INTEGRATION OF PASSIVE COOLING DESIGN STRATEGIES IN SHOPPING MALLS, ZARIA, KADUNA STATE

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ABSTRACT

Globally, shopping malls trends have been changing from open precinct to larger shopping malls. This transition is heading towards a more enclosed and air conditioned environment as compared to the older forms of shopping centres such as arcade and plazas, which were designed opened. Shopping malls in Nigeria are therefore evolving into high consumption area of electricity, as a result of reclusive design approach due to minimum or no use of natural ventilation. The aim of this thesis is to investigate the passive design strategies used to achieve passive cooling in shopping malls. The objectives assessed the existing shopping malls and evaluate the passive cooling design measures used to reduce the effect of excessive heat aside the use of energy consuming devices. A descriptive survey method was adopted with the use of an observation schedule where selected samples within the study area were examined to determine the frequency of use and effectiveness of passive cooling design strategies used in the samples. Findings from the samples were analysed and interpreted to show if the design strategies are appropriately incorporated to serve the purpose of achieving thermal comfort or are rather used for aesthetics. Findings shows the frequency of the parameters used in the course of the study and it is finally observed from the selected samples that shopping malls in Nigeria are mostly dependent on active cooling system rather than the passive cooling strategy. Also, the result shows that most of the facilities adopt the use of courtyard to enhance air circulations within the building than other forms of central openings like atrium and skylights, courtyard were used in about 40% of the samples while the 3 other forms of large openings shared the remaining 60% from the samples taken. However the highest number of the respondent attest to the fact that they are mostly affected by thermal discomfort in the afternoon than other time of the day these respondents' population amounts to approximately 73% of the sample population. The findings reveal that a very high proportion of the sampled shopping malls depend mostly on the use of mechanical devices such as fans and air conditioners to enhance cooling in its indoor environment. Lastly, It is worthy of note that this thesis emphasized on the design strategies to reduce dependency of artificial means of enhancing passive cooling. These can be achieved through proper building orientation, adequate planting and installation of green landscape elements, effective use and proper positioning of shading devices and careful selection of building material that allow for proper thermal insulation.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

With increased environmental awareness in the built industry in Nigeria, contexts like energy conservation and passive design strategies have tremendously gained high importance and considerations in building designs. Built environment professionals are not restricted to creating shelter alone but also providing therapeutic and comfortable environment. A healthy and comfortable shopping environment would help in protecting public health as well help enhance economic transactions in the place. Therefore, paying attention to both the internal and external environmental quality of the shopping malls is essential to ensure the health and safety of all users of the shopping mall (Hu and Li, 2015).

It was asserted that mechanical equipment has a higher maintenance and low replacement regime generally than natural ventilation approach (American Society of Heating, Refrigerating and Air Conditioning Engineers, ASHRAE (2004). However, cooling of building through the passive design approach encourages the utilization of natural ventilation and reduces the level of dependency on the mechanical equipment which are more cost intensive and less durable at the same time hence making it a key factor to consider in large commercial buildings such as shopping malls.

With time shopping centres are transforming from simple scaled open shopping plazas to large scale shopping malls which as compared to older types of shopping mall are

becoming more enclosed and an air conditioned environment rather than the old opened design, which is naturally lit and ventilated making them are more energy efficient than modern malls. Hence building professionals as a result of this transformation are geared towards building malls which seems likely to replace the arcades and plazas in the society.

Normally in shopping malls, a larger percentage of energy (about 70%), is consumed by heating, ventilation and air conditioning systems (HVAC) which are used to enhance the indoor environmental quality. The remaining 30% energy are used for other forms of energy consumption (Harper *et al.*, 2006). It is therefore advisable that a definite approach have to be adopted to reduce or possibly eliminate the use of active energy because mechanical indoor comfort provision account for the sizable percentage of energy used in most building (Akande, 2010). However, the use mechanical systems in shopping centre can be reduced drastically by incorporating design strategies for passive cooling hence reducing energy demand. These are passive design means to improve indoor environmental quality in buildings. Passive measures, specifically natural or hybrid ventilation rather than air conditioning, can significantly reduce the energy intake (Hatamipour and Abedi, 2008). Lastly, renewable energy can be incorporated in the design reducing energy consumption (Charles *et al.*, 2010).

1.2 Statement of Problem

It requires a very high energy consumption to achieve the desired indoor environmental quality inside shopping malls. Hence there is the need to design shopping malls with passive design features that would enhance indoor air quality as well reduce the energy demands at the same time, one of the ways of preventing high rate of dependence on active energy system for indoor comfort is for the designers to cater for the extreme

temperature which is a major challenges of the dry-hot climate from the design stage (Akande, 2010). This study from the various research consulted shows that the need for passive cooling design strategies in building cannot be over emphasised especially in hot-dry climate.

1.3 Aim and Objectives of the Study

The study is aimed at integrating design strategies that can be adopted to achieve passive cooling and improve the indoor environmental quality in shopping malls especially in a hot-dry climatic location. The following objectives have been set to guide the study:

1. To determine the design strategies used to achieve passive cooling in shopping environments.
2. To investigate the degree of presence of passive cooling design features in the existing samples.
3. To evaluate the effectiveness of the passive cooling design strategies examined in the samples from both observation and user perception.
4. To design a proposed shopping mall using passive design features to achieve a good indoor environmental quality.

1.4 Justification to the Study

The use of reclusive design approach has led to high consumption of electricity in shopping environments today, this is attributed to the fact that natural daylight and ventilation are used minimally or not used at all, thus increasing the need for mechanical ventilation which in turns increase energy consumption. In most shopping malls, air conditioning systems are used to provide indoor air quality. However, older shopping centres used design augmented natural ventilation in spaces to provide good

environmental quality. Thus, there is need for the architects and planners to examine and evaluate passive design of shopping malls to identify the associated problems with a view to sustain these older energy efficient forms.

1.5 Scope and Limitation of the study

1.5.1 Scope of the study

This research work covers only the design of a shopping mall in Zaria town, Kaduna State having large supermarket bigger than 5000m^2. The tenants mix for the proposed mall include convenience, retailers shop, major anchor boutiques, clothing stores, shoe shops, entertainment (cinemas), restaurants, and other services like accommodation, medical and banking facilities.

1.5.2 Limitation to the study

This thesis encountered some draw back due lack of sufficient statistical information on thermal discomfort, indoor air quality and energy consumption in the area of study and Nigeria as a whole.

1.6 Contribution to Knowledge

This research work would assess and integrate the design features for passive cooling in shopping malls and hence be of help to architects and other built environment professionals to achieve the desirable indoor environmental quality. This would motivate innovative trend of shopping mall design and encourage the use of passive cooling design techniques in mall designs especially in the hot-dry climatic region.

1.7 Study Area

Zaria is a one of the metropolitan cities in Kaduna state with a population estimated as 408,198 according to the 2006 census population. Being the 11th largest city in Nigeria,

Zaria has a population count of about 695,089 inhabitants. It falls within the North western region of Nigeria and was formerly known as the capital city of the Zazzau kingdom.

Zaria has a tropical wet and dry climate with warm or hot weather throughout the year, a wet season that starts from April and end at September and another dry season from October to March. Dogara *et al.* (2017) came up with the result of an analysis that revealed the gradually annual temperature rise in Zaria as a result of intense radiation from the sun just as observed globally. This analysis justify the need for a passive cooling design strategy to be adopted in buildings in Zaria as a result of its continuous increase in temperature.

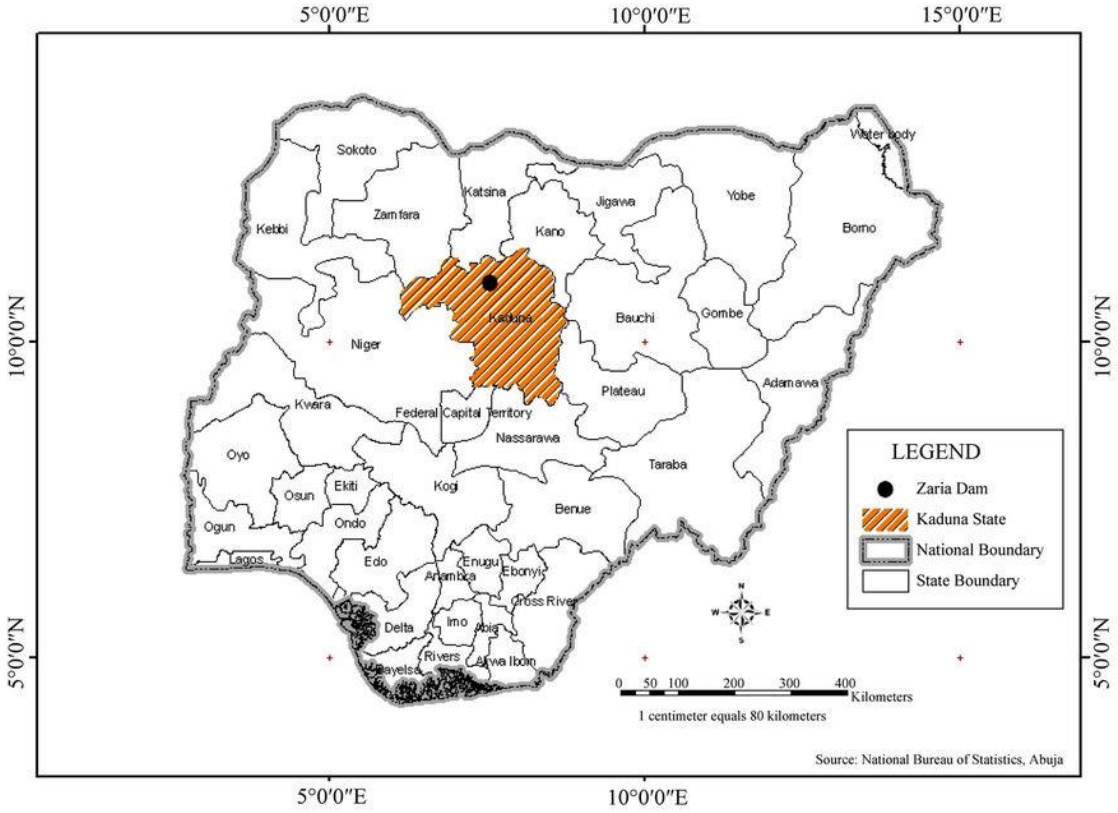

Figure 1.1: Location of Kaduna State in Nigerian (Source: Tanko *et al*., 2016)

Figure 1.2: Kaduna State showing Zaria and other Local Governments (Source: Tanko *et al*., 2016)

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 General Overview of Shopping Malls

Historically, a fully enclosed shopping mall was first seen in the mid-1950s. A vast range of definitions has been developed for shopping mall which reflects the series of changes experienced in the retail industry. In simple terms, a shopping mall can be referred to as being a building containing many retail divisions managed as a single property. As the economy improves, shopping malls are no longer only seen as a place to go shopping for the daily needs but they have become an attractive place for recreation and socializing (Sari *et al.,* 2011).

The complexity of shopping malls in recent times is continuously increasing as regarding size and qualities (Pitt and Musa, 2009). Also it can be regarded as a structured arrangement consisting of various identical retail outlets which forms a single unit. It is highly organized and structured commercial complex or unit which has varieties of retail outlets and recreational facilities that offers a comprehensive service to shoppers.

In the same vein, it can be deduced from the above definitions that a shopping mall can be explained to be a commercial real estate consisting of various business functioning together hence balancing retail services, catering, entertainment, leisure and other various attached units. Lastly, a shopping mall is a type of shopping area whereby one or more building forms a complex containing retail outlets with connecting walkways that enhance swift movement of shoppers from a unit to the other.

2.2 Evolution of Shopping Malls

Historically, shopping malls are easily linked to the ancient Roman and Greek eras. In ancient Greek, a city called 'agora', was the prime shopping area. The "agora" was enormous and opened ended so to enable retailers carry out their transaction with ease. In Rome, the then Emperor of Rome, Emperor Trajan constructed the first shopping mall (McKeave, 1977). The structure of the shopping mall was semi-circular, it has a big vaulted hall, and aerially the shopping mall looked like a basilica. The shopping mall has a common corridor where a collection of shops displayed their goods for customers' view and also contained important functions such as restaurants and bars.

Historical review of shopping malls from 1980s-2008 revealed; in Europe between 1980 and 1990 more than 16,000 shopping malls and centres were constructed. In that decade shopping malls were characterized by increasing super-regional shopping malls having floor area greater than 24,000m². In these malls manufacturers can display their product with ease from the factory outlet. Also in the 1990s, entertainment gained increasing popularity hence shopping malls began integrating entertainment outlets including children's play areas, live music, cinemas, food courts, amusement parks, aquarium so as to multiply activities for entertainment.

Gruen and Smith (1960) explained that earlier, shopping malls were basically architecturally significant constructions which enabled wealthier patrons carryout shopping activities, cultural activities as well as interact socially in an enclosed space protected from the weather However today, these expectations and designs have been meet and even surpassed in modern shopping centres.

2.3 Evolution of Shopping Malls in Nigeria

From historical evidences, markets have been a vital part of most towns and villages in Nigeria. The roles of markets in the economy of communities and the country at large cannot be overemphasised as they plays a very important role being a commercial institution. Market are not limited to serving as a determinant factor in the economy of both rural and urban societies, they are also seen as a social entity. Over the years, markets have attained this distinctive socio-cultural value (Vagale, 1974).

In developing economies like Nigerian, small-scale retail outlets account for most of the economic activity of the general public. Every neighbourhood centre has been observed to have up to three or more shops. These retail outlets are mostly found in residential areas to provide goods and services daily to serve the need of the populace. Standard retail outlets became operational in the country between 1960 and the early 1980s, however as a result of the unfavourable business condition, unfavourable government policy combined with general economic recession their numbers decreased, thus making the country void of standard shopping centres. As a result of this, traditional retail market increased in numbers therefore constituted majority of retail structure in Nigerian. Facts from the united state department of agriculture, USDA (2011). However stated in their annual report on Nigerian retail food sector that the percentage composition of retail food outlet in Nigeria was comprised of supermarkets (1%), convenience stores and street shops (34%), traditional open air market (65%) as is illustrated in Figure 2.1.

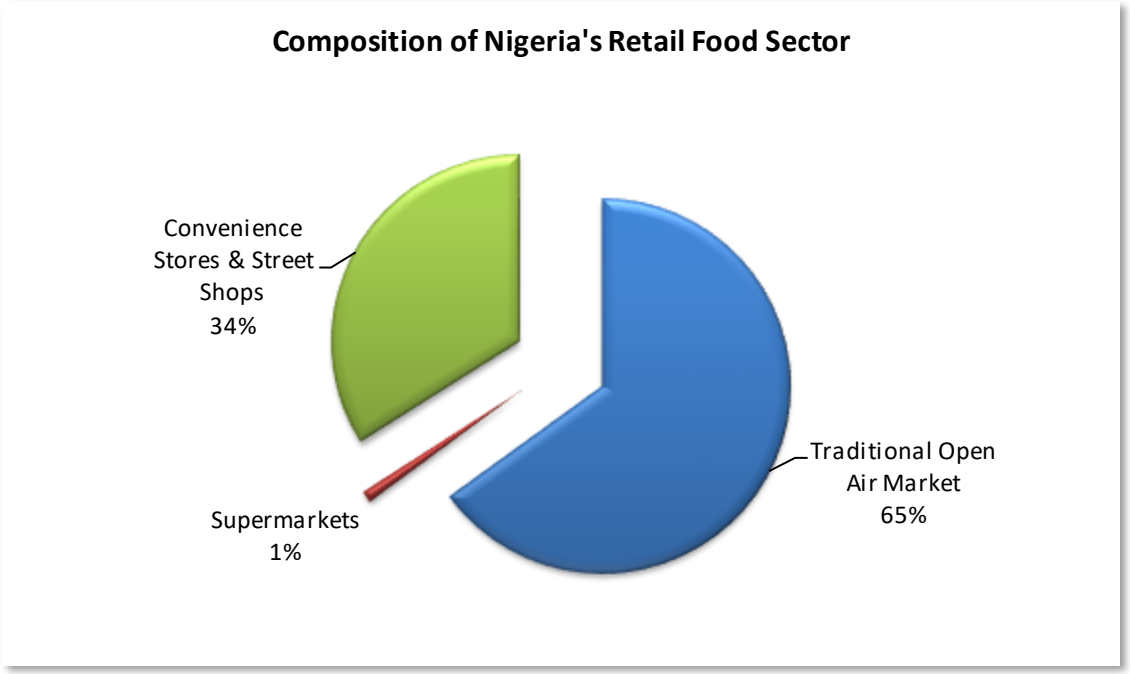

Figure 2.1: Composition of Nigeria retail outlet
(Source: USDA, 2011)

Although traditional open-air centres are still foremost, significant changes and growth have been observed some decades ago. These are attributed to the establishment of International supermarket brands which has enhanced the steady growth of retail outlets into becoming a very formal and modern day facilities providing wide range of shopping experiences in a modern, customer-friendly, building. Figure 2.2 extracted from USDA (2011) annual report of Nigeria retail sector also depicts attributes that had enhanced the change from traditional to formal retail in Nigeria.

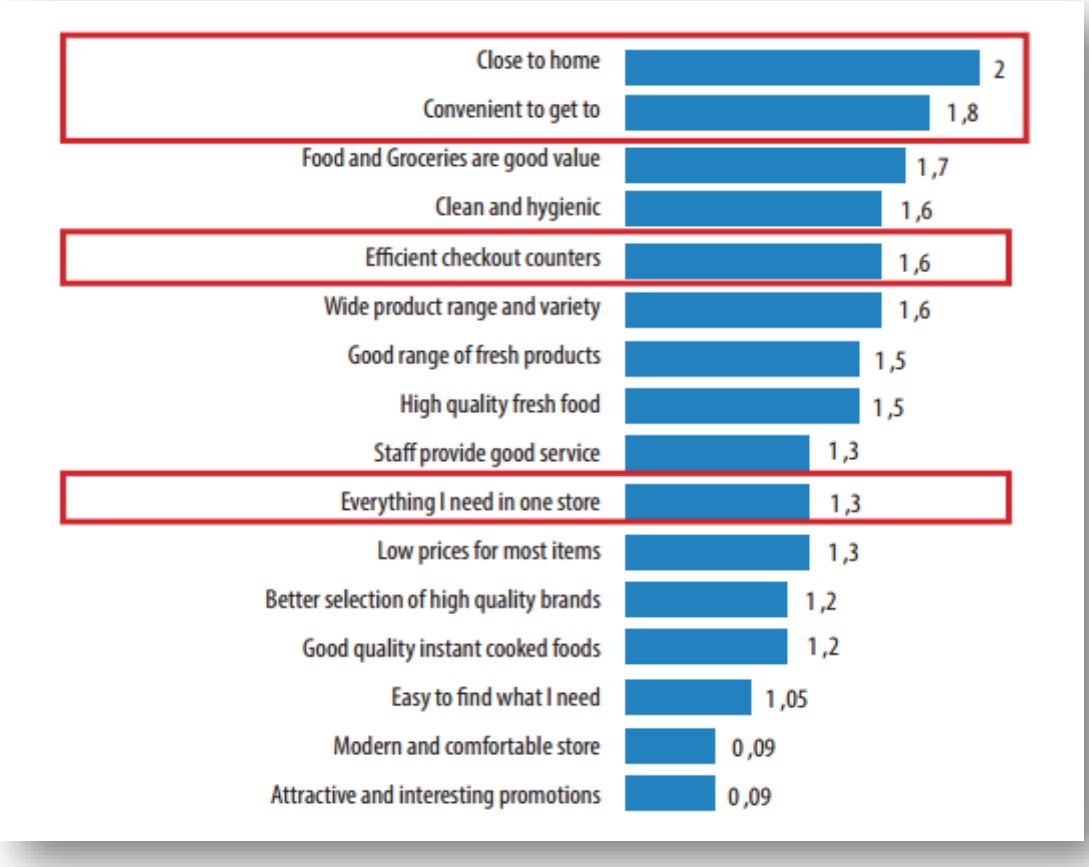

Figure 2.2: Attributes causing traditional to formal retail switch in Nigeria (Source: USDA, 2011)

Uzuegbunam, (1990) further stressed that shopping malls are presently overtaking old markets places as a result of planned and organised development.

2.4 Shopping Malls Types and Classification

In researches, no specific definition or classification has been given on shopping malls. There exist already many discrepancies regarding the classification of shopping malls. Hence this study would classify shopping malls as elaborated in the literatures below;

1. Mcgoldrick and Thompson (1992)
2. Dawson (1983)
3. International Council of Shopping Centers (ICSC, 2004).

2.4.1 Classification of shopping mall according to McGoldrick and Thompson (1992)

According to McGoldrick and Thompson (1992), shopping malls can be divided into two major categories, namely "out-of-town" and "in-of-own". "Out-of-town" shopping malls are those located within rural or undeveloped areas, while "in-of-town" shopping malls are those within the town and developed area.

2.4.2 Classification according to Dawson (1983)

This classification highlights types of in-of-town shopping malls which is recognized by building professionals. These are neighbourhood mall, community mall and regional mall.

i. **Neighbourhood Mall**

Neighbourhood mall are shopping malls built to provide a range of handy goods as well as offer services to residents in a certain environment. In the United States, neighbourhood mall range in size with a floor area between 3,000 to 10,000m² and typical centres almost 5,000m². These neighbourhood malls consists majorly supermarkets, restaurants, drugstore and hardware store (Dawson, 1983). In this neighbourhood malls, shopping area usually occupies up to 30% to 50 % of total floor area. In a ten minute walking distance, the expected patronage in this neighbourhood malls is about 2,500 to 40,000 people (Dawson, 1983). Typical neighbourhood malls are found in residential areas developed to serve the daily needs of residents.

ii. Community mall

Community shopping mall offers a wide range of merchandize than neighbourhood malls (Urban Land Institute, 1977). These malls are usually designed to provide service for a large part of the community thus they have usually have up to 10,000 to 30,000m² total floor area so as to efficiently provides its services to over 40,000 to 150,000

people. In most community mall, tenant mix includes supermarkets, small variety stores and other service outlets representing more than 40% of the total floor space. Community shopping malls are mostly located at major route of the main road network in a community. This is an important criterion for site selection of a community shopping mall as it helps capture a larger catchment area.

iii. Regional mall

Regional shopping malls are another form of shopping malls, it floor area space ranges between 50,000 and 100,000m². The design incorporates pedestrian walk ways or arcade (open or enclosed), connecting major anchor stores. In the location of regional shopping malls, site selection is a very important. The significance of regional shopping malls cannot be over emphasised as they affect population shift, local transport network and nearby community (Lam 2012). Regional planning authorities are often involved in the design and planning of regional malls, this is to ensure that the regional mall is well incorporated into the town or city master plan. Table 2.1 shows Dawson's classification of shopping centres.

Table 2.1: Classification of shopping centres according to Dawson

Characteristics	Strip	Community	Neighbourhood	Regional	Super-regional	Infill	Extension	City Center Restoring
Total area (sq.m)	1,500	5,000	20,000	50,000	100,000	2,500	15,000	40,000
Number of storeys	Only one	Usually only one	Usually only one	One or more	Usually only one	Usually only one	Usually only one	Several
Open-air/closed	Open-air	Usually open-air	Both	Usually closed	Closed	Usually closed	Usually closed	Closed
On-site center management	No	No	Sometimes	Mostly	Yes	No	Sometimes	Yes
Association of tenants	No	Mostly	Mostly	Yes	Yes	No	Mostly	Yes
Possibility for the settling of independent retailers	Yes	Some	Little	No	No	Yes	Some	Little
Anchor tenant	No	Supermarket	Mixed store	Department store	Department store	No	Variable	Department store
Control of the tenant composition	Weak	Weak	Medium	Significant	Weak	Medium	Significant	Significant
Optimal site	Near a regional center	Local road network intersection	City road network intersection	City road network and intercity highway intersection	Within the conurbation between cities	Highest-prestige retail neighbourhood	Near city center restoration	Traditional city center
Significance as growth pole	No	No	Limited	Some	Some	No	No	Significant

(Source: Dawson, 1983)

2.4.3 Classification according to international council of shopping centers

The classification of mall as elaborated by the International Council of Shopping Centers (ICSC, 2004) helps in identifying up to nine varieties of shopping center. One of these classifications subdivided the shopping malls into both regional and super regional malls.

2.4.3.1 Mall or shopping mall

There are usually referred to as a closed shopping center, they contains pedestrian walkways or arcades with regulated lighting and air-conditioning. A shopping mall is basically either a regional centre or a super-regional centre.

i. Regional malls – It has a general retail business which includes fashion clothes and other services. The key attraction is the mixing of fashion apparel stores and anchor tenants.

ii. Superregional malls – These are very similar to the regional centres however, they are much bigger. Hence, there is increased number of anchor tenants with a wider variety of stores.

2.5 Shopping Malls Configuration

The configurations of shopping malls comes in various form, these depends on its types and classification as shown in Figure 2.3. These are;

i. Strip malls - linear (Opened)

ii. Double Strip malls - Partially covered

iii. Shopping Plaza (mini mall) - Partially or Fully covered

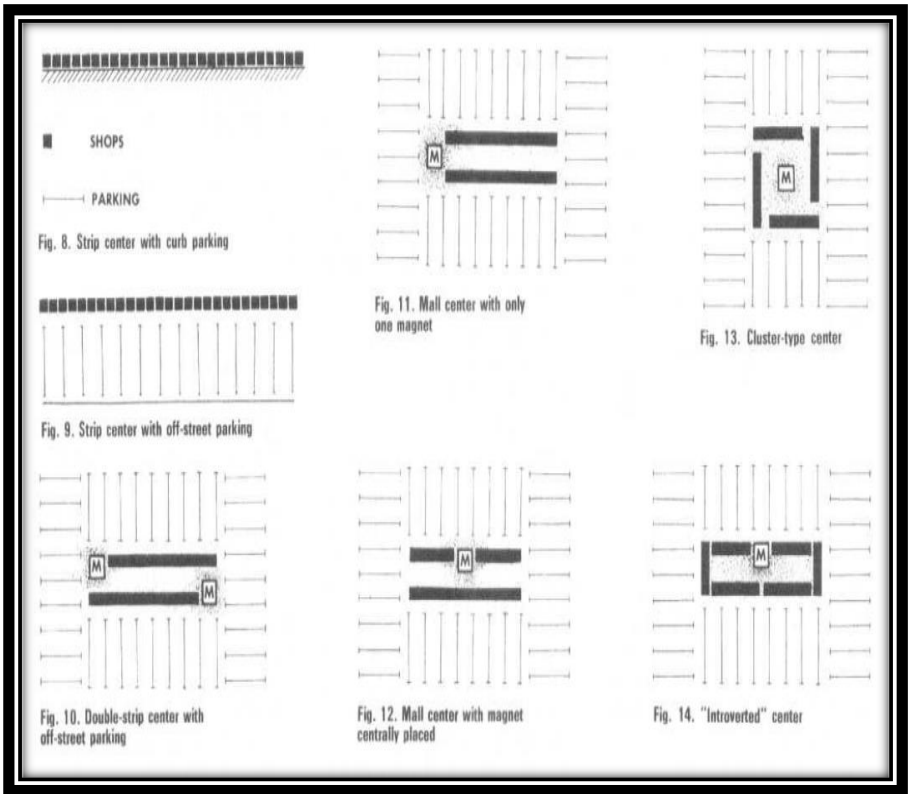

Figure 2.3: Shopping Centre Configuration (Source: Chusid, 2015)

2.6 Design Concepts of Shopping Malls

Design concepts for shopping malls are in three basic types. They are the introverted design concept, extroverted design concept, and super complex design concept.

i. Introverted Design Concept

The introverted design concept arranges group of shops and other retail outlets in the direction of an open courtyard (Odoma, 2000).

ii. Extroverted Design Concept

This design concept arranges group of shops and other retail facilities to envelop a central courtyard while transactions are done externally (Odoma, 2000).

iii. Super Complex Design Concept

This design allows for all retail transactions in complex to happen under a single unit. This concept makes it possible to move easily within the complex without being exposed to external elements (Odoma, 2000).

2.7 Tenant Mix

According to ICSC, (2004), shopping mall is defined as a collection of a number of retail and commercial service outlet in a well-structured and designed building or a group of buildings managed as a unit. This explanation highlights the adequate planning and proper control of each units of retail outlet in a shopping mall usually done by a centre manager. The relationship existing between the spaces occupied by various types of store is termed the tenant mix which is also seen as a form of retail geography (Dawson, 1983).

Previous research on retail outlet highlighted tenant mix as an important feature that determines the success of a shopping mall's (Abratt, fourie and pitt 1985, Anikeeff, 1996). Undoubtedly, tenant mix is a vital element in creating the image of a shopping

mall's. Tenant mix in retail industry is a concept which has been recurrently highlighted, It determines the patronising power of a shopping mall as more shoppers are attracted to a shopping owing to of proper tenant mix which increases sales (Abratt *et al.*, 1985).

Tenant mix in shopping malls is still treated as a "puzzle" by some malls managers and researchers as it is seen as an art performed by the management team. It is a dynamic condition which is affected by market changes, customer preference and fashion trends. Thus the "ideal" condition attained in a certain market phase might be inappropriate for another. Being an almost perfectly competitive market, marketing strategies in the retail industry are thus influenced by the actions of different competitors. Thus, there is a need for mall managers to constantly adjust tenant mix so to be abreast with market changes and trends (Bruwer, 1997).

A good tenant mix contains various harmonious or complementary retail outlets and service providers, effective space allocation (both in size and number), it should also make provision for proper arrangement of tenants which would enhance swift customer's transaction and other retail activities. In a broader context, tenant mix also involves consideration of the inclusion of adequate public facilities and services. Other vital facilities that enhance the quality of the shopping mall's environment which satisfy shoppers' needs, such as goods and services, convenience, entertainment, dining area, recreational and other required facilities are all the major parts of the components that make up an ideal tenant mix (Scott, 1970).

2.8 Thermal Comfort

2.8.1 Concept of thermal comfort

According to studies, comfort is treated as a subjective feeling. Hence, thermal comfort is a feeling that acquaints fulfilment with the thermal environment. It can be simply defined as a state of thermal balance. Outside comfort exist nervousness, which is defined according to the amount and extent of warm push. Relief inside the building is effectively established by keeping structures away from warmth during hot weather condition and by counteracting with warmth in cold weather condition (Ogunsote, 1993).

The ANSI/ASHRAE standard 55, explained thermal comfort as a condition where the mind is totally satisfied with its immediate environment. Subjective evaluation is usually employed to assess thermal comfort. Hence, thermal comfort is maintained within shopping malls by using heating, ventilation and air conditioning (HVAC).

2.8.2 Importance of thermal comfort

Numerous works related elements are highly dependent on thermal comfort. Studies have shown the importance of thermal comfort in an environment. Huizenga *et al.* (2006) reiterated that thermal comfort enhances productivity and health of occupants hence workers in a good thermal environment are more efficient and productive. Thermal discomfort on the other hand, results to sick building syndrome symptoms. The adaptive models for thermal comfort allows for flexibility in designing naturally lit and ventilated structures with good and desirable indoor air quality. The type of model will help save a lot of energy and helps improve occupant ambience within the building.

2.8.3 Thermal balance in the human body

The human body gets vitality from absorption of sustenance through digestive system. This procedure involves transforming food (a source of chemical energy) into heat (thermal energy), which are later dissolved during our metabolic activities (Ogunsote, 1993).

The two types of metabolism are;

(a) **Basal metabolism** is the least heat required to maintain vital involuntary activities in the body, such as breathing, blood circulation, heartbeat, and internal organs activities.

(b) **Muscular metabolism** is the heat produced by the muscles when carrying out some work or activities in the body.

Almost 80% of energy produced in the body is given off as heat as result of the inefficiency of the process of converting chemical energy into physical energy.

Aside basal and muscular metabolism, the body can also gain heat from its surrounding. This is done either by conduction, convection and radiation also the body can lose heat by these processes i.e. conduction, convection, radiation and as well by evaporation. Figure 2.4 illustrate the thermal balance of the human body.

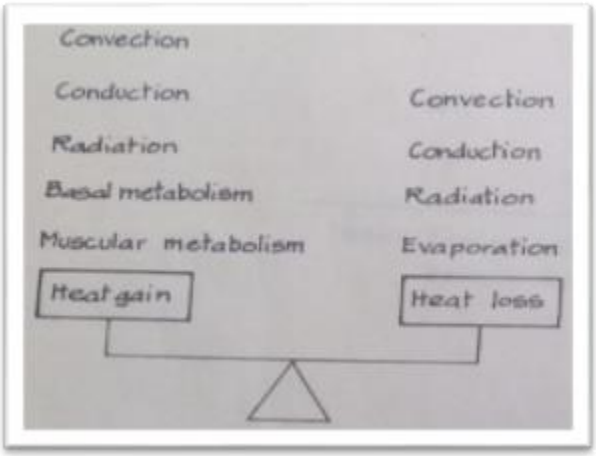

Figure 2.4: Thermal Balance in the Human Body (Source: Ogunsote, 1993)

In order to keep up consistent profound body temperature and warm heat lost by the body must be equivalent to heat gained (Ogunsote, 1993).

2.8.4 Factors affecting thermal comfort

Thermal comfort is highly influenced by some factors which affects the thermal state these are major climatic parameters such as ambient air temperature, humidity level, radiation, air speed and other personal factors i.e. intrinsic clothing, level of activities. These personal factors are greatly influenced by the characteristics of the occupant such as age, sex, body shape, state of health, ethnic grouping, diet, sleep, colour of clothing, acclimatization, availability of fresh air, transients, colour of a space enclosure and noise (Evans, 2007).

i. Ambient Air Temperature

An important factor factors influencing thermal comfort is the ambient air temperature of the environment as it determines the general body temperature. Naturally humans feel hot at high temperature and likewise feel cold at low temperature. Approximate temperature range of about 16 to 28^{o}C is required by humans to attain comfort.

ii. The Mean Radiant Temperature

This is defined as the measure of the amount of radiation that moves to and fro particular surfaces in an enclosed space. It is measured using the globe thermometer. At a globe temperature range between 16 to 28^{0}C, the human body can achieve comfort provided that the mean radiant temperature and the dry bulb temperature do not differ by up to 5^{0}C.

iii. Air Speed

This is defined as the measure of the movement of air at a particular point without regards to direction. According to ANSI/ASHRAE Standard 55, air speed is defined as the average speed of air which the body is exposed to, with respect to time and location.

iv. **The Relative Humidity**

This is simply defined as the ratio of water vapour in the air to water vapour that the air can hold at a specific temperature and pressure. Sweating is a heat loss mechanism on the skin and act as sensors to determine relative humidity of the environment, it is effective in reducing temperature of the body during the hot weather. At a relative humidity between 20 and 90%, the body can achieve thermal comfort ASHRAE, 2004.

2.8.5 Basic way of achieving thermal comfort

Attaining good thermal environment to ensure thermal comfort, two basic methods can be used. These are;

(a) Passive method: This method involves using architectural design and planning strategies to reduce solar radiation and its effects on the interior and exterior parts of the building.

(b) Active method: This method involves using mechanical aid to regulate the temperature of a building. These aids are basically air conditioning system, and sensors.

Thermal comfort in the proposed shopping mall would be achieved through passive cooling design strategies. Architectural design strategies and features to be employed to achieve thermal comfort will be detailed at the subsequent sections.

2.9 Passive Design

The passive design approach reduces energy consumption in a building by using the building architecture to enhance thermal comfort through passive solutions from the design stage. Hence, the use of natural movement of heat and air, passive solar gain and cooling is a major consideration in passive design so as to achieve good thermal comfort. This methods help to reduce dependence on mechanical systems and also the energy demand of a building by a very large percentage, it is also environmentally safer as it help to reduce CO_2 emissions. The passive design can be categorized under two broad classes. These are Passive design strategies/measures and features/element (Akande, 2010).

2.9.1 Passive design strategies

Passive design help in reducing the needs for mechanical systems as well as the energy demand of a building. It involves architectural design considerations employed to achieve thermal comfort. These considerations include heating, ventilation cooling, lighting a building construction using passive design.

2.9.1.1 Passive heating

In this method, reduced energy loss, attraction and store of solar gains that are required to meet the optimal energy requirements of the building systems is achieved by combining a well-insulated model with other key elements. These elements include; orientation, shape of building, buffer spaces and double facades, space planning, high-performance window (clear, low-e), mixed-mode heat recovery ventilation (HRV), window to wall area ratio, operable external shading, high-performance insulation, thermal mass and minimized infiltration (Akande, 2010).

2.9.1.2 Passive ventilation

In this approach, air is allowed into the space by using naturally occurring patterns of air flow around and within the building. Structural building design can hence be made to optimize these natural air movement to achieve good thermal comfort. Thus the design process of building should consider the various architectural features that influence the air flow through a building. Also other factors such as building shape, interior walls layout, nature of flooring techniques and even the choices of furniture should also be considered. There are design limitations effective ventilation in a space. However, the use of various ventilation methods can help to achieve an adequate indoor air quality. Figure 2.5 to 2.7, shows the passive ventilation.

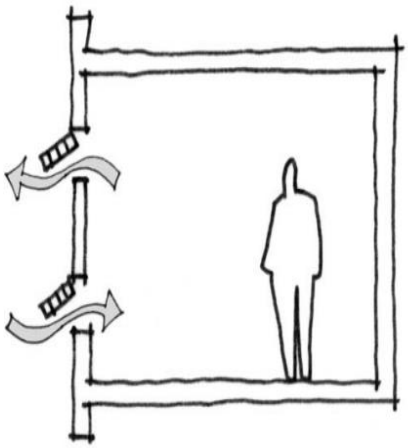

Figure 2.5: Single sided ventilation
(Source: Chusid, 2015)

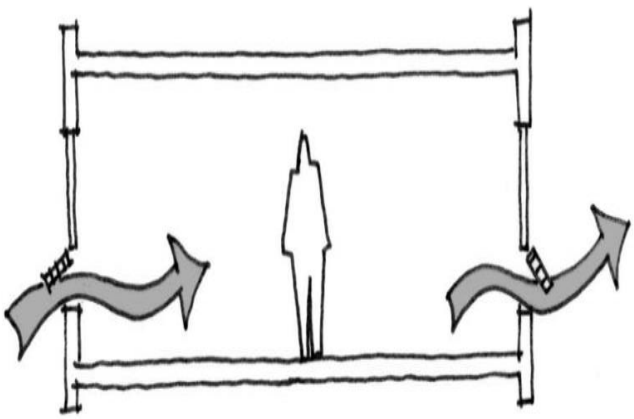

Figure 2.6: Cross Ventilation
(Source: Chusid, 2015)

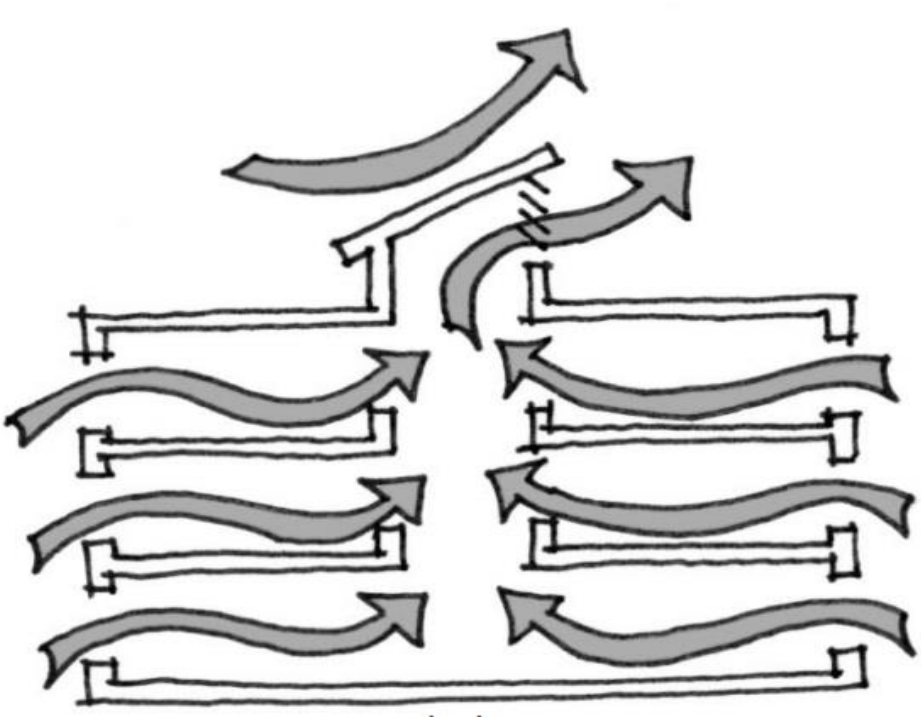

Figure 2.7: Stack effect through atrium
(Source: Alexandra ***et al*****. 2012)**

Passive elements such as orientation, operable windows, buffer spaces and double facades, building shape, space planning, openings to corridors and lobbies, central atria, wind towers affects the natural ventilation of a building.

2.9.1.3 Passive cooling

In the passive cooling design, overheating is prevented by trapping solar gains and ejecting internal heat gains. An important aspect of this method involves the significant reduction or total removal of the use of mechanical energy source (Akande, 2010). These strategies includes fixed/operable external shading, stacked windows, low window to wall area ratio, nocturnal cooling, passive ventilation, thermal mass, passive evaporative cooling, earth-tempering ducts.

2.9.2 Passive design features

These are the architectural design or planning component used to improve the thermal comfort of a building. These includes:

1. Site Orientation
2. Building Shape and Massing
3. Landscape consideration (Vegetation)
4. Openings (windows, court yard and atrium)
5. Solar Shading and buffer spaces
6. Thermal Mass and insulation

2.9.2.1 Site orientation

To reduce the cooling loads in building mostly in tropical atmospheres characterized by extreme sun radiation, proper building orientation becomes very vital. The orientation of the building's longest part can be subsided towards the sun to reduce radiation through the walls.

2.9.2.2 Landscape considerations

Landscape consideration is a good technique for achieving effective ventilation in a building, it can be used to protect the building from incessant heat and also used to divert cool and breezy wind into the building. This feature is aimed at how the temperature of air within a building can be decreased by proper arrangement of environment around the building, an example of such arrangement is illustrated in Figure 2.8 below. An important component in landscape consideration is the use of vegetation to prevent solar radiation from directly striking the surfaces of the building and on the building envelope made of concrete, bricks and probably asphalt. The use of vegetation is an efficient way to reduce the energy absorption of a building so as to

achieve effective space cooling as a result of reduced solar radiation coupled with adjustment of indoor and outdoor environment. Studies by Nyuk & Yu, (2009) clearly demonstrated that that proper landscape can be used to achieve up to 25-80% heating and cooling.

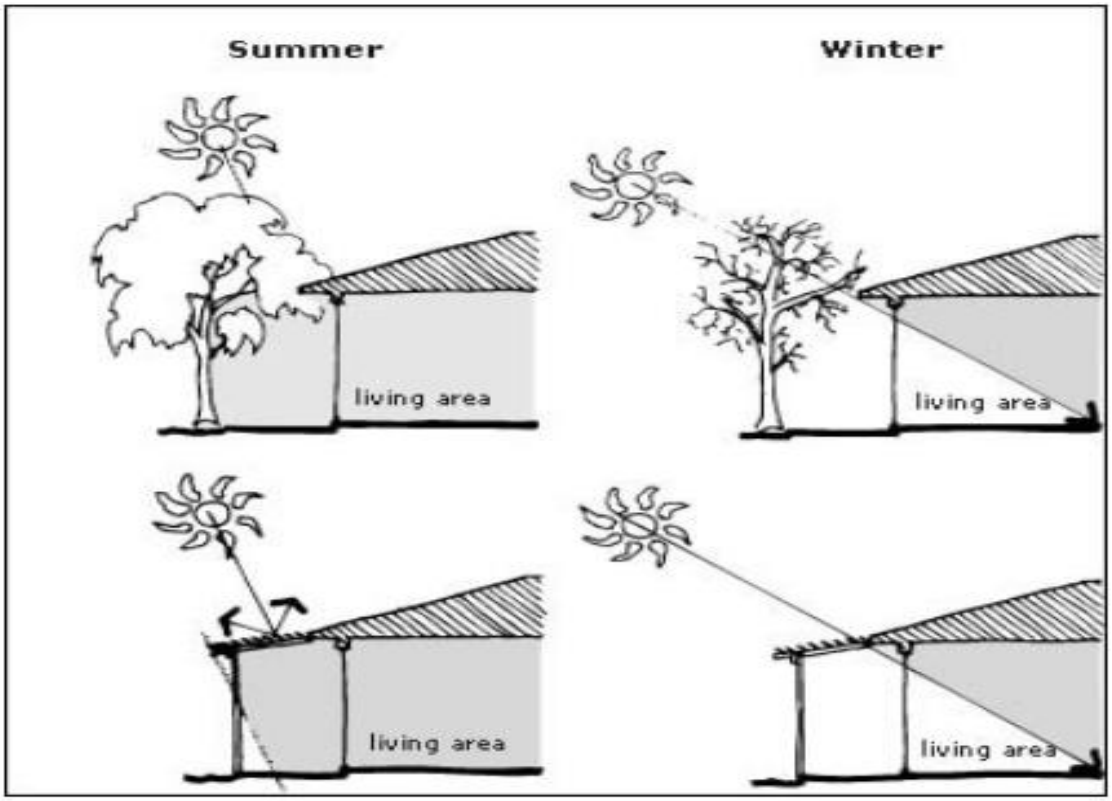

Figure 2.8: Landscape consideration for shading
(Source: Chusid, 2015)

2.9.2.3 Solar shading using overhangs and shading devices

Shading is an important protective measure that can be used to lessen heat gain. Nick and Koen (2005) affirmed that heat experienced by an occupant can be decreased by almost 8^{o}C using shading. Shading devices can hence be installed in different components of a building e.g. covering windows with shading devices to prevent direct radiations of the sun into the building. Other exterior shading device includes vertical and egg-case sun-shading device; overhangs, trellises and rooftop overhang.

A building orientation and the climatic condition of its prevalent environment determine the requirements for shading. However, for specific building orientation, there are suggested shading types. These are shown in the Table 2.2, Figure 2.9 and 2.10.

Table 2.2: Shading types for building based on orientation

Orientation of building	Suggested shading types
North	Adjustable or fixed horizontal shading device above window and extending past it on both side
East and west	Adjustable or fixed vertical louvers shading element; deep verandas or pergolas with climbers
NE and NW	Adjustable shading element or pergolas with climbers to allow solar heating or verandas to exclude it
SE and SW	Planting: deciduous in cool climates, evergreen in hot climates

(Source: Chusid 2015)

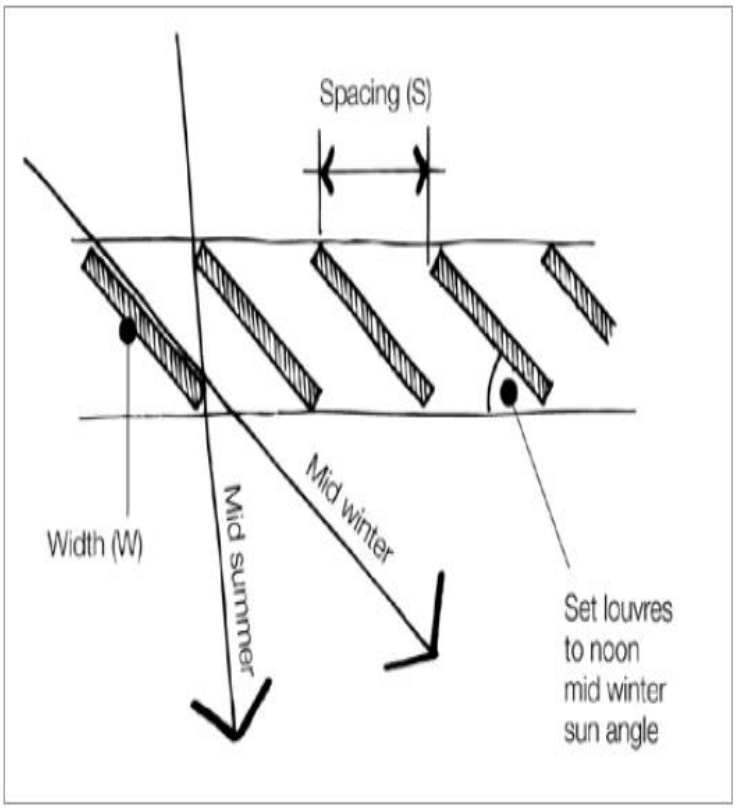

Figure 2.9: Spacing for fixed louvers
(Source: Chusid 2015)

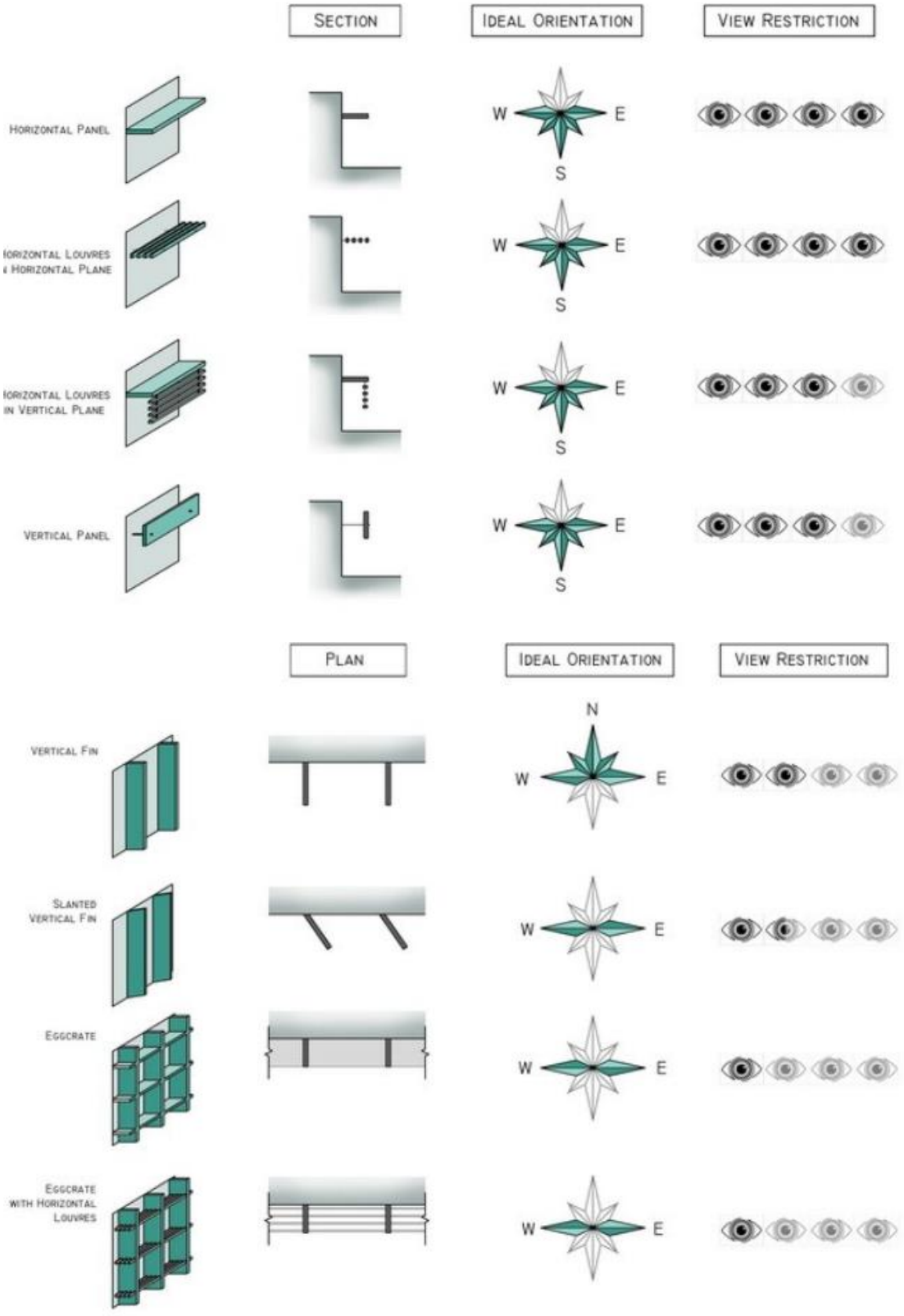

Figure 2.10: Solar shading device
(Source: Chusid, 2015)

2.9.2.4 Use of High Thermal Mass to Reduce Heat Absorption

Some building materials can also be used to for effective cooling and heating of building, these materials absorb heat and release it during the day and night respectively. Two major parameters are used to define these materials i.e.; the thermal capacity and time lag. The mass of a building construction is average when the exposed mass area is equal to the floor area as shown in Figure 2.11. Thus, one square meter of exposed thermal mass exist for every square meter of floor area (Oikos, 1997). For optimum efficiency, thermal mass should be exposed to the living spaces.

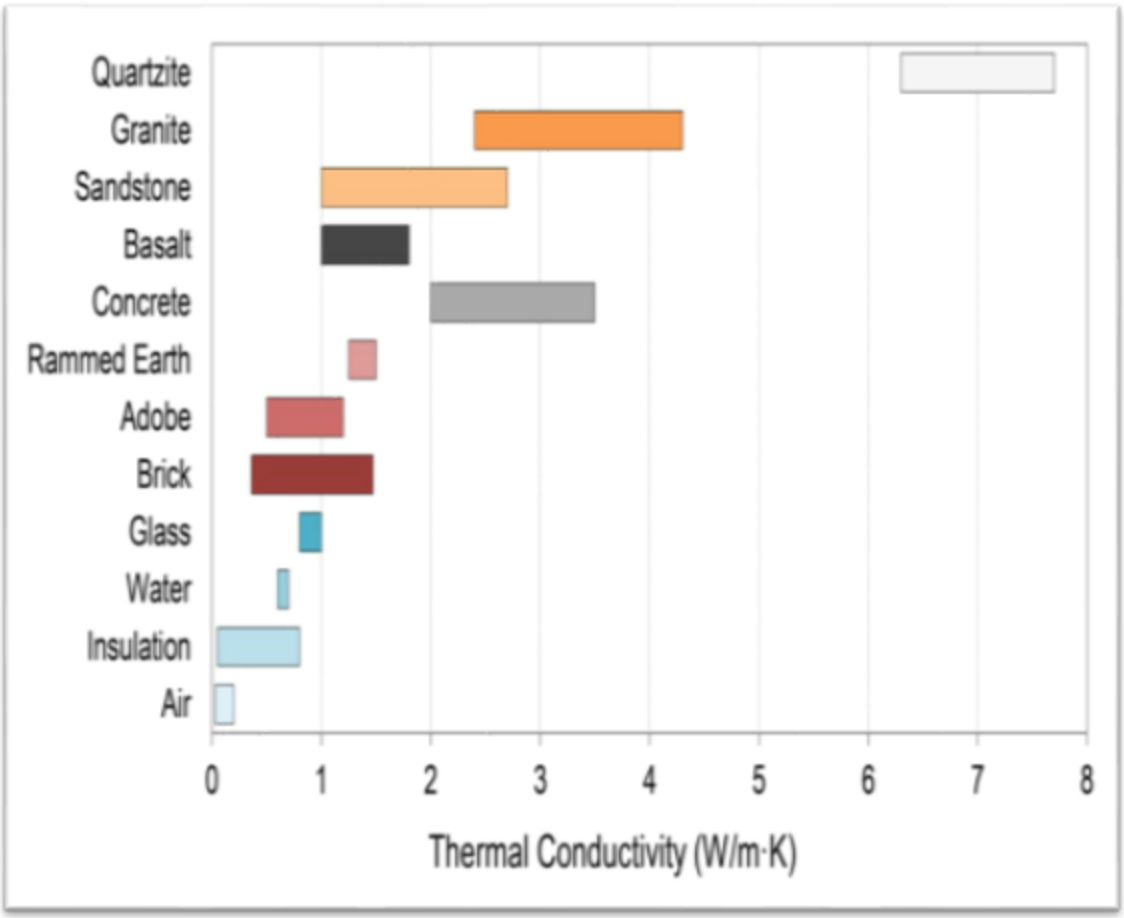

Figure 2.11: Thermal conductivity of some building materials (Source: Chusid, 2015)

2.9.2.5 Use of High Thermal Mass with Night Cooling

The use of high thermal mass on building depends on the daily heat gain of mass combined with ventilation at night that cools the building as shown in Figure 2.12 below. The building must be closed at day when the sun is up and high and opened at night when the weather is cool to flush the heat away (Oikos, 1997).

Figure 2.12: How Thermal Mass Works
(Source: Chusid, 2015)

2.10 Comfort Zone

Comfort zones are meant to provide an acceptable indoor thermal condition for occupants wearing typical indoor clothing and carrying out near sedentary activity. According to ASHRAE STANDARD (55-1992), an environment is said to be an acceptable thermal environment if it at least at least 80% of the occupants of such environments finds it thermally acceptable. The comfort zone is, 22.8 ^{o}c < ET < 26.1^{o}c for summer, 20.0 ^{o}c < ET < 23.9 ^{o}c for winter. Figure 2.13shows the standard effective temperatures.

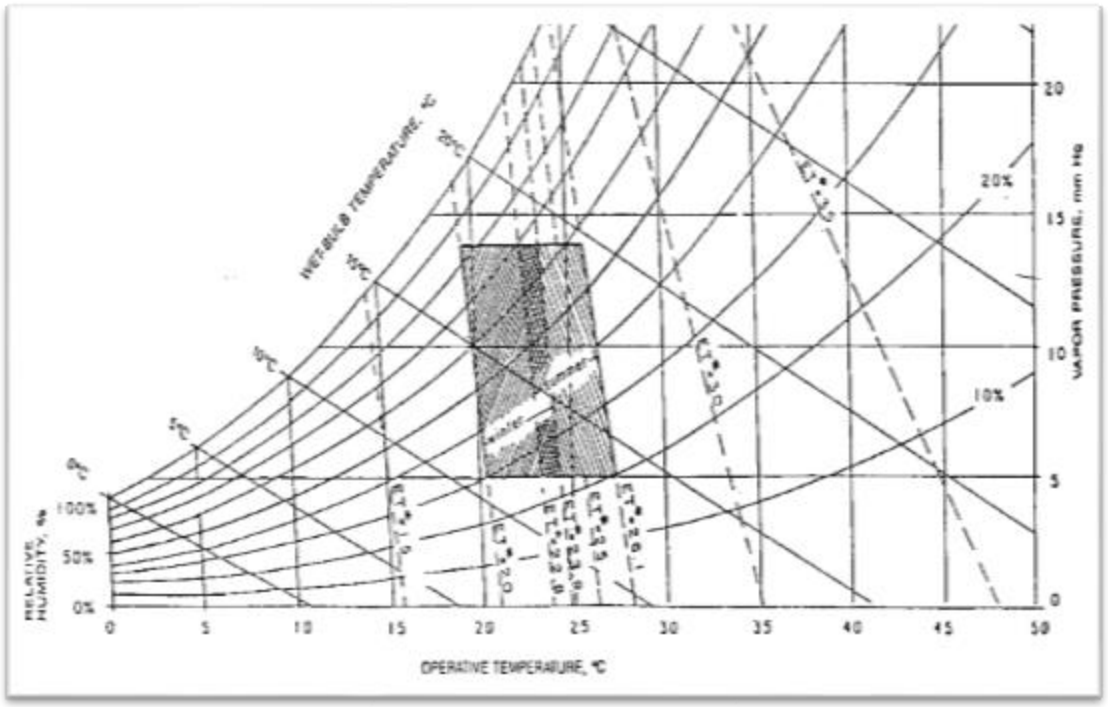

Figure 2.13: Standard Effective Temperature
(Source: ASHRAE, 2004)

2.11 Summary of Literature Review

The integration of passive design concept is very essential in achieving good thermal comfort in a built environment. This design techniques help to achieve a suitable indoor environmental quality with adequate consideration for users' health/comfort. It is very important to note that the natural movement of cool air in and outside the building is very important, therefore it is very essential to consider the air movement in the design of any building that emphasize more on passive cooling mechanism, however, proper combination of properly placed vegetation cover in the designing of landscape and site planning also enhances the possibilities of achieving a qualitative indoor environment because of the connectivity between the inner part of the building and its landscape environment. Also, as stated in the objective of this research work passive cooling design considerations like building orientation, (shape, size, and position of the building), openings for natural ventilation and lighting, thermal mass and insulation

materials are also very essential to achieving suitable indoor air quality as they will serve as a cooling mechanism in terms of creating shades with the use of both vertical and horizontal shading elements, preventing the building from absolute penetration of heat and solar radiation as the building will be oriented in a way that best avoid the façade and other open part to long hour of heat and solar penetration, and lastly the use of thermal mass and insulated building envelop can reduce the effect of heat inlet to the building as the walling material has a natural way of reducing the effect of the incessant heat by a reasonable temperature there by cooling up the building to improve the comfort of the shoppers, staff and other users of the mall.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Research Method

Descriptive survey method was adopted for the study as it is most suited for achieving the project objectives. This method analytically defines important and accurate information as it's related to the state of the research focus or problem using discovered facts to make correct and justifiable deductions. The three basic method of conducting descriptive research were adopted during this research, and these are the observational method (the use of observation schedule), case study method, and the survey method (the use of questionnaire).

3.2 Data Collection and Sources

Both primary and secondary data sources were explored for collection of various data used during the course of the research. These include the following;

i. Case Studies

ii. Books, articles and journals

Existing shopping mall facilities within the study area were used for case study evaluation. Structured questionnaire and observation schedule were used to collect variables regarding existing passive cooling design strategy. Also, images of case studies were taking to give more visual information about them. The case study was investigated to evaluate the existing problem on the selected shopping mall relating to passive cooling design features and also to serve as a guide for the proposed design by adopting necessary features to achieve a better design.

3.3 Method of Data Collection

Different information accumulation approaches were utilized in an offer to assemble significant data with respect to the proposed task these are:-

i. Primary Data

ii. Secondary Data

3.3.1 Primary data

Primary data is simply explained as first hand data obtained from the researcher's field survey. Field interview and observation were hence used as primary data source for the study. The problems of thermal discomfort in shopping centres were observed and also the passive design strategies used to achieve comfort were studied using observations schedule.

3.3.2 Secondary data

Literatures were reviewed to obtain in depth theoretical background of the research work on which decisions were taken. Information obtained were used as bases, criteria, and variables for observation, planning and designing of the proposed shopping mall with a view to achieving a passively cooled indoor environment.

3.4 Sampling Technique and Sample size

Simple random sampling technique was used during the course of the study. Ten samples were taken cognisance of within the study area Kaduna. The shopping malls were purposively selected while the respondent were randomly selected, 319 Questionnaire and an observation schedule were used simultaneously for the ten selected samples. The Sample Size and Address are illustrated in Table 3.1.

Table 3.1: Sample Size and Address

S/N	Sample Population	Address
1	Silent Shopping Mall	Aliyu Makama Road, Barnawa Kaduna
2	9 Star Shopping Mall	1 Shehu Laminu Avenue Kaduna
3	Abc Stores Ent.	Alkali Road, City Centre, Kaduna
4	Ahafsusan Complex	Ibadan Street , Kakuri Kaduna
5	Al-gambary Stores	Katsina Road Kakuri Kaduna
6	Asada Shopping Complex	Sultan Rd, Ungway Rimi, Kaduna
7	Asd City Mall	Independence Way, Kaduna
8	NNDC Mall	Azikiwe expressway, kaduna.
9	Barnawa Shopping Mall	Barnawa, Kaduna
10	Dalema supermarket,	Isa kaita road. Ungwa munchi , kaduna

(Source: Field Work, 2019)

3.5 Variables for the Study

A well-structured observation schedule was used as an instrument for data collection which collected data on variables used to assess thermal comfort design features in shopping centres. The variables used for the assessment are listed as shown in Table 3.2.

Table 3.2: The Parameters used for the Study

S/N	Parameter
1	Materials
2	Openings (windows, trium and courtyard)
3	Ventilation System
4	Energy Consumption Level
5	Shading Devices

(Source: Field Work, 2019)

3.6 Method of Data Analysis and Presentation

Primary Information for this study which was used to determine the passive cooling strategies in the selected shopping malls was collected through observation. A statistical package was used to analyse field data to get quantitative results.

3.7 Summary of Research Methodology

The descriptive research method is a method that involves collecting adequate data and information on a particular problem or phenomenon. It was adopted during the field survey to determine the design features and strategies used for achieving passive cooling, and to measure their effectiveness in existing shopping malls.

CHAPTER FOUR

4.0 DATA PRESENTATION AND DISCUSSION

Microsoft Excel statistical package was employed for the analysis of field data from the survey of existing shopping malls. Ten shopping malls samples were randomly selected within the study area. This was done to assess the existing passive cooling strategies used in their design. Hence, the obtained results from the field survey were analysed in line with the following project objectives;

4.1 The Design Strategies used to Achieve Passive Cooling in Shopping Environment

Objective one of the study which is to determine the design strategies employed to achieve good thermal comfort through passive methods in the mall was carried out by the researcher through several literature reviews in line with passive design features and how they can be applied in shopping mall design to achieve a qualitative indoor environment and optimise its thermal comfort. Thus, the following elements listed below were selected and are utilized in the proposed design.

1. Sun Shading devices (horizontal and vertical fins will be used.)
2. Openings (windows, atrium and courtyard)
3. Vegetation (trees, shrubs, hedges, grasses and climbers)
4. Building materials considering their respective thermal mass and insulation properties. As such; bricks, polystyrene block wall, concrete floors with glazed ceramic floor tiles, adobe wall plaster and solar reflective roof will be used
5. Building orientation (shape and position of building)

4.2 The Degree of Presence of Passive Cooling features in the existing samples with the use of a Structure Observation Schedule

Determination of the degree of the presence of passive cooling design features and strategies adopted in the construction of the malls was the objective two of the study. This was accomplished by observing the selected building to check for the presence of various design consideration used to achieve passive cooling. Below is the sample population and their respective acronym used to code them for easy computation of result.

Table 4.1: Selected Building with their Respective Acronym

S/N	Sample Population	Acronym
1	Silent Shopping Mall	SIL
2	9 Star Shopping Mall	9 STAR
3	Abc Stores Ent.	ABC
4	Ahafsusan Complex	AHF
5	Al-gambary Stores	ALG
6	Asada Shopping Complex	ASA
7	Asd City Mall	ASD
8	NNDC Mall	NNDC
9	Barnawa Shopping Mall	BAR
10	Dalema supermarket,	DLM

(Source: Field Work, 2019)

4.2.1 Types of opening in the mall

The type of openings used in the selected shopping malls were critically observed, a chart and a table was used to project the analysed result. The result obtained is indicated in Figure 4.1 below.

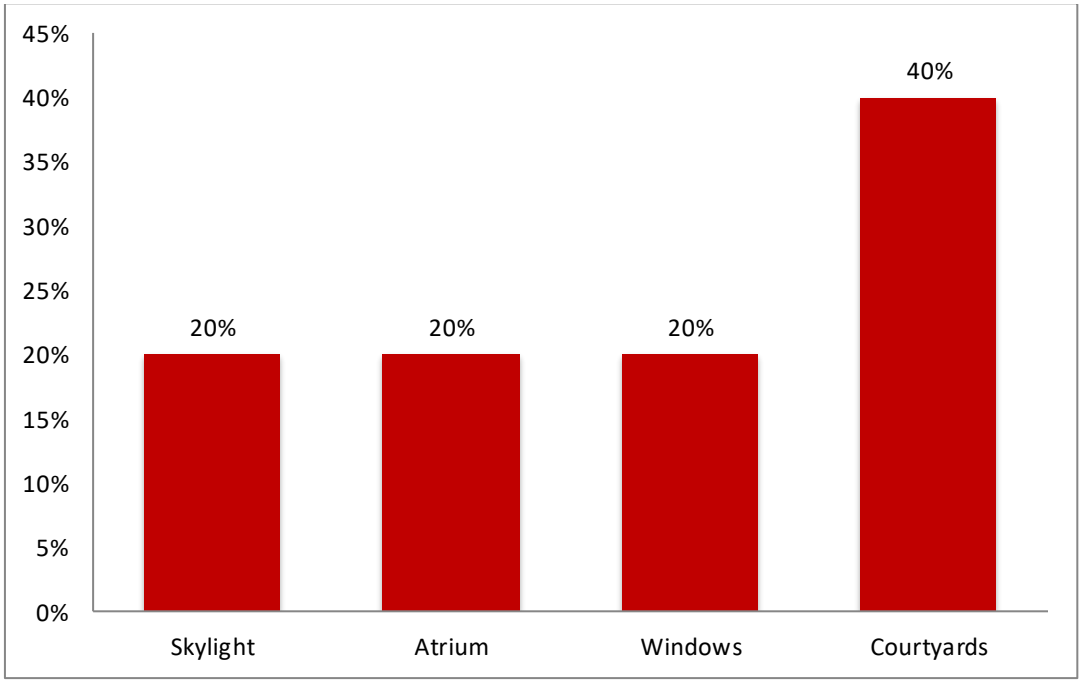

Figure 4.1: The Degree of Usage of different kind of openings in the selected samples (Source: Field Work, 2019)

4.2.2 Description of energy consumption in the mall

The rate of energy consumption in the shopping malls were read from power meters, the obtained result are projected using chart and table. The result obtained is indicated in Figure 4.2 below.

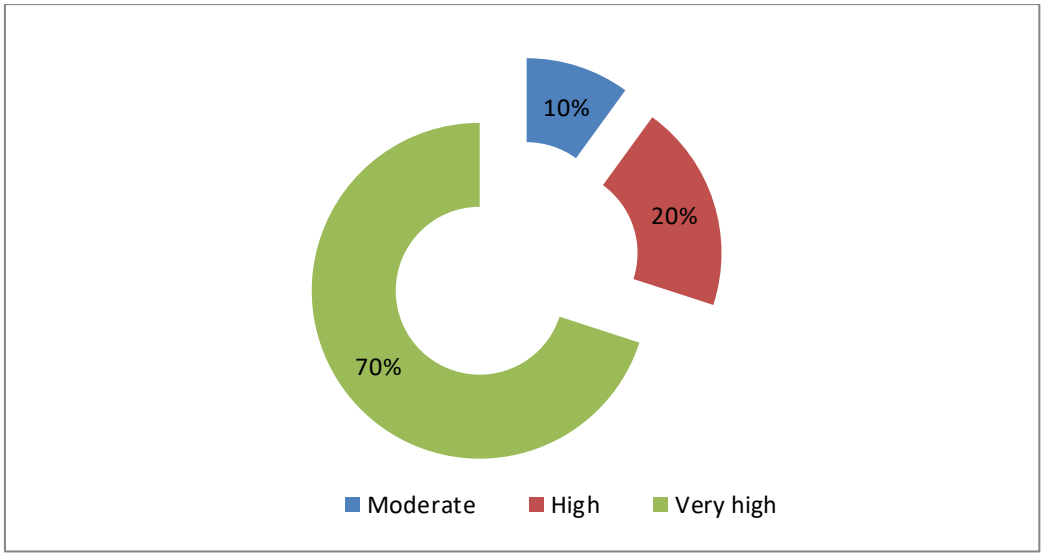

Figure 4.2: The Variations in the rate of Energy Consumption in the Malls (Source: Field Work, 2019)

4.2.3 Nature of materials used for ceiling

The nature of materials used for ceiling in the shopping malls were also critically observed, a chart and a table was used to project the analysed result. The result obtained is indicated in the Figure 4.3.

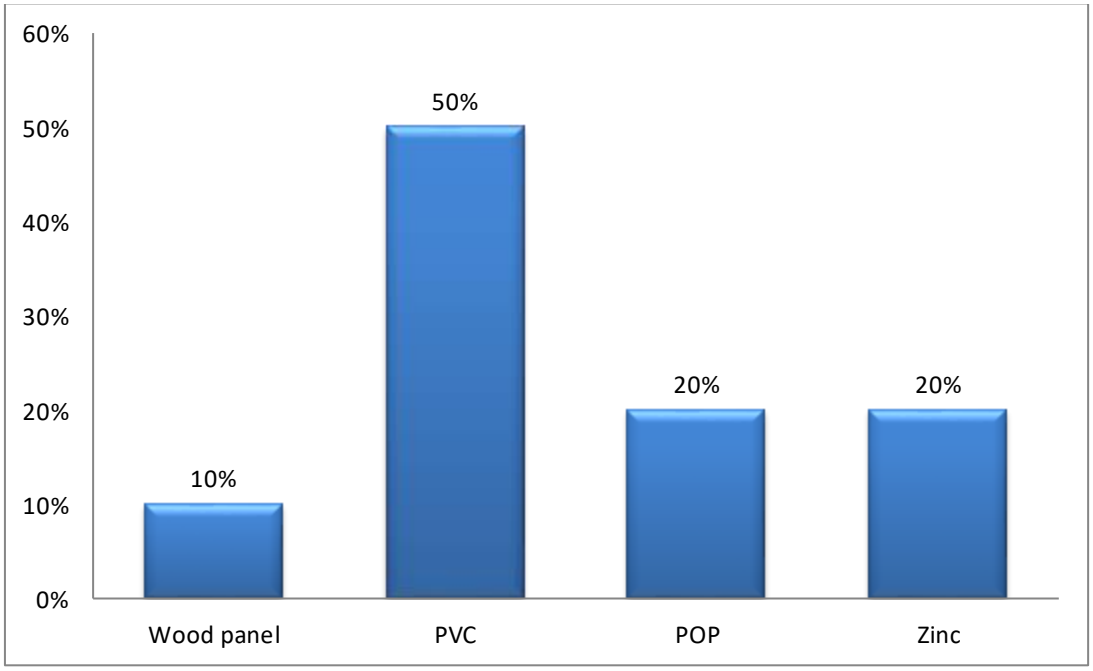

Figure 4.3: The Variation in the use of Ceiling Material (Source: Field Work, 2019)

4.2.4 Ventilation system in the malls

The ventilation system used in the selected shopping malls were critically observed, a chart and a table was used to project the analysed result. The result obtained is indicated in the Figure 4.4.

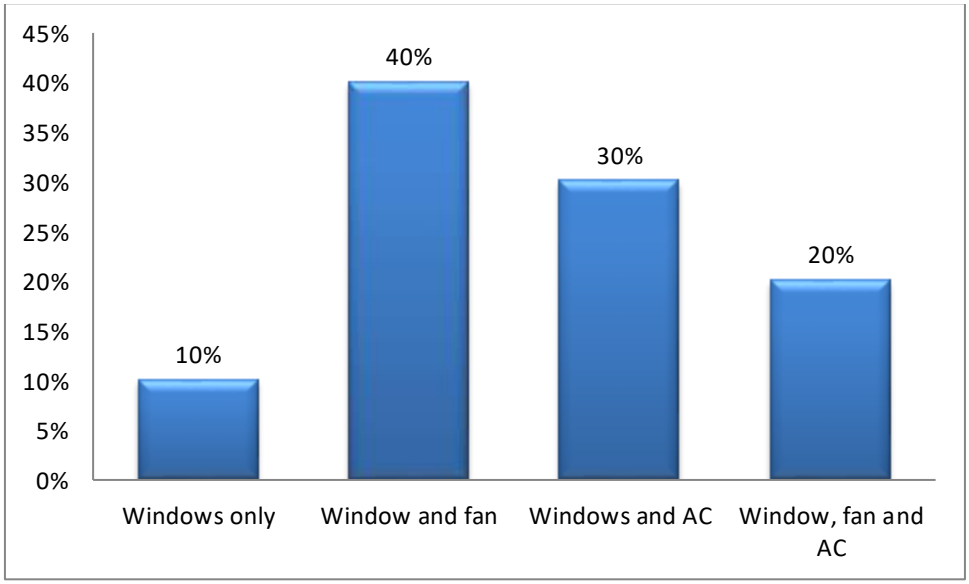

Figure 4.4: The variation in the nature of the ventilation system adopted in the malls (Source: Field Work, 2019)

4.2.5 Summary of findings from the degree of presence of passive cooling features in the existing samples with the use of a structure observation schedule

From the analysis of the observation schedule as obtained by the researcher, the following are the summary of the findings illustrated above.

i. Nature of Opening Used In the Selected Samples (Floor)

In the openings identified in the shopping mall, 20% used atrium, 20% used sky light, 20% also used windows and 40% used courtyards.

ii. Description of the Energy Consumption in the Mall

From the analysis of questionnaire in the observation schedule from the researcher, it was observed that 1% is moderate, 2% is high, 7% is very high.

iii. Materials Used To Construct the Shopping Mall (Wall)

From the analysis of questionnaire in the observation schedule from the researcher, it was observed that 30% used brick while 70% used block wall.

iv. Materials Used To Construct the Shopping Mall (Floor)

From the analysis of questionnaire in the observation schedule from the researcher, it was observed that 1% used ceramic tiles, 70% used terrazzo while 1% used pvc.

v. Materials Used To Construct the Shopping Mall (Roof)

From the analysis of questionnaire in the observation schedule from the researcher, it was observed that 5% used PVC, 2% used pop while 2% used zinc.

vi. Materials Used To Construct the Shopping Mall (Ceiling)

From the analysis of questionnaire in the observation schedule from the researcher, it was observed that 7% used ceramic tiles, 1% used thatch while 2% used aluminium (long span)

vii. Ventilation Used In the Mall

From the analysis of questionnaire in the observation schedule from the researcher, it was observed that 1% used windows only, 4% used windows and fan, 3% used windows and AC while 2% used windows, fan and air conditioner.

4.3 The Effectiveness of the Passive Cooling design strategies and features in the samples with the use of a Structured Questionnaire to understand the user Perception

Objective three in this research work covered the examination of users' perception of the selected facilities thermal comfort. This was done by distributing a total of 319 questionnaires across the selected sample out of which 19 of them are invalid and the remaining 300 were valid and are used for the result computation, the result obtained from the questionnaire distribution are illustrated below.

Question 1: How would you describe your knowledge on thermal comfort?

The frequency of the knowledge of the respondents on thermal comfort were collected, a chart was used to analyse the result collected on this particular question from the questionnaire. Figure 4.5 below illustrates the result for the knowledge of the building users on thermal comfort.

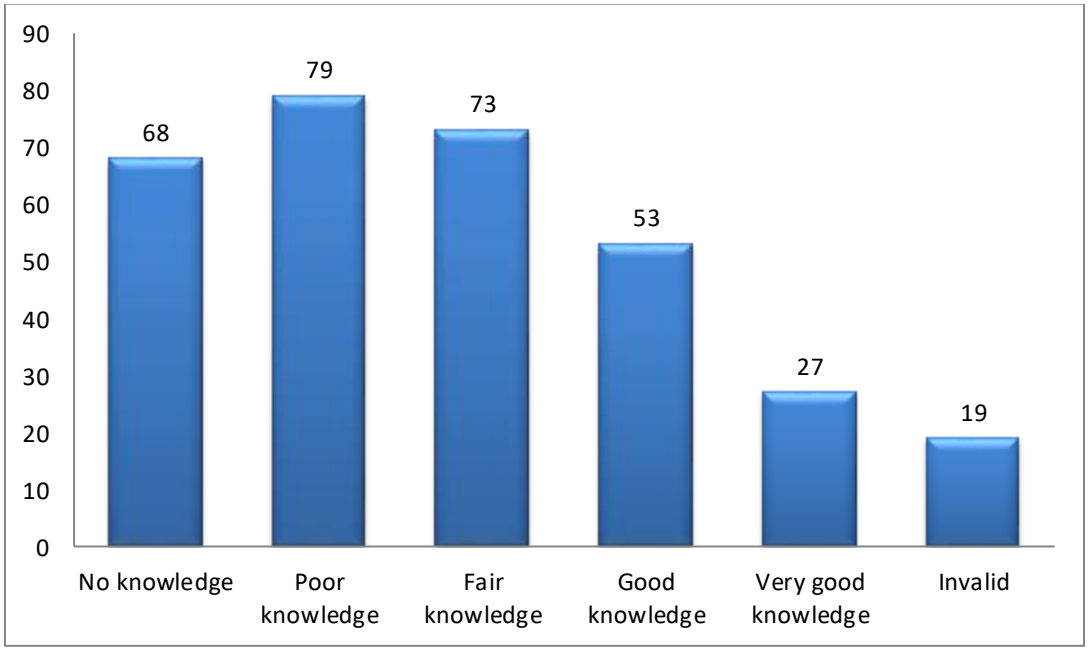

Figure 4.5: The result for the knowledge of the building users on thermal comfort (Source: Field Work, 2019)

Question 2: in your own opinion has thermal discomfort affected you?

The result for the above question were obtained and Figure 4.6 was use to analyse the result collected on this particular question from the questionnaire.

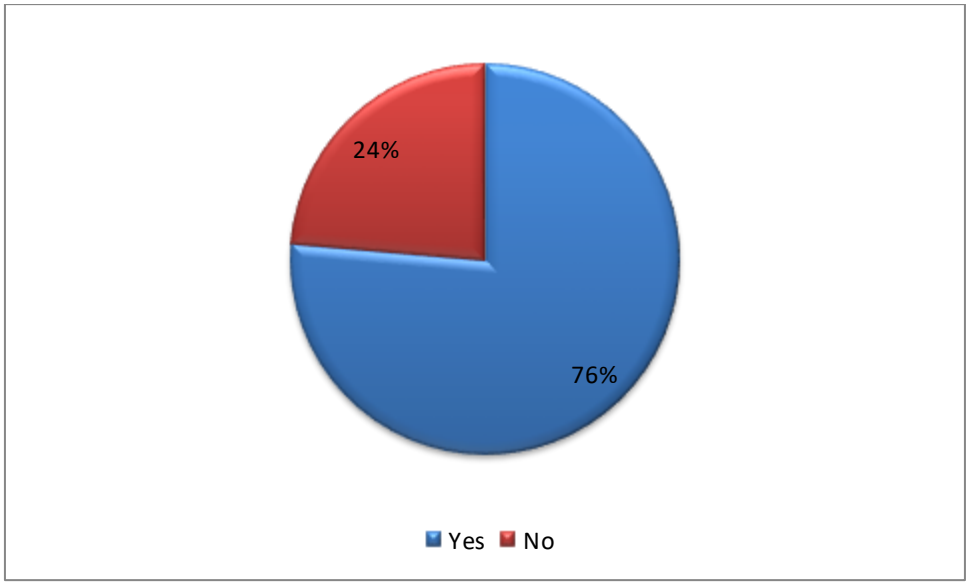

Figure 4.6: The result for the question 2
(Source: Field Work, 2019)

Question 3: in what aspect of your life has thermal discomfort affected you?

The result for the above question are collected, analysed and illustrated in the Figure 4.7 below.

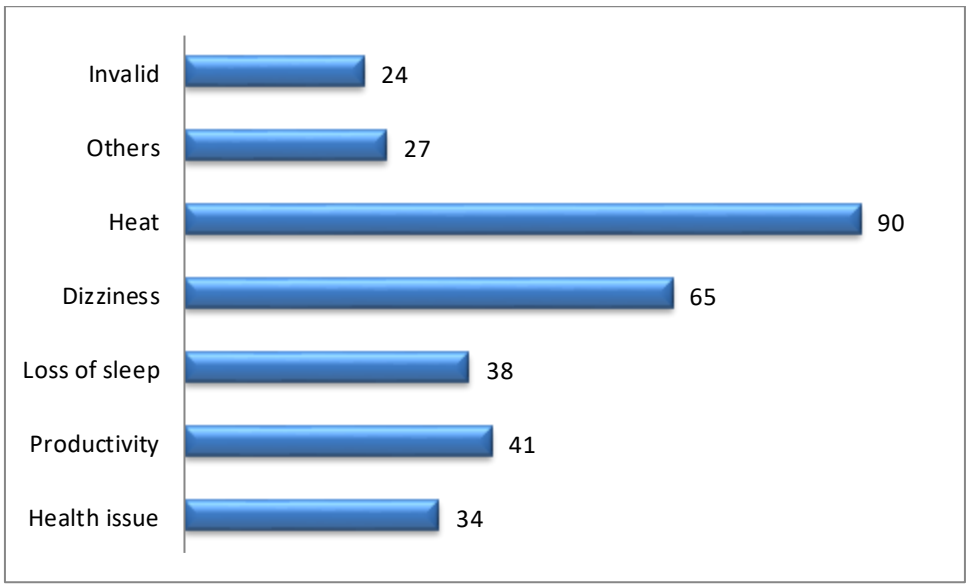

Figure 4.7: The result for the question 3
(Source: Field Work, 2019)

Question 4: what time of the day do you experience thermal discomfort within the mall?

The result for the above question are collected, analysed and illustrated in the Figure 4.8below.

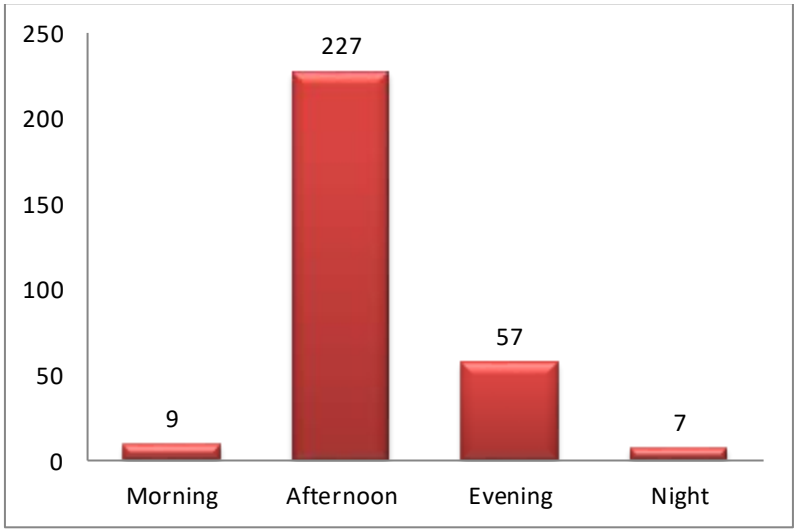

Figure 4.8: The Analysis for the question 4
(Source: Field Work, 2019)

Question 5: Do they utilize mechanical element (fan and AC) to achieve comfort within the mall?

The result for the above question are collected, analysed and illustrated in the Figure 4.9 below.

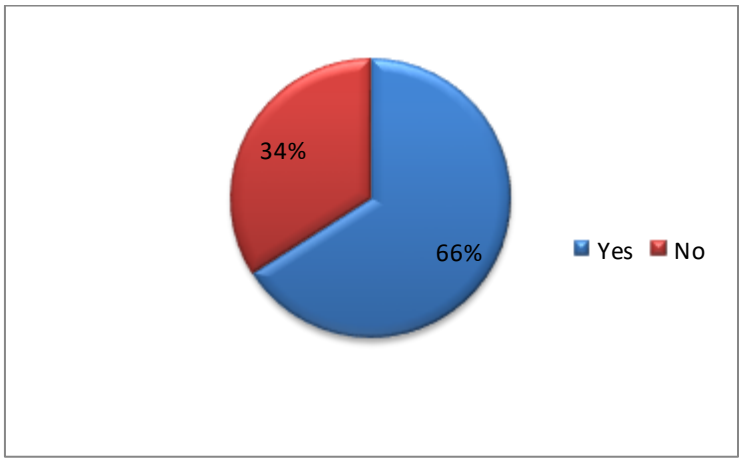

Figure 4.9: The analysis for the question 5
(Source: Field Work, 2019)

4.3.1 Summary of findings from the effectiveness of the passive cooling design strategies and features in the samples with the use of a structured questionnaire to understand the user Perception

From the analysis of the observation schedule as obtained by the researcher, the following are the summary of the findings illustrated above.

a. Knowledge on thermal comfort

21.3% had no-knowledge of thermal comfort, 24.8% had poor knowledge of thermal comfort, 22.9% had fair knowledge of thermal comfort, 16.6% had good knowledge of thermal comfort, and 8.5% had very good knowledge of thermal comfort.

b. Thermal discomfort affecting health

From the questionnaire analysis, it was observed that 71.8% chose yes while 22.3% chose no.

c. Aspect of life thermal discomfort affects most

From the questionnaire analysis, the aspect of thermal where it affected their health are as follows, 10.7% belong to health issue, 12.9% belongs to productivity, 11.9% had the problem of loss of sleep, 20.4% had the problem of dizziness, 28,2% had the feeling of heat, while 8.5% belongs to others.

d. Time of thermal discomfort in the mall

From the questionnaire analysis, it was observed that different time of the day in which people has thermal discomfort are 2.8% beliefs thermal discomfort affect them in the morning, 71.2% beliefs thermal discomfort affect them in the afternoon, 7.9% beliefs thermal discomfort affect them in the evening while 2.2% beliefs thermal discomfort affect them at evening.

4.4 Proposed Shopping Mall using Passive design features to achieve a good Indoor Environmental Quality

The last objective of this study was to design a proposed shopping mall using passive design features to achieve a good indoor environmental quality.

4.4.1 Site location

The site is located at Hanwa layout Zaria, beside the Kaduna-Zaria-Kano dual carriage road Kaduna state, Nigeria. It is located beside the main road in order to serve both the inhabitant of the town and the travellers as shown in Plate I, because there is provision for accommodations and other forms of activities that can serve both the travellers and the inhabitant of the ancient city of Zaria.

Plate I: The Proposed Site
(Source: Google Earth, 2019)

4.4.2 Site selection criteria

The following considerations were put in place during site selection for the proposed facility located at Hanwa layout based on the;

i. Easy accessibility from major and minor access road.

ii. High development potential.

iii. Flat terrain hence reduced grading cost.

iv. It can easily be used by both the Neighbourhood and travellers.

4.4.3 Site selection justification

The site location is very accessible from anywhere within the city. The site can easily be accessed as it is close to the Neighbourhood attracting patronage from many people.

4.4.4 Site characteristics

The site is characterized with a loamy soil on a relatively flat ground, a major and minor access road with sparse vegetation.

4.4.5 Climatic conditions

The proposed site is located in Zaria, Kaduna state, which is characterized by a tropical savannah climate. Zaria has an average temperature of 24.9°c while the average rainfall is 1050 mm as shown in Figure 4.10 below.

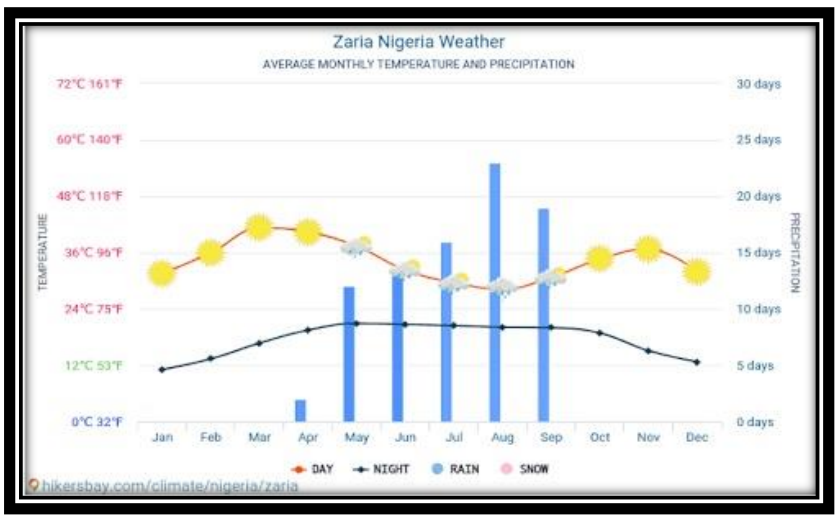

Figure 4.10: Average Monthly Temperature and Precipitation in Zaria (Source: Dogara et al, 2017)

4.4.6 Site analysis

a. Vegetation: The area of the site is attributed with sparse vegetation therefore shrubs and grasses spring up quickly during rainy season majorly in areas which rapidly water easily. Zaria is characterised by a tropical climate and a sparse number of tree cover, shrubs with flowers and grasses. An images of the vegetation of the site is shown in Plate II below.

b. **Topography**: The site is relatively flat with a gentle slope towards the South-West direction.

c. Accessibility: The site location is adjacent to the dual carriage road that passed through Zaria from Kaduna to Kano. The site is easily accessible by both the travellers plying the road and also to Zaria neighbourhood from anywhere in the town.

Plate II: Vegetation on Site
(Source: Field Work, 2019)

d. **Trade wind:** The site planning process critically considered the two trade winds. Clusters of trees would be planted along the North-East trade wind path to prevent the effect of the dry, dirty and dusty wind on human as well as the environment. On

the other hand, the design would utilize the South-West trade wind for ventilation and cooling purposes.

4.4.7 Schedule of accommodation

Table 4.2: The accommodation schedule of the proposed design

S/N	LEVELS	FUNCTIONAL SPACES	AREA (m^2)	NUMBER REQUIRED	TOTAL AREA (m^2)
1	GROUND	Main entrance	32	1	32.00
2	FLOOR	Service Lift	10.80	2	21.60
3		Electronic store	102.60	1	102.60
4		Kitchen	36.90	1	516.60
5		Store	10.40	1	10.40
6		Sitout	12.85	1	12.85
7		Restaurant	45.6	1	45.60
8		Drinks and ice cream store	24.6	1	24.60
9		Atm room	24.6	1	24.60
10		Atm gallery	42.8	1	42.80
11		Anchor tenant	160.30	1	160.30
12		Cctv room	32.00	1	32.00
13		Multipurpose hall	204.8	1	204.80
14		Wc	295.20	4	295.20
15	FIRST	Fabrics unit	75.9	1	75.90
16	FLOOR	Children clothing store	90.15	1	90.15
17		Service lift	10.80	2	21.60
18		Mail boutique section	30.60	1	367.20
19		Toilets	12.85	8	308.40
20		Anchor tenant 2	98.75	1	98.75
21	SECOND	Cosmetic shop	76.90	1	76.90
22	FLOOR	Aquarium	334.15	1	334.15
23	PLAN	Service lift	10.80	2	21.60
24		Wall clock and wrist watch store.	76.90	1	76.90
25		Toilets	12.85	12	308.40
26		Computer and accessories store	86.75	1	86.75
27		Male saloon	36.90	1	36.90
28		Female saloon	36.90	1	36.90
29		Board room	30.50	1	30.00
30		general lounge	15.80	2	31.60
31		Bed rooms	16	8	128.0
32	THIRD	games arcade	25.50	1	25.50
33	FLOOR	gold and jewelleries	75.25	1	75.25
34		Shoes and foot wear stores	75.25	1	75.25
35		Service lifts	10.80	2	21.60
36		Toilet	12.85	14	205.60
37		Maintenance unit	9.40	1	9.40
38		Relaxation bar	15.95	1	15.95

(Source: Field Work, 2019)

4.4.8 Design considerations and planning principles

This design followed effective planning principles and considerations like function and circulation as guidelines to achieve a good, functional, comfortable, and aesthetically pleasing environment.

a. Function

The spaces sizes distribution in the design would be determined by activities carried out in them with proportion to users population at a particular time. Architectural data and were used to determine minimum standard requirement, time server standard was used as reference.

Figure 4.11: Some Special Analysis
(Source: Field Work, 2019)

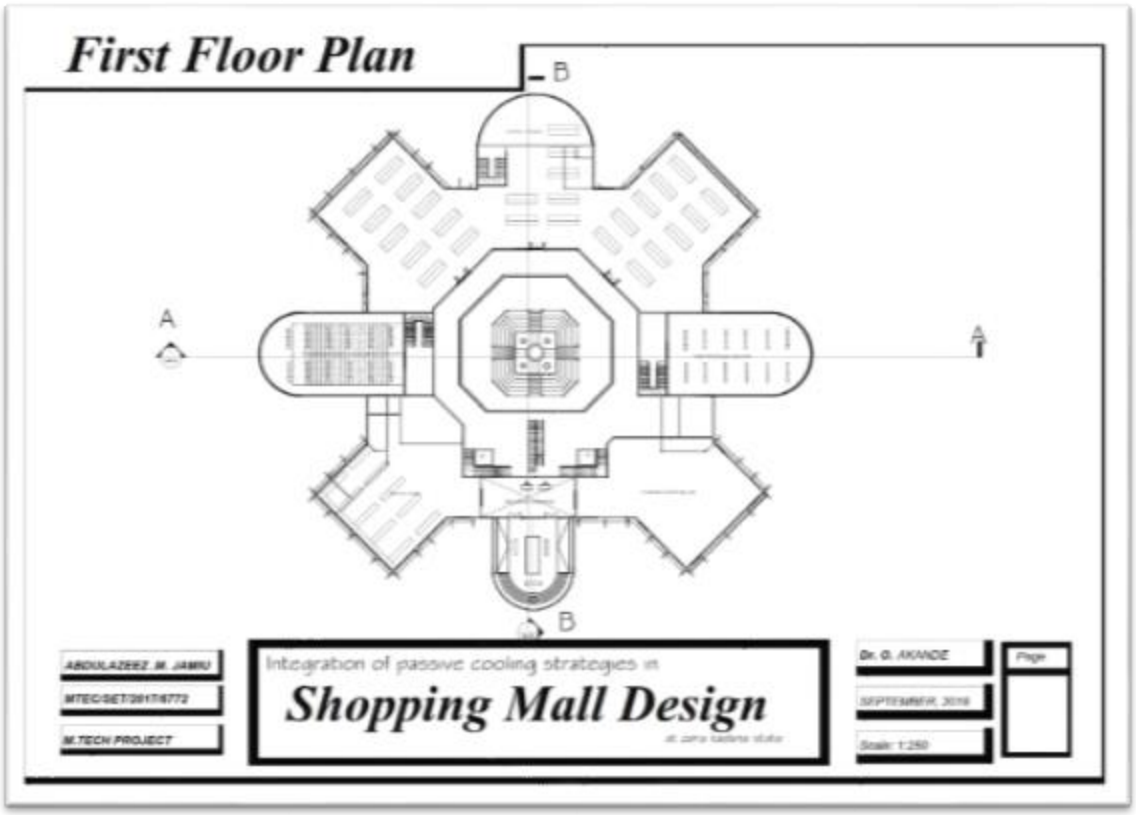

Figure 4.12: The Ground Floor Plan of the proposed design
(Source: Field Work, 2019)

b. Circulation

Effective circulation is the provision of adequate space for customers and staff of the mall to move around freely within the shopping mall. Shopping carts was used to preventing any form of disturbance. Effective circulation in the shopping mall was achieved through the use of correct dimensions of circulation elements such as stairs, lifts and escalators including a very spacious service terrace on every floor.

4.4.9 Design concept

The popularly known area symbol was adopted as concept for the design because of its situation in a very ancient city of the northern protectorate '*Zaria*'. the name of the symbol is arewa knot, the knot is an emotive symbol of Northern Nigeria adopted by sir Alhaji Ahmadu Bello(Sardauna of Sokoto) in the 1950s pre independence era (Brian

2008). The shape of the knot is then translated into forming the floor plan of the proposed design.

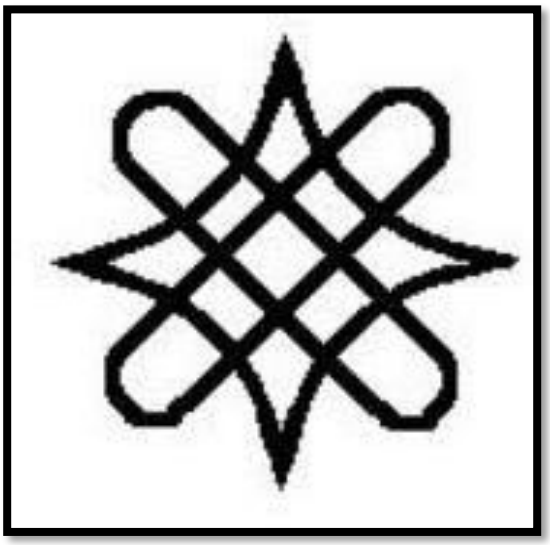

Figure 4.13: The arewa knot (Source: Wikipedia.htm

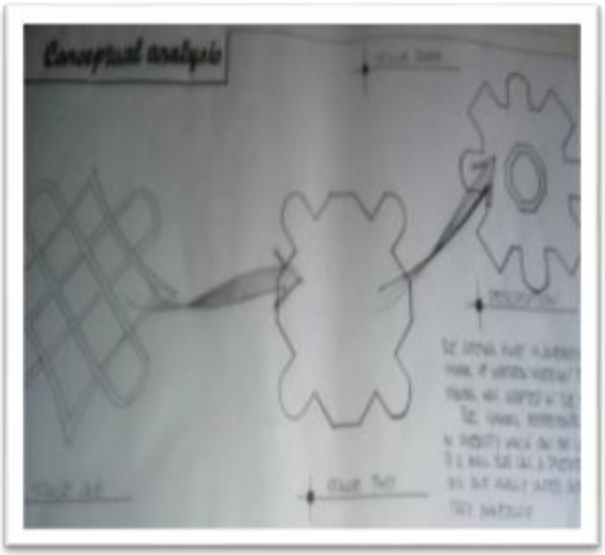

Figure 4.14: Conceptual Development (Source: Field Work, 2019)

4.4.10 Construction

Three categories are used to explain construction of the proposed design i.e. substructure, super structure and roof structure.

1. Substructure (foundation type)

A pad foundation type with regular columns made with a column base fixed at particular spacing to structural engineer's details was employed for the proposed shopping centre.

2. Super Structure;

This design was made of frame structure consisting of beams and column to support the structure.

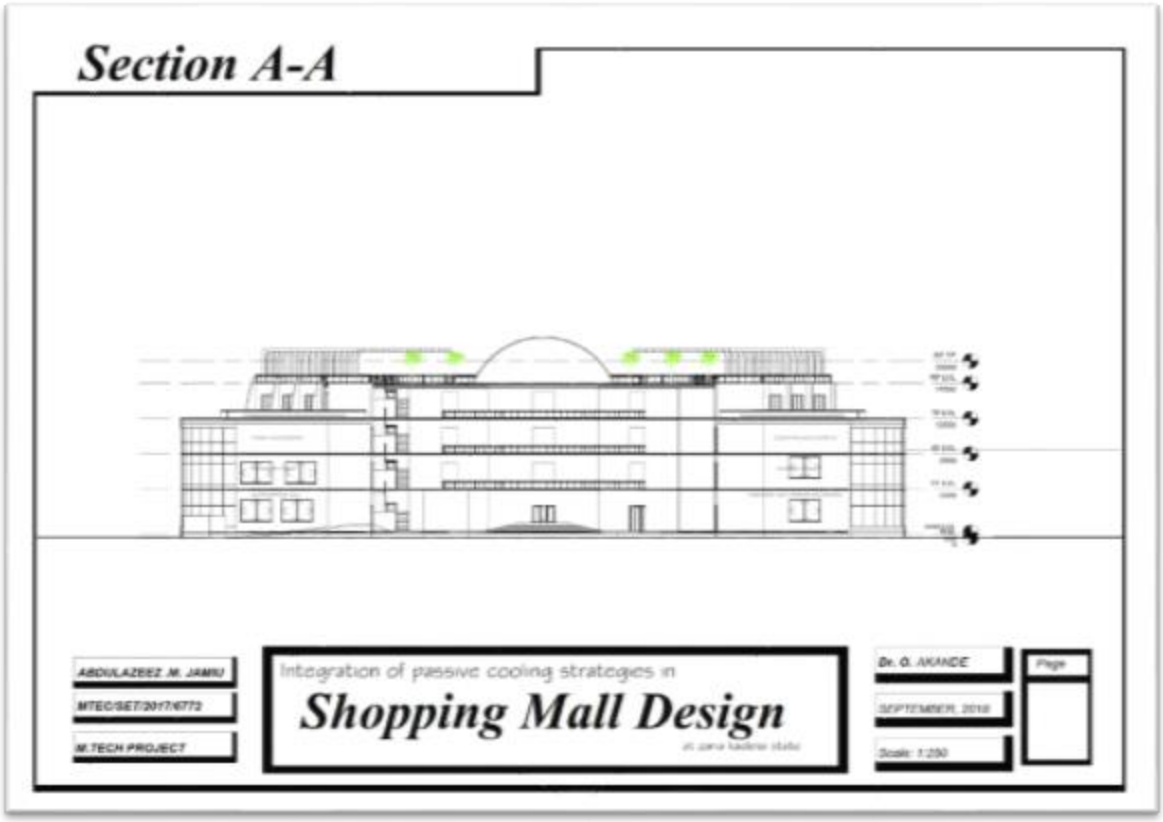

Figure 4.15: A Sectional Detail of the Beams and Columns
(Source: Field Work, 2019)

3. Roof Structure

The roof structure for the design was made of steel girders having reflective long span aluminium roof servicing which would to reduce heat gain from the sun into the building through the roof. This consists of the following;

I. Green roof system

II. Gable roofing system

III. Glazed atrium

IV. Barrel vault system

V. Solid slab cover.

4.4.11 Materials and finishes

Materials and finishes used in the proposed design were selected based on heat insulation capacity, durability and cost of the material, sustainability and aesthetic value.

i. **The roof materials:** Roofing system was basically divided into three parts with their distinctive roof materials, and finishes. The parts are explained below;

   a. **Gable roof system**; the materials used for this part is a steel girder with a reflective roof covering to reduce heat gain, so as to give room for passive cooling within the building.

   b. **Dome roof**; this is a circular dome roof over the atrium and would be designed has glazed aluminium roof light, to designer's specification.

   c. **Flat roof (decked area) system**; this is created in areas where there are machine rooms. The decked areas are created to ensure access to machine roof during services and repairs. They are strictly made with reinforced concrete floor slab, treated with two layers of bituminous felt to make the floor water proof.

   d. **Barrel vault roofing system**; this commonly referred to as tunnel vault or a wagon vault, is a roofing system formed by the extrusion of a single curve along a given distance.

ii. **Wall materials:** Polystyrene blocks of non-load bearing (partitions) was used to construct the walls for the proposed shopping centres, this was done according to drawing specifications. Materials such as glass curtain wall, laminated plywood, and glass fibre were also used.

iii. **Floor finishes:** Reinforced concrete floor slab would be used for floors structure with finishes ranging from glazed ceramic tiles terrazzo flooring, and marble flooring based on the functions in every space provided.

iv. **Ceiling finishes:** The ceiling for the proposed design would make use of gypsum plaster ceiling board hanged in areas with concrete floor slab. This would also enable it function as a thermal insulator.

v. **Painting**: Emulsion paint, adobe plaster and stucco paint are the three cement types to be used for the proposed shopping mall. Application of the cement would be done according to material specifications.

4.4.12 Landscape and external works

1. **Soft Landscaping:** The soft landscaping elements used in the design include trees (golden palm, masquerade trees and umbrella tress), grasses (Bermuda) and hedges (yellow bush). These soft landscaping elements will enhance aesthetic quality hence creating an aesthetically pleasing environment for users of the shopping mall as well as serves as buffer against harsh trade wind and the absolute solar radiation.

2. **Hard Landscaping**: Major hard landscaping work in the proposed design includes concrete pavements, unit pavers interlocking stones for walkways with precast concrete kerbs. Other hard landscaping element includes; fountains and grass-crete system of landscape where both the hard and soft landscape element are combined together.

4.4.13 Building services

i. **Electricity:** Kaduna electricity Distribution Company (Kaduna electric) transformer would supply electricity into the building. Also, interrupted power supply would be ensured in the shopping mall by an automatic generator plants with a relay sensor.

ii. **Water Supply:** Two water mains would be used to channel water into the site water reservoir using an indirect system of cold water supply before distribution.

The two water mains are water board and boreholes. The boreholes are dugged at specific locations positions inside the building and channelled into a reservoir before supply and distribution.

iii. **Refuse disposal:** Refuse bin would be placed at specific location in the building. The refuse bins would be arranged in categories and used to collect different classes of refuse. Thus different refuse bin would be used to collect refuse materials based on their categories so as easily sort recyclable waste from non-recyclable waste. Finally, the refuse bins when filled would be moved by the city's refuse collection vehicles.

iv. **Ventilation and cooling:** The proposed design utilized passive design features i.e. natural ventilation, cooling to obtain a cool indoor environment. The court yard, ventilated atria and proper fenestration were incorporated into the design and employed as natural ventilation source while shading elements such as window stack effect, indoor landscaping were employed to enhance natural cooling**.**

v. **Drainage and Sewage disposal:** The drainage system used in the proposed facility is designed to collect roof and surface water into the main drainage system. Services duct would be used to collect sewage and then transfer them to inspection chambers before finally channelling into septic tanks sunked very close to the toilet areas alongside the soak away pit for easy maintenance purpose.

vi. **Fire Security:** Fire safety is an important concern in building design as a fire breakout in a building is a disastrous event which could destroys lives and properties. Hence, this proposed design has incorporated preventive and protective gadgets in strategic locations to prevent accidental fire outbreak, or

reduce its consequence peradventure it eventually occurs. These include automated smoke detectors, sprinkler system, temperature sensors and fire alarms as well as other manual fire-fighting equipment such as hose reels and fire blanket and fire extinguishers.

vii. **Security:** Security within the shopping mall is of great concern to customers, staff and management. Hence, user's safety within and outside the building is ensured by incorporating two entrance and an exit with a security checkpoint. CCTVs, sensors and actuators radar were installed at specific points in the shopping mall. A security control room is also provided in the space created will also serve as a relief and protection for the user of the mall.

viii. **Maintenance:** The maintenance of a building during and after construction is an vital task which is of high significance to architects and other professionals in the built industry. Maintenance improves the building's aesthetic value and help to decrease the rate of degradation. The proposed design incorporates adequate preventive maintenance measures such as routine checks, services and repairs of the building's components to maintain the aesthetic value of the building, ensure proper building functioning and as well as certain users safety. The maintenance measure is enforced in the design by the creation of service duct, and a planned maintenance office.

ix. **Acoustics:** Carefully selected materials and finishes were used for construction of floors, walls, roof, doors and windows, this is to ensure efficient control of sound. Though acoustics is not of great importance in shopping malls, however soft landscape elements were strategically incorporated as sound barriers.

4.5 Summary of Findings

The assessment of shopping malls with similar microclimate conditions was used for basis of the study so as to provide a pleasant shopping environment for residents of Zaria, Kaduna state. Ten buildings were randomly selected, critically observed and assessed. Observation schedule and questionnaires were hence used to evaluate the degree of presence and effectiveness of passive design features for thermal comfort here are the comprehensive detailed summary of the findings from the field work.

Gender Analysis

From the gender analysis, it was observes that 53.6% and 39.8% are male and female respectively

Age brackets

From the analysis of the age brackets, it was observes that between the ages 16-30 are about 38.2%, 31-45 years of age are in the range of 33.2%, 46-60 years of age are 10.7% and 61-75 is for 11.9% respectively.

Educational Qualification

15% had no formal education, 11% had GSCE/O-level, 12.2% had ND/Diploma, 34.8% had HND or Degree and 21% had post-graduate qualification.

Marital Status

25.1% of the sample population are single, 52.0% are married and living together, 10.3% are divorced, 4.7% are widowed while 1.9% are married but lived separately.

Nature of job

From the questionnaire analysis, it was observed that 10.7% of the sample population are unemployed, 13.2% are unskilled labour, 19.7% are skilled labour, 2.8% are farming, 30.1% are trading, 11.9% are civil servant, 5.6% chose other professions.

Status in the mall

From the questionnaire analysis, it was observed that 81.8% of the people in the mall are customers while 12.2% are staff.

Years of visitation in the mall

From the questionnaire analysis, it was observed that between 0-9months 23.2% visited the mall, 1-2years were 22.3%, 2-3years were 32.9%, 3-4years were 11%, and also 4.7% have been visiting the malls above 4 years ago.

Knowledge on thermal comfort

From the result of the survey analysis, it is obtained that 21.3% had no-knowledge of thermal comfort, 24.8% had poor knowledge of thermal comfort, 22.9% had fair knowledge of thermal comfort, 16.6% had good knowledge of thermal comfort, and 8.5% had very good knowledge of thermal comfort.

Consequences of effect of thermal discomfort on the respondents

From the result analysis, the consequences of thermal discomfort on the respondents are as follows, 10.7% affects health issue, 12.9% affects productivity, 11.9% had led to loss of sleep, 20.4% had the problem of dizziness, and 28.2% had the feeling of heat, while 8.5% belongs to others.

Time of thermal discomfort in the mall

From the result analysis, it was obtained that different time of the day in which people has thermal discomfort are 2.8% beliefs thermal discomfort affect them in the morning, 71.2% beliefs thermal discomfort affect them in the afternoon, 7.9% beliefs thermal discomfort affect them in the evening while 2.2% beliefs thermal discomfort affect them at evening.

Material used to construct the wall of the mall

From the result analysis, it was observed that 28.5% of the mall used bricks as walling material, 46.7% used sand crate block wall, and 18.8% used cement-screed in the construction of the wall of the mall.

Material used to construct the floor of the malls

From the questionnaire analysis, it was observed that 56.7% of the mall used ceramic tiles, 28.5% used terrazzo, 8.8% used wood panel in the construction of the floor of the mall.

Material used to construct the ceiling of the malls

From the result analysis, it was observed that 9.1% of the mall used terrazzo, 9.4% used asbestos ceiling, 28.8% used PVC ceiling, 37.9% used POP ceiling, and 8.8% used other materials in the construction of the ceiling of the mall.

Material used to construct the roof of the malls

From the questionnaire analysis, it was obtained that 9.1% of the mall used asbestos roofing, 9.4% used thatch, and 18.8% used zinc while 56.7% used aluminium in the construction of the roof of the mall.

Ventilation type in the mall

From the questionnaire analysis, it was observed that 0.6% had none of either air conditioner, fan or window in the mall, 11.0% had only windows, 21.0% used both windows and fan, 40.4% used both air conditioner and windows, and then 11.0% used both the window, fan and air conditioner in the mall.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Shopping mall can be designed as opened-air centre and enclosed centre with facilities ranging from shops, food, theatre, recreational and entertainment activities and sometimes accommodation. However, they can be designed to be partially opened incorporating passive design features to achieve a qualitative indoor environment, through natural means of cooling and ventilation.

This research work revealed the presence of some passive cooling design features in existing shopping malls, but most of which were not very effective as some of these measures are only meant for aesthetics. Thus, the integration of design features and strategies to reduce using artificial means of cooling and ventilation in the proposed facility is very vital.

This drastically reduce the high energy demands and use of mechanical methods for achieving thermal comfort within the shopping facilities thereby making users psychologically happy and hence increase productivity.

5.2 Recommendations

With the aim of creating a thermal comfortable shopping precinct the indoor air conditions, incorporate some passive cooling design strategies to enhance natural means of ventilation, cooling and lighting becomes very vital.

This study stresses the need to integrate effective passive design features which would enhance the quality of shopping environments. Hence, the following are recommended;

i. Proper tenant mix ratio should be adopted to improve shopping experience of shoppers within the facilities and also to attract more customers.

ii. Passive cooling design features should be incorporated in buildings to improve the indoor air quality for the comfort of its users and as well for aesthetic purposes.

iii. Using open roof courtyard which allows natural ventilation, lighting and cooling of the interior space.

iv. Adequate landscaping of the indoor environment with indoor plants and trees to improves indoor air quality and conditions.

v. Using thermal insulated materials to reduce heat gain, thereby improving the thermal comfort and indoor air quality.

vi. Proper building orientation to decrease the dependence on active means for achieving thermal comfort.

vii. The use deep verandas (balcony) and shading element to reduce direct impact of solar radiation on the building.

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APPENDIX A

SAMPLE OF QUESTIONNAIRE

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA
SCHOOL OF ENVIRONMENTAL TECHNOLOGY
DEPARTMENT OF ARCHITECTURE

Dear respondent,

A study on the integration of passive cooling design strategies in shopping mall, Zaria, Kaduna state.

Interview schedule.

This questionnaire is designed to collect data for an ongoing research to assess the passive cooling consideration in relation to the dry hot climatic condition of Zaria, Kaduna state, therefore all responses will be strictly confidential and used for research purpose only.

Thanks for your anticipated cooperation.

SECTION A: background information.

Questionnaire Number **:** _____

Date: _____ Time _____

1. Gender: Male _____ Female _____

2. Age **:** 16-30____ 31-45____ 46-60____ 61-75____ 76 and above____

3. Address: _____ LGA_____

   state_____

4. What is your highest educational qualification?

   ☐ No formal qualifications ☐ GCSE/ O-Level ☐ ND or Vocational ☐ HND or Degree ☐ Post Graduate Qualification

5. Marital status (tick the most appropriate)

   ☐ Single ☐ Married ☐ Divorced ☐ Widowed ☐ Separated

6. What is the nature of your occupation?

☐ Unemployed ☐ Unskilled Labour ☐ Skilled ☐ Labour

☐ Farming ☐ Civil rvant

Others(specify)……

SECTION B: respondent's level of interaction with the building

7. Are you a customer in this complex or a staff indicate below please

☐ Customer ☐ Staff

8. How long have you been visiting/(working with) the shopping mall?

☐ 0 - 9month ☐ 1 - 2 years ☐ 2 - 3year ☐ 3-4 years ☐ Above 4 years

SECTION C: Thermal Perception

9. How would you describe your knowledge on thermal comfort?

☐ No knowledge ☐ Poor Knowledge ☐ Fair ☐wledge ☐

Good knowledge Very good Knowledge

10. In your own opinion, has thermal discomfort ever affected your health?

☐ Yes ☐ No

11. in what aspect of your life has thermal discomfort comfort affected you?

☐ Health issues ☐ Productivity ☐ Loss of sleep

☐ Dizziness ☐ heat ☐ others;

(specify)…….

12. How will you describe the thermal comfort condition of this mall?

☐ Very Bad ☐ Bad ☐ Good

☐ Very Good ☐ Excellent

13. What time of the day do you experience thermal discomfort within the mall?

☐ Morning ☐ Afternoon ☐ Evening ☐ Night

14. Do you utilize mechanical element (like fan and AC) to achieve comfort within the mall?

☐ Yes ☐ No

APPENDIX B

OBSERVATION SCHEDULE

SECTION D: building characteristics (observation schedule).

This section is to be filled by the researcher

1. The kind of openings identified in the shopping mall

☐ Sky lights ☐ atrium ☐ Windows ☐ Court yard

2. Description of the energy consumption in the mall?

☐ Very Low ☐ Low ☐ Moderate
☐ High ☐ Very high

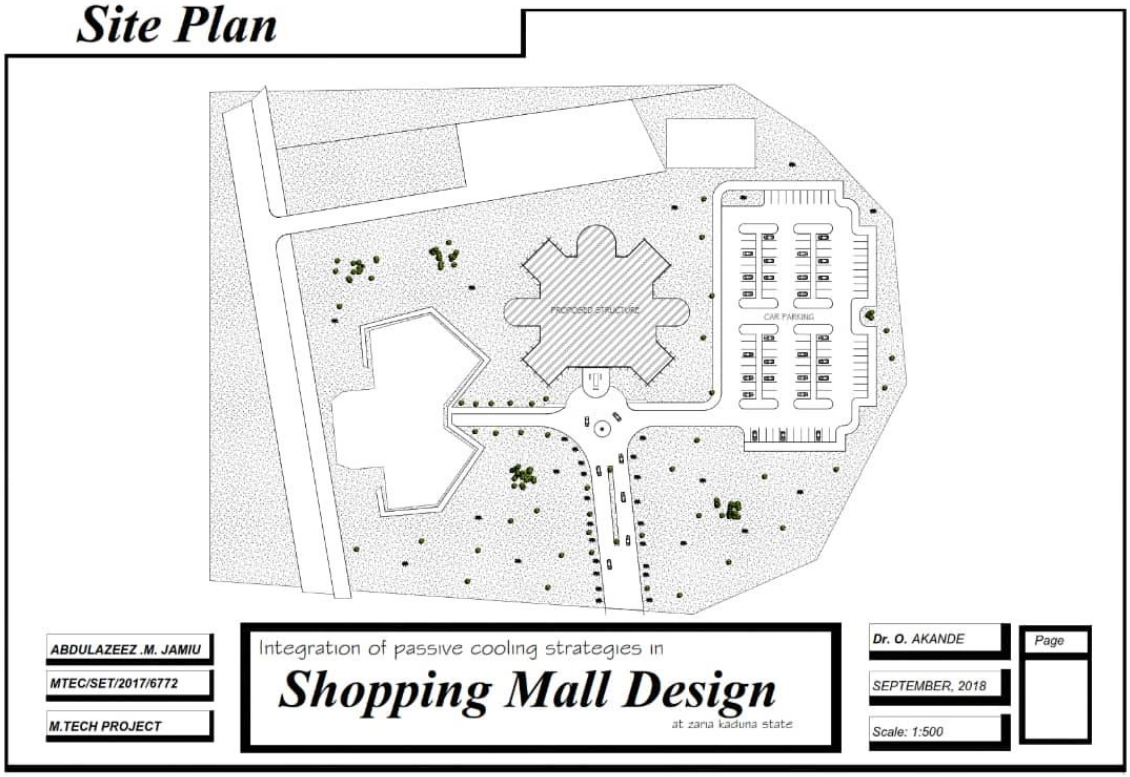
3. material(s) used to construct the shopping mall?

S/N	BUILDING COMPONENT	MATERIALS																	
		MUD	BRICK	STONE	BLOCK WALL	CEMENT-SCREED	CERAMIC TILES	TERRAZO	MOSAIC	CEMENT + RUG	CEMENT + CARPET	ASBETOS	WOOD PANEL	PVC	POP	THATH	ZINC	ALUMINIUM (LONG SPAN)	CONCRETE
1	WALL																		
2	FLOOR																		
3	CEILING																		
4	ROOF																		

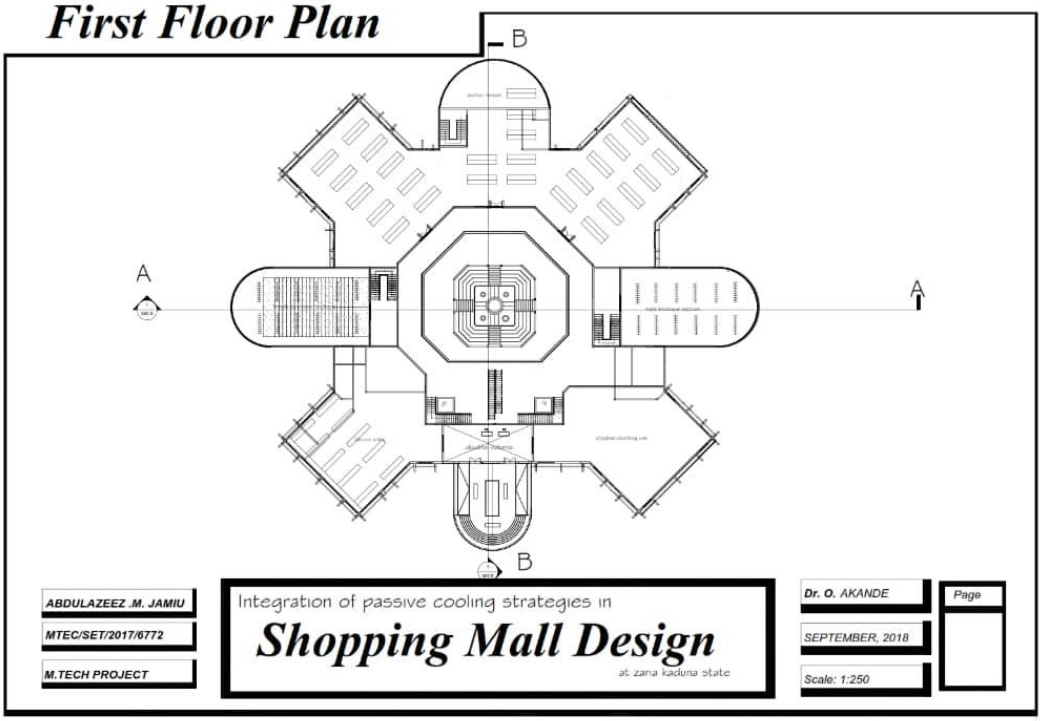
4. Ventilative cooling system.

What type of ventilation system are used in the shopping mall?

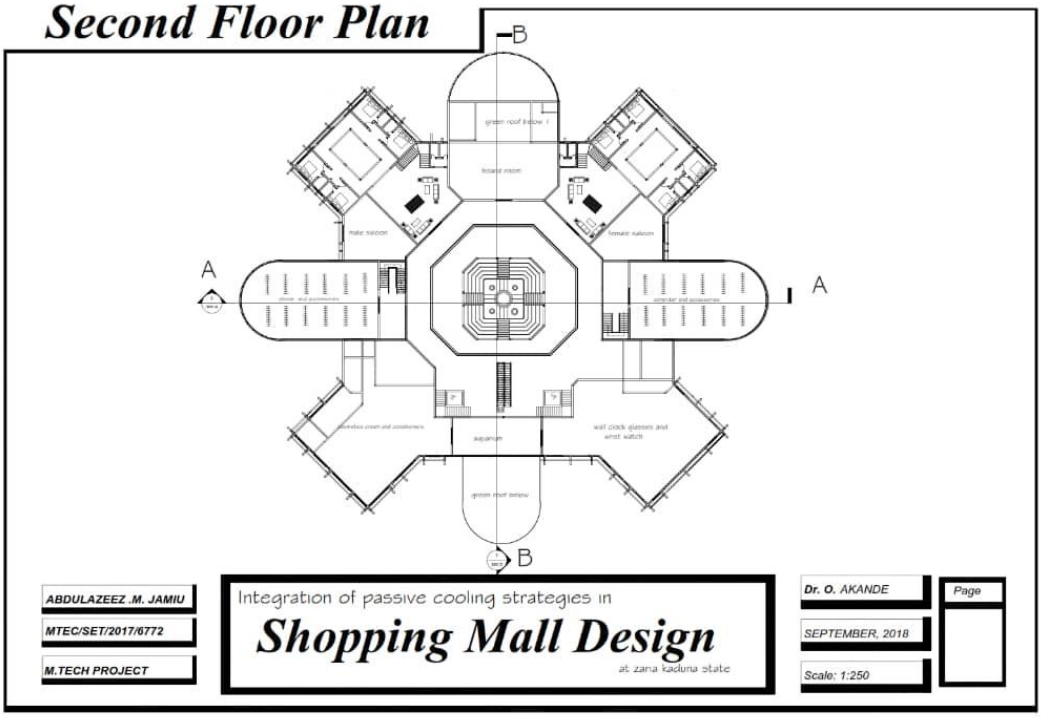
None (No window, No fan, No AC)	Windows only	Windows & Fan	Windows & AC	Windows & Fan & AC



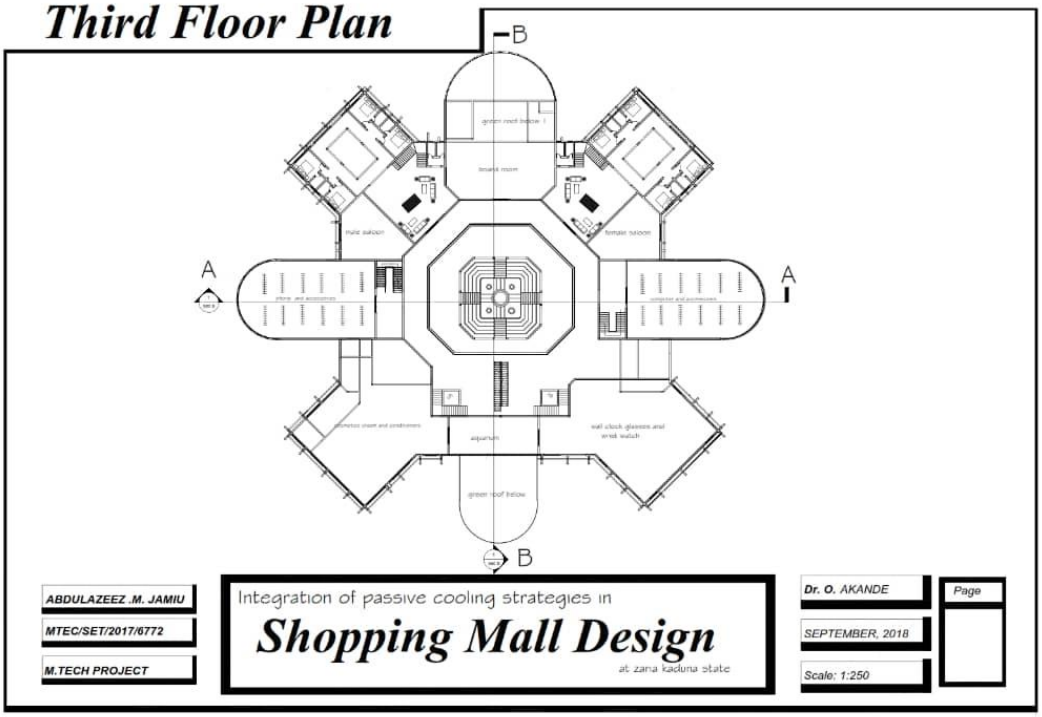
APPENDIX C: SITE PLAN



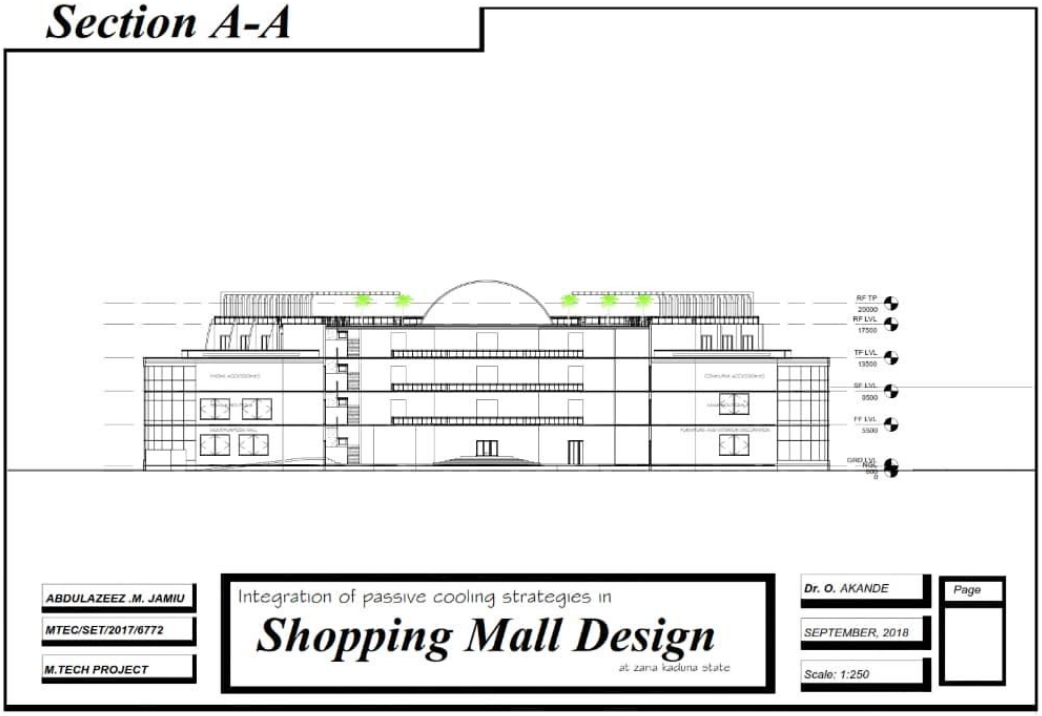
APPENDIX D: FIRST FLOOR PLAN



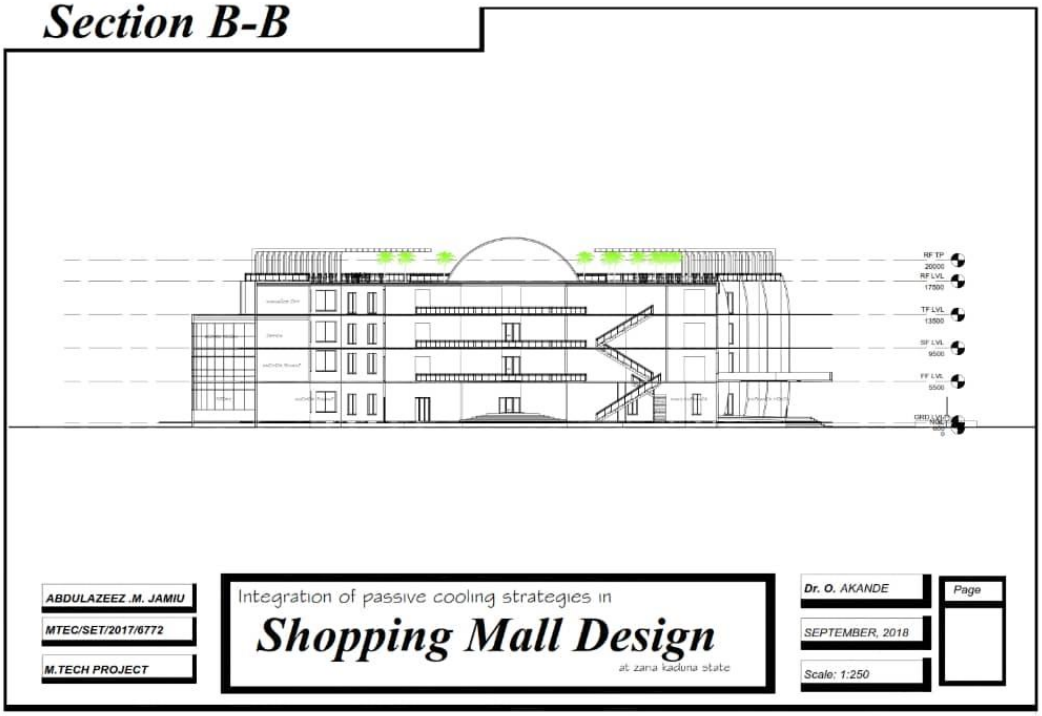
APPENDIX E: SECOND FLOOR PLAN



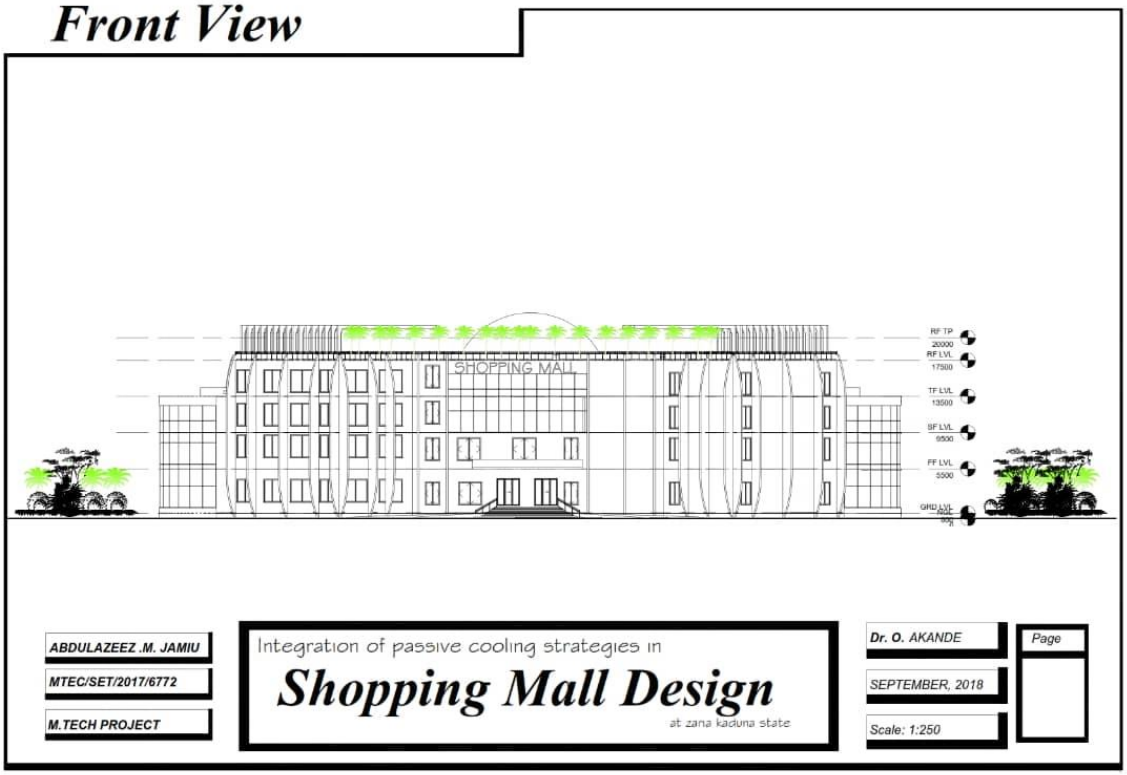
APPENDIX F: THIRD FLOOR PLAN



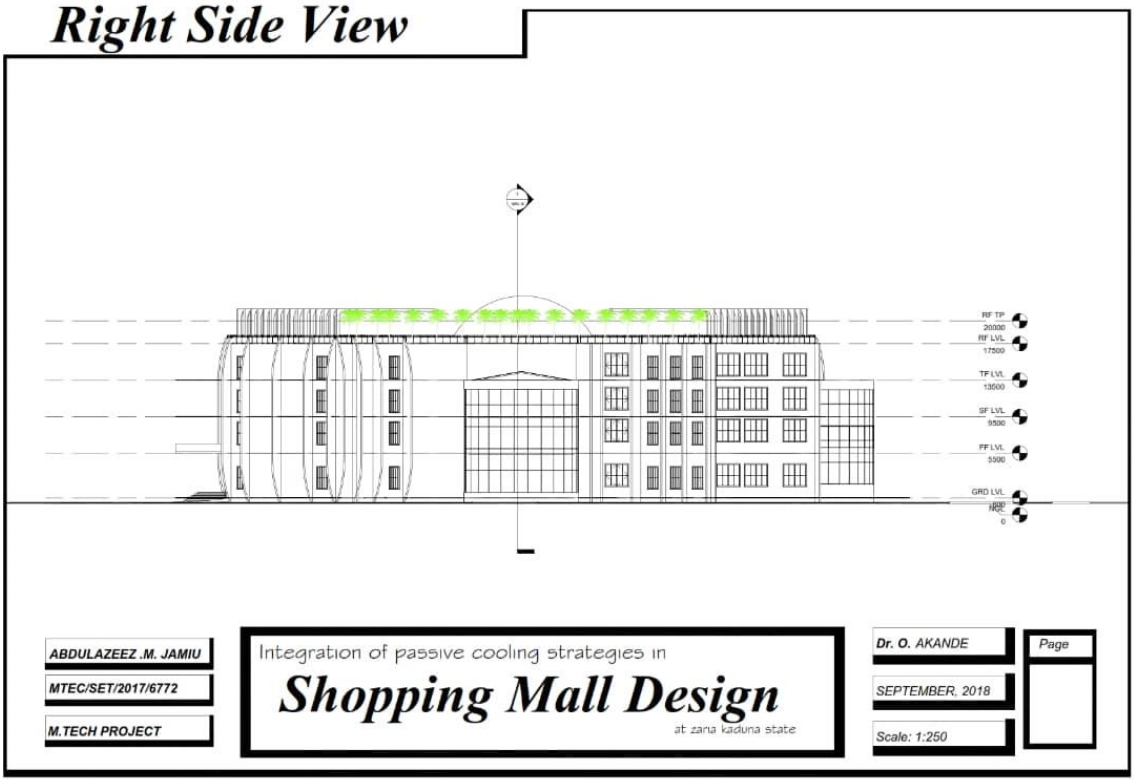
APPENDIX G: SECTION A-A



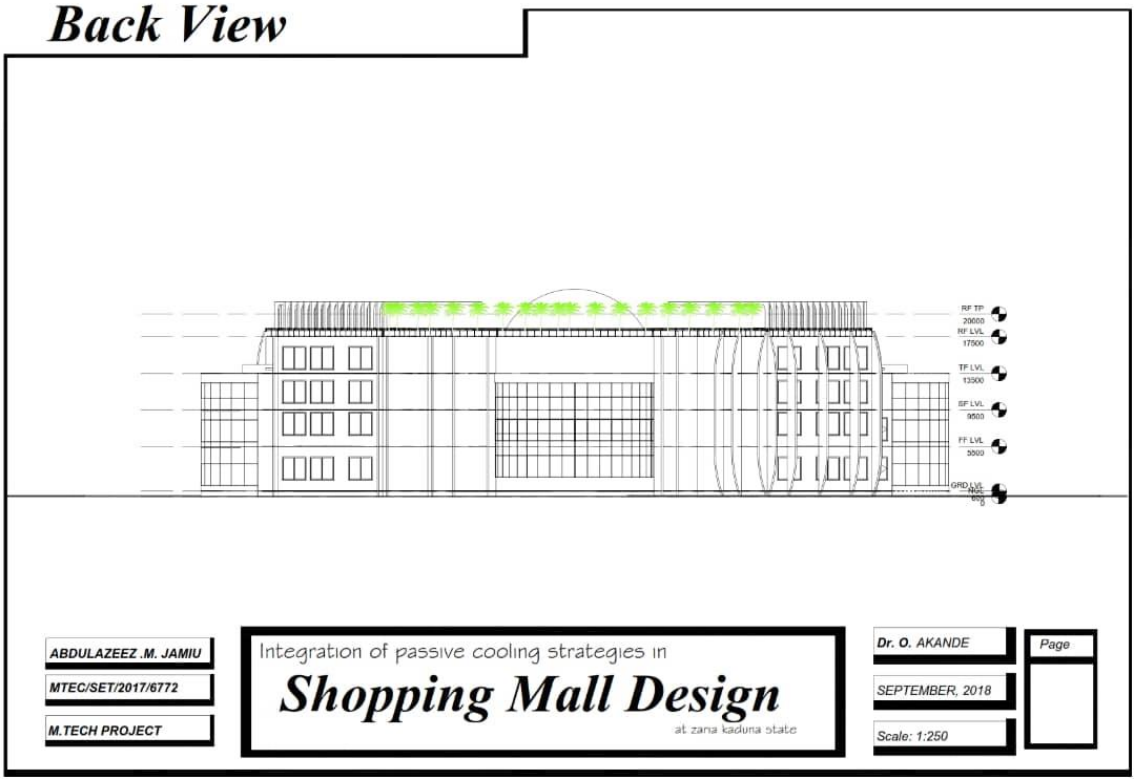
APPENDIX H: SECTION B-B



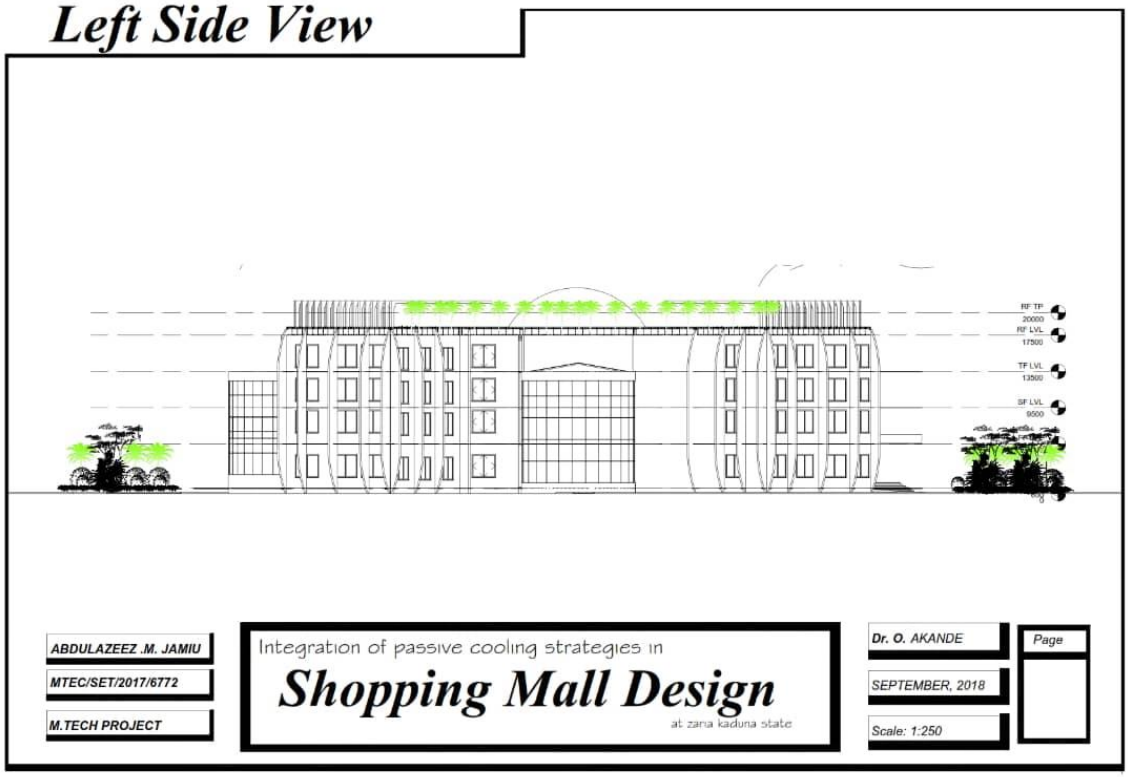
APPENDIX I: FRONT VIEW



APPENDIX J: RIGHT SIDE VIEW



APPENDIX K: BACK VIEW



APPENDIX L: LEFT SIDE VIEW

APPENDIX M: AERIAL 3D VIEW

APPENDIX N: APPROACH 3D VIEW

APPENDIX O: 3D VIEW OF ROOF GARDEN

APPENDIX P: 3D VIEW FROM ENTRANCE