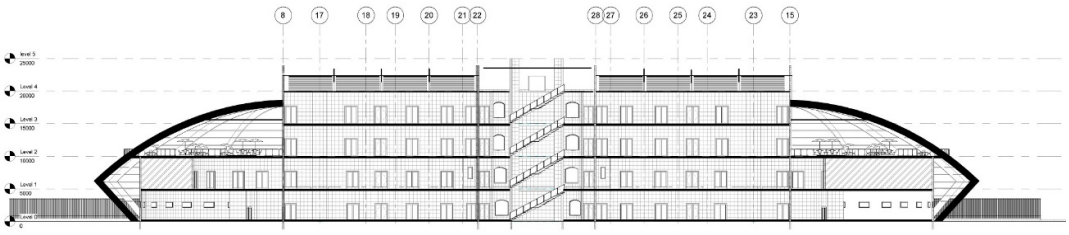
Appendix III: Approach and Rear Elevations of the proposed building



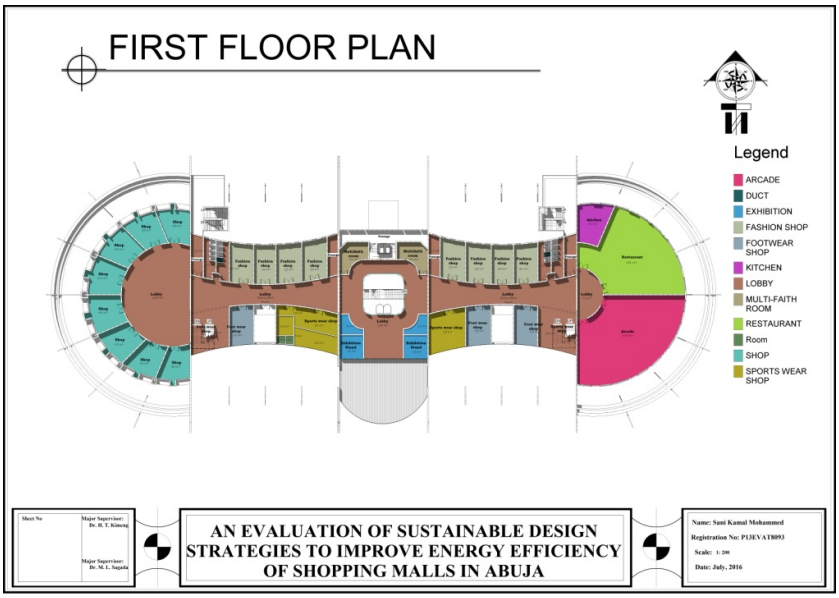
Appendix IV: West and East Elevations of the proposed building



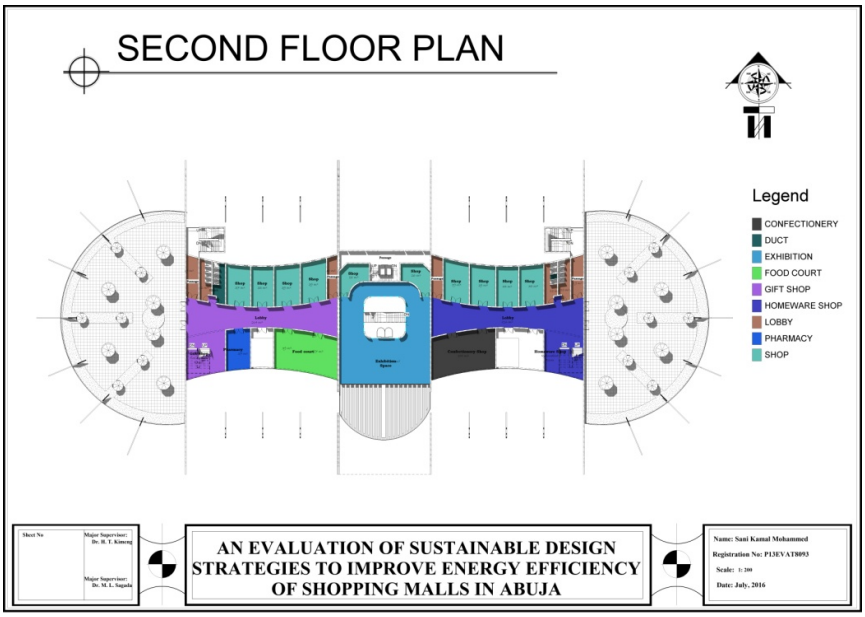
Appendix V: Roof Plan of the proposed building



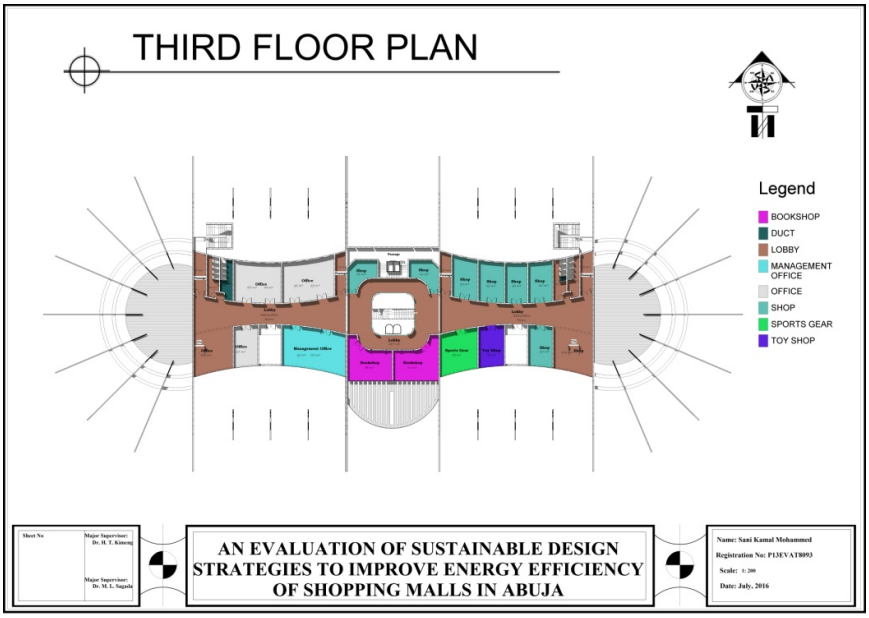
Appendix VI: Section of the proposed building



Appendix VII: First Floor Plan of the proposed building



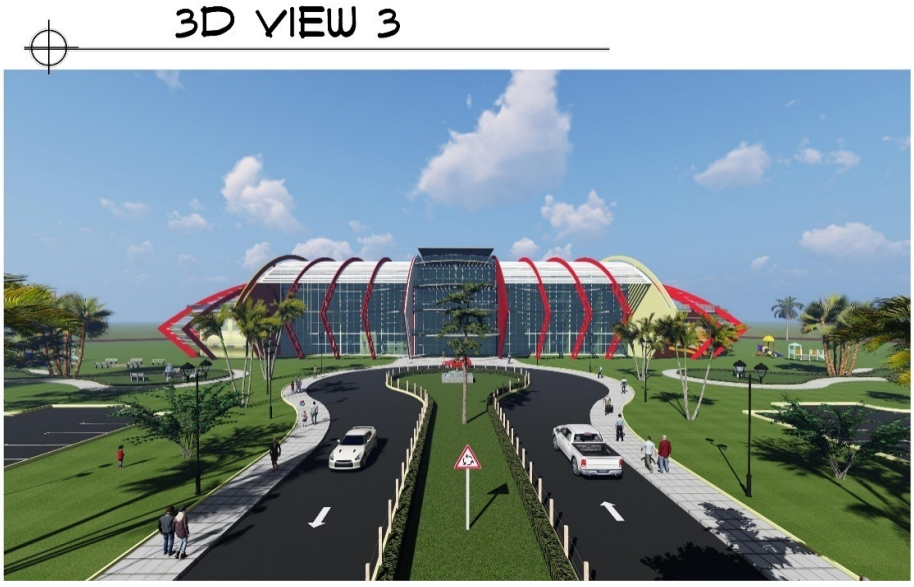
Appendix VIII: Second Floor Plan of the proposed building



Appendix IX: Third Floor Plan of the proposed building



Appendix X: 3D View of the proposed building



Appendix XI: 3D View of the proposed building



Appendix XII: 3D View of the proposed building