

# **Sustainable Design Strategy for Mitigating Carbon Emissions in Airport Facilities**

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In Architecture**

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### **Certification**

This is to certify that Omowumi Elizabeth Akinyemi with matriculation number LCU/PG/002095 carried out this research work titled **“Sustainable Design Strategy for Mitigating Carbon Emissions in Airport Facilities”** in the department of Architecture, Faculty of Environmental Design and Management, Lead City University, Ibadan, Oyo State, for the award of Master Degree (MSc) in Architecture and that this has not been previously submitted.

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### **Dedication**

This research work is dedicated to Almighty God for His enabling grace and enduring mercy to complete it.

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## **Acknowledgement**

Thank you to Lead City University (LCU) for creating this incredible opportunity and enabling environment to conduct the research work and the library of the above-named institution used as part of my data collection. I sincerely appreciate both academics and administrative staff of Post Graduate (P.G.) School and most especially our P.G. Provost, Prof Folakemi Oredein for their huge input to my achievement in this M.Sc. program.

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Even though the above-mentioned institutions and persons have assisted in the process of this research work, I alone stand responsible for the errors, if any, found in the work.



## **Abstract**

Sustainable airport facilities design and strategy contribute to reducing emissions of carbon globally. The general goal of this research study is to appraise the environmental and physiological impacts of carbon emissions on our immediate environment, airports having long-term effects and to know sustainable design strategies for minimizing its emission. The study of this thesis was carried out to respond to the need for sustainable strategies in designing and planning airport facilities. In this study, physical observations were secured with airports locally while international case studies were carried out via web research survey to examine various sustainability design ideas in existence at different. Population study of this research was done through a purposive sampling method by listing the Nigerian airports and airports already implementing sustainable measures both locally and internationally. Collection data was carried out by case studies, online research journals, and professional books related to the design topic. Presentation of results was done using descriptive statistics. Results showed that foreign airports used their locally sourced materials while Nigerian airports used Aluminum composite panels; Natural ventilation, alternative energy sources, and water conservation was disregarded. This study stresses the necessity to consider sustainability strategies in the design of airport facilities, and strategy measures that can be implemented to avoid the degradation the of environment, boost the well-being of airport workers and passengers, and thus reduce operational costs.

**Keywords:** Design strategy, Sustainable, Airport facilities, Mitigating, Carbon Emissions

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## List of Acronyms

| Abbreviation      | Meaning                                      |
|-------------------|----------------------------------------------|
| ACA               | Airport Carbon Accreditation                 |
| ACI               | Airports Council International               |
| ADG               | Aircraft Design Group                        |
| AEDC              | Abuja Electricity Distribution Company       |
| AEC               | Architecture, Engineering and Construction   |
| ATC               | Air Traffic Controller                       |
| ARP               | Airport Reference Point                      |
| CO <sub>2</sub>   | Carbon (IV) oxide                            |
| DFID              | Department for International Development     |
| DGCA              | Directorate General of Civil Aviation        |
| DLR               | Docklands Light Railway                      |
| EPCOT             | Experimental Prototype Community of Tomorrow |
| FAA               | Federal Aviation Administration              |
| FCT               | Federal Capital Territory                    |
| GHG               | Green House Gas                              |
| GtCO <sub>2</sub> | Gigaton of carbon dioxide                    |
| IATA              | International Air Transport Association      |
| ICAO              | International Civil Aviation Organization    |
| IEA               | International Energy Agency                  |
| IFR               | Instrument Flight Rules                      |
| INECO             | Insulation Engineering Company               |
| IPCC              | Intergovernmental Panel on Climate Change    |
| LCU               | Lead City University                         |
| NAA               | National Airports Authority                  |

|       |                                             |
|-------|---------------------------------------------|
| NLR   | National Aerospace Laboratory               |
| NPIAS | National Plan of Integrated Airport Systems |
| NZEB  | Net Zero Energy Building                    |
| PHC   | Port Harcourt                               |
| RAF   | Royal Air Force                             |
| UFR   | Upper Flight Region                         |
| USA   | United State of America                     |
| VFR   | Visual Flight Rules                         |
| WAAC  | Western African Airways Corporation         |
| WWDR  | World Water Development Report              |

## **Chapter One**

### **Introduction**

#### **1.1 Background to the Study**

An airport is a vicinity in which airplanes such as helicopters, wing planes, and small airships deplane and emplane, and aircraft can be maintained and kept at the airport. An airport consists of a runway for planes, and a helipad to take off and land, taxiway, apron, and buildings such as firefighting and rescue services, control tower, hangar, and terminal building. The aviation industry is a fast-growing sector contributes significantly to providing critical infrastructure like runways, taxiways, ground parking and transportation, lighting, navigational and approach aids, and various support facilities necessary for conveying millions of passengers and air cargoes annually from one locality to another. The air transport sector continues to grow as man prefer to fly is one of the quickest, and most secure modes of transporting passengers and air cargo, and this enables economic growth and opportunities. It is an avenue for creating employment for people; tourism and social benefits. Despite the important role of the aviation industry generally, air transport services harm our environment such as air, water, and noise pollution and natural resources consumption (Ekici, F., Orhan, G., Gümüş, Ö., & Bahce, A. B. 2022; Budd, 2017; Daley, 2016;). Shown below in Figure 1.1, are the negative environmental impacts related to airport operations and the need for sustainability in the 21<sup>st</sup> century.

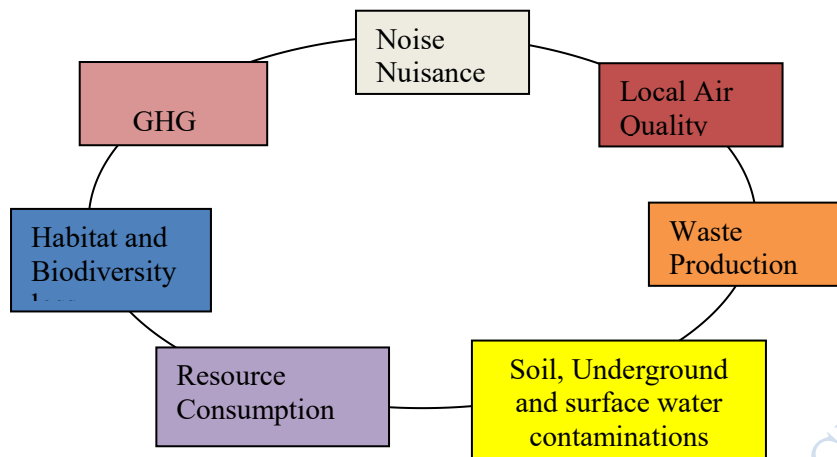


Figure 1.1: Airport operations and environmental impact  
Source: NLR, DLR, and INECO (2013)

Globally, climate change has continued to garner much attention given the scientific backing that Green House Gas (GHG) emissions are driving the temperature of our planet to unprecedented high levels. Naturogenic and anthropogenic activities of man increase the concentration of carbon dioxide (CO<sub>2</sub>) in the atmosphere considerably since the industrial revolution and has currently reached dangerous levels not experienced in the last three, and a half million years ago (Hashimoto, K. (2019). The air transport industry is among the top ten emitters of CO<sub>2</sub> globally contributing a warming effect of about 4.9% on the earth, and could emit 56 GtCO<sub>2</sub> (Gigaton of carbon dioxide) from 2016 to 2050 (Nam, V. H. 2019). This is a major problem necessitating quick global reaction by Intergovernmental Panel on Climate Change's (IPCC) current response to minimize carbon emissions by 2050.

Climate change has been a main threat to attaining sustainable human development in many developing countries like Nigeria being the world's 17<sup>th</sup> biggest GHG emitter in 2015. It may not be possible for Nigeria to completely eliminate fossil fuel usage but its dependence can be minimized. Excessive release of carbon emissions increases earth's temperature thus flooding low-lying areas, melting polar ice caps, and increase in sea levels and if it continues, it may lead to shortage of food, increase in mortality rate

(Ogundipe et al., 2020). Current research by Ukhurebor, K. E., Athar, H., Adetunji, C. O., Aigbe, U. O., Onyancha, R. B., & Abifarin, O. (2021) shows that there might be increase in sea level from 1990 levels to 0.3m by 2020 and 1m by 2050, and rise in temperature up to 3.2°C by 2050 in an extreme climate change scenario. Carbon emissions generate air, noise, and water pollutions which have negative effects on children's academic performances, contamination of close water bodies, poor air quality, sleep, and can lead to cardiovascular risk. Exposure to carbon emissions by airport staff, and passengers may cause difficulty in breathing, sweating, headaches, dizziness, and high blood pressure, and may lead to poor staff performance, and makes passengers or visitors uncomfortable, and their visit exhausting.

Nigerian airport authorities like FAAN adopted different initiatives both internal, and global practices on the reduction of carbon emissions in the facilities used in airport sector, and these are the use of renewable solar energy, planting of trees, measuring, monitoring, and management of carbon footprint.

Sustainability of airport facilities is an emerging area of interest to lessen emissions of carbon to minimize environmental impact thus improving users' quality of life, maintaining a good, and consistent rate of economic growth, and improves social progress of the airport workers, and its immediate environment. The design strategy of reducing emissions can be achieved either by active or passive sustainability or a combination of both and it aims to meet the present, and future generation's needs (Uysal, M. P., & Sogut, M. Z. (2017).

The sustainability of airport is complicated because it encompasses areas such as designs, emissions reduction, water conservation, and construction techniques. As a response, this research identifies effective sustainable practices for mitigating carbon emissions in airport facilities to improve decision-making in airport planning.

## 1.2 Problem Statement

Urbanization birthed the annual increase in global population expansion of the built environment and advanced use of technological equipment such as aircraft to move people from one location to another resulting in the global rise of CO<sub>2</sub> emissions. The aviation industry has been a breeding ground of bad air quality within the terminal building and its surrounding properties because of the challenges of CO<sub>2</sub> emissions and its negative effects on our environment and man. There are several environmental concerns such as CO<sub>2</sub> emissions, waste and water management, fossil fuel, and several others from vehicles, aircrafts, and buildings which remain a threat to our planet. Emissions of carbon have a significant distressing effect on our planet at large rate of GHG emissions in the atmosphere resulting in climate change and global warming (Njeri Gitau, 2019). Global emissions of carbon must decrease to avoid crisis in the aspects of environment and economy. Natural and human activities are the major sources of CO<sub>2</sub> emissions in the atmosphere and this continues to rise extensively since the industrial revolution reaching dangerous levels not experienced some years back. In Nigeria, major contributory factors to these emissions are from fossil fuel due to epileptic power supply to power their mechanical and electrical equipment and other useful equipment, airport vehicles for arriving or departing, emissions from waste disposal and processing (Somorin, T. O., Di Lorenzo, G., & Kolios, A. J. (2017).

Application of a sustainability design approach in the reduction of CO<sub>2</sub> emissions in aviation industry will increase the productivity of airport, lessen its hazardous impact of climate change and building up their flexibility to the expected changing operational condition. Sustainable design reduces the impacts of CO<sub>2</sub> on our environment, health and users' comfort of building by reducing the consumption of non-renewable resources, minimizing waste thereby improving building performance and creating a healthy and

productive environment. It also helps in preserving consistent rate of economic growth and making progress socially.

Although, several authors (Greer, F., Rakas, J., & Horvath, A. 2021; Tsai, W. H. 2020; Bo Li, Wen Zhang and Ran Lei, 2018) have investigated the reduction in Airport Carbon Emissions and systems for managing them but none has focused on the application of sustainable design strategies to mitigate the effect of carbon emissions and this is the gap this study will fill.

The designs of airport sustainable development activities must be a general approach that includes the economic, ecological, social and health aspects. Therefore, a quick attention is needed in the society to stay healthy and have better sustainable environments is required in mitigating carbon emissions in airport facilities.

### **1.3 Aim**

The aim of this thesis is to achieve sustainable design strategy in Ibadan Commercial Airport facilities located with a focus on mitigating carbon emissions in Alakia – Ibadan, Southwest of Nigeria.

#### **1.3.1 Research Objectives**

1. To assess the environmental impacts of carbon emissions on our immediate environment through airport facilities.
2. To examine the physiological effects of carbon emission on passengers and their visitors together with the long-term effect on airport staff.
3. To examine the current measures airports are adopting as a means of carbon emissions reduction.
4. To identify sustainable design strategies that can be used to reduce carbon emissions effects.

#### **1.4 Research Questions**

1. What are the environmental impacts of carbon emissions on the immediate airport environment?
2. What are the physiological effects of carbon emission on travelers and their visitors and the long-term effects on Ibadan Airport staff?
3. What are the current measures airports are adopting as a means of carbon emissions reduction?
4. What sustainable design strategy can be used to minimize the effects of carbon emissions in airport facilities?

#### **1.5. Significance of the Study**

Beyond the oil revenues, the aviation industry plays a fundamental part in the country's economy via its ability to move people and freight quickly and safely globally. The significant role of the aviation industry cannot be overemphasized with its contribution to man's standard of living, enabling us to explore new areas, visit our loved ones and eliminate barriers placed by geographical constraints with remarkable statistics. The air transport industry provides more than 21 million job opportunities (Dimitrios, D., & Maria, S. (2018)), and world trade worth approximately 40% being carried while this improves productivity (Budd, L., & Ison, S. (2017)).

Communities enjoy the benefit of importing their goods to the international market through the means of air transportation and this helps to preserve their businesses, provides employment opportunities, and boosts the economy of such localities.

Ibadan is one of the largest cities in Nigeria and Sub-Sahara Africa deserves an international airport. It stimulates commercial activities which invariably boosts local economy of Ibadan city and other satellite townships around it.



There will be airline operators plying this route which makes traveling easier and more affordable for people due to insecurity challenges and bad road network in Nigeria. It serves as an international alternative route to Lagos rather than redirecting the flight to Accra in Ghana, Ibadan would serve better (in case of weather or other challenges) and promotes ease of movement for pilgrims (Muslims and Christians) to perform their spiritual rights at will instead of flying to Mecca and Israel from Lagos.

The sustainability design strategy will further lower airport energy and operating costs thereby reducing their local contribution to global GHG levels and further creating healthy environments.

### **1.6 Scope and limitation of the project**

The existing Ibadan airport facility needs a facelift from its current dilapidated and substandard state to an international standard accommodating international flight. Presently, Ibadan airport design needs to expand its facilities to meet global standard. It has an existing runway of 2400m /45metres and to bring it up to a minimum international requirement of 3.3km/60 metres and increasing its existing parking area of approximately 25,200m<sup>2</sup> to 76,500m<sup>2</sup> in order to fly wide-body aircraft (Worldstage, 2021).

Airport GHG emissions include methane, nitrous oxide, sulfur dioxide, hydrofluorocarbons, CO<sub>2</sub> and perfluorocarbons gases which makes up the largest of GHGs (Moiceanu, G., & Dinca, M. N. 2021). This study will be limited to carbon emissions in airport facilities



### 1.7 Operational Definition of Terms

1. **Apron:** It is a parking position for airplanes to load and unload of passengers and goods from aircrafts.
2. **Airport:** It is a multifaceted facility comprising runway and terminal buildings for embarking and disembarking and maintenance of airplane with facilities to satisfy passengers.
3. **Aircraft Apron:** It is an area where aircraft park and can also be called ramps.
4. **Airport Terminal:** It is a building between the landside and airside within the airport where passengers go through the administrative check and security control to deplane and enplane from an aircraft.
5. **Airport Runway:** It is a demarcated rectangular zone within the land airfield equipped for aircraft to take off and land.
6. **Air Transportation:** It is one of the most global essential industries which connect modern world, people, cultures and businesses across continents.
7. **Carbon Emission:** it is the release of carbon into the atmosphere contributing to climate change.
8. **Control Tower:** It is a building designed within an area to control pilots and observe the movement of airplanes to ensure their safety using radars and radio as a means of communication.
9. **Climate:** It is an average weather condition of an area predominant for a long time.
10. **Fossil fuel:** It is a means of generating energy that consist of coal natural gas and oil.
11. **Hangar:** It is a building that which houses aircrafts to be maintained and properly overhauled.

12. **Parking:** This is a place provided for vehicles of both airport staff, visitors and passengers to park.

13. **Taxiways:** They are pathways on the aerodrome surface to maneuver aircrafts without colliding with one another.

14. **Sustainability:** It is ability to strategize and design buildings that will recognize the current needs and still meet the needs of the future generations.

15. **Environment:** This is the conditions where living and non-living things operate.

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## Chapter Two

### Literature Review

#### 2.1 Conceptual Review

According to Your Dictionary (2022), “an airport refers to a place where airplane deplane and enplane normally equipped with hard surfaced landing strips, control tower, hangars, aircraft maintenance and refueling facilities and accommodations for passengers and cargo”. An airport can simply be said to be a facility used to connect passengers from ground transportation to air transportation.

Figure 2.1 shows the three components of an airport which are broadly divided into landside, terminal and airside.

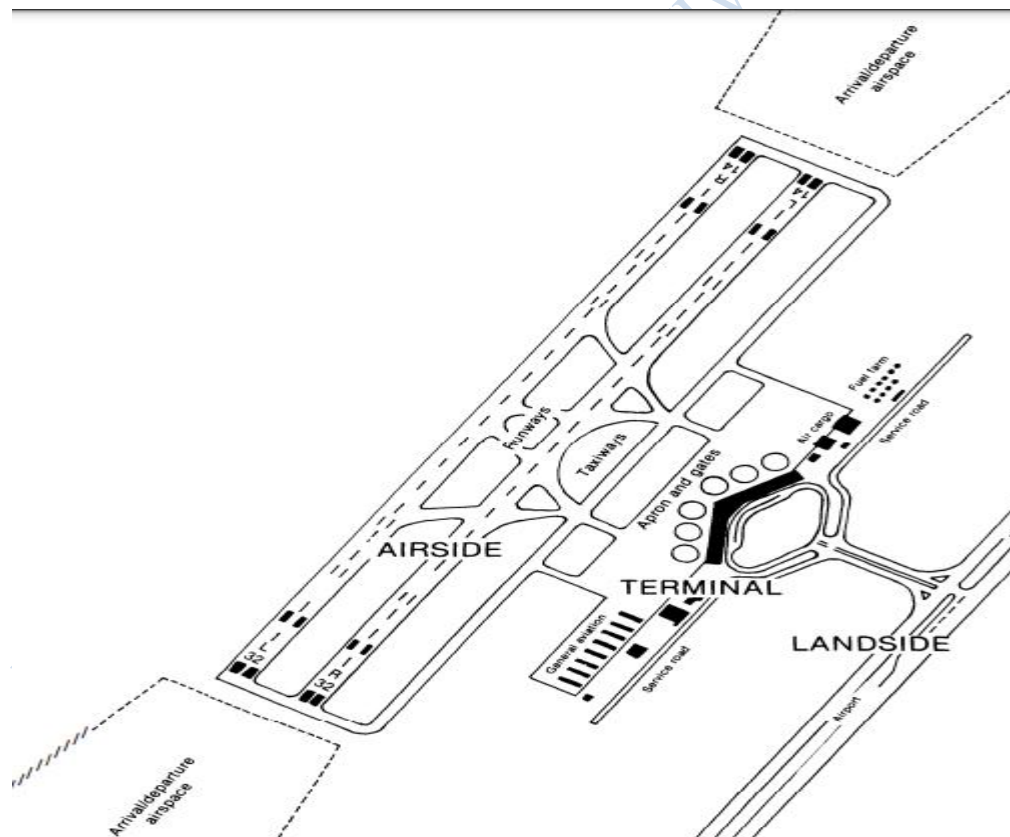


Figure 2.1 Three Components of Airport  
Source: Federal Aviation Administration

The landside component covers arrivals and departures of both passengers and visitors together with their movement through the terminal building to disembark and embark the aircrafts. It includes departures and arrivals curb, parking lots and access roads. The terminal component is a designed area for administration of airport facilities and constitutes passenger servicing infrastructure from arrivals and departure curbs, security and health checkpoint and also concourses allowing access to airside operations. The airside component illustrates the platform for movement of aircraft within the airport and has taxiways, ramps and runways (Guerra de Oliveira, S., Tibaut, A., & Dell'Acqua, G. (2019).

In general, an airport comprises a runway, a hangar and terminal building and needs a variety of other facilities which may include control tower, facilities for passengers and fixed based operator services. Airports are known as one of the busiest transportation hubs globally.

There are other terms used such as aerodrome, airstrip and airfield to describe airport. However, airstrip and airfield are referred to as facilities with runway while aerodrome refers to surface for aircraft to take off and land.

### **2.1.1 Historical background of Airport**

Crave of human beings to flying as a means of transportation had been on for decades ago and this desire inspired Diego Martin de Auguilera who was a farmer created a wooden structure with feathers to glide above a river with a total distance of 360 meters. In 1903, the Wright brothers made the first ever flight with an airplane on an untitled flat piece of land to embark. College Park Airport was the first ever airport in history and was completed in 1903 by the Wright brothers with these facilities: hangars, fuel tanks; strip of earth marked with chalk and a simple platform to board the plane shown in figure 2.2.



Figure 2.2: First flight with aircraft  
Source: Wikipedia, 2022



Hangars and ramp at College Park Airport

During World War I, airplanes were used as a mean of moving troops, supplies, personnel and combat. Croydon Airport in South London was the first international airport to open due to the increased aircraft traffic during World I and II and also the accumulation of commercial facilities to take cater for the military airfields.

The deplaning and emplaning of most passengers' transport aircraft before World War II was mostly at 600 meters with extra clear areas for blind landing or unfavorable weather with the total area not greater than 500 acres. In between 1920 and 1930, the first approach lighting system was used to give angle of descent and proper direction to aircraft that were landing and taking off. The design of airport became more sophisticated after World War II and terminal buildings were in groups with arrangement of runways in group around the terminal building which allowed expansion of the facilities.

It was discovered that 986 airports were have built by end of World War II and also about 500 military airports were handed over to municipalities or government and there has been an increase in the need of more airports mainly due to challenges of urbanization.



### **2.1.2 History of Nigerian Aviation**

The unquenchable thirst of man dictated his movement from one location to another through different means of transportation especially flying by airplane.

In 1925, the challenges and possibilities of the African continent to Civil Aviation interest grew more and this made British, Belgians and French had plans for their own countries.

Initially, the British government had a Royal Air Force (RAF) that was residence in Khartoum, Sudan because of the crises that were persistent in Kano and the RAF commanding officer was quickly sent indicator from London to fly to the area and record the situation; then the pilot took off with a Bristol fighter jet with a breath-taking flight but safe landing on the horse race course in Kano and this the first record of aviation activity in Nigeria but the activity was referred to as a just simple accident of history because Kano has never been a destination for aircraft (John, C. S., 2019). After this event, RAF had a base in Cairo where flights came from and this later became a yearly occasion and routes were made available with frequency to Maiduguri. Aviation sector grew and there was need to have more aerodromes. As a result of this, the representative of Air Ministry in London came to Nigeria to survey and locate possible sites and airfield were selected such in Kano, Lagos, Minna, Osogbo, Maiduguri and Kaduna. Imperial airways launched flights between Nigeria and Sudan in 1935 which was the first civil plane that arrived in Kano and extended to Lagos, Port Harcourt, Kano, Jos and Enugu.

Nigerian government created a new air service system called 'Nigerian Air Services' after the regular service stopped in the early 1940s. Gambia, Nigeria, Sierra Leone, Ghana and four British colonies jointly developed Western African Airways Corporation (WAAC) in 1946 (Komba, S. T. 2018). Nigerian government formed Nigerian Airways after gaining independence and this made Nigeria and Ghana pulled out of the developed joint airline company and this led to airline industry in Nigeria. Since the creation of Nigerian



aviation sector, there has been increase in growth and private establishments were allowed to operate international routes to support the Nigerian Airways to handle the increase in the aviation industry. Federal Airport Authority of Nigeria manages the activities of commercial airports in Nigeria.

### 2.1.3 AIRPORT

#### 2.1.3.1 Types of Airports

Mainly, types of airports can be divided into three and they are: Domestic, Regional and International. However, each type of airport has features which are different from one another and figure 2.3 shows different types of airports below.

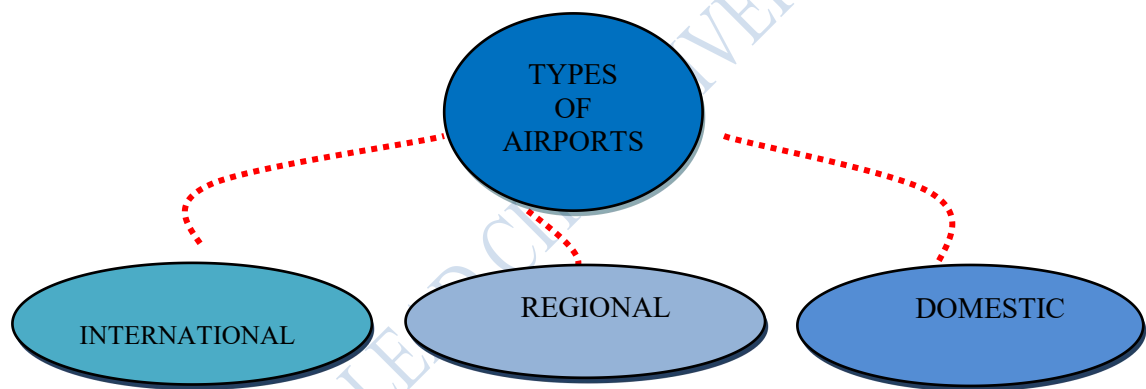


Figure 2.3 Types of Airports  
Source: Jaspreet & Akshay (2015)

#### A. *International Airport*

1. It connects directly to other airports.
2. It is equipped with immigration and customs facilities to handle traffic borders.
3. It handles booked commercial air services for goods and passengers.
4. It serves as a place where unmanned flights may land and accommodate connecting passengers.
5. It consists of runways and facilities to accommodate aircrafts with specified dimensions.

### *B. Regional Airport*

1. It serves traffic in a geographically sparsely populated area.
2. It does not have customs and immigration services to handle cross-border traffic..
3. Its aircraft operates smaller airplane.

### *C. Domestic Airport*

1. It only operates flights in the same country.
2. It does not have customs and immigration services and cannot process foreign flights.
3. Its runways adequate to service medium range aircraft.

#### 2.1.3.2 Categories of Airports

FAA classifies airports by type of activities including primary, reliever, cargo service, reliever, commercial service (and general aviation airports, as shown below (Chung, S. K. 2019):

#### **A. Commercial Service Airports**

These are public airports with a minimum of 2,500 passengers on board yearly to accommodate the service of regular passenger. Commercial Airport can be further classified as:

- i. Non primary commercial service airport is a type of commercial service airport with minimum of 2,500 and not exceeding 10,000 passengers boarding yearly.
- ii. Primary Airport is a type of commercial service airport over 10,000 passengers on boarding annually.

**B. Cargo Service Airport** is an additional facility in airport services necessary for transportation of goods with an annual total of landed weight over 100 million pounds.

Landed weight means the aircraft's weight to fly only cargo either within or outside the same state or international air transportation.

**C. Reliever Airport** is a type of commercial service airports selected by the FAA to ease congestion and to increase general aviation contact to the general public and can be publicly or privately owned.

**D. General Aviation Airports** are airports with passengers of not up to 2,500 yearly for general use with no regular service.

#### 2.1.4 CLASSIFICATION OF AIRPORTS

FAA and ICAO classified airports based on their modes of passenger movement, air traffic control, and type of ownership.

##### 2.1.4.1 Classification based on Mode of Air Traffic Control (ATC)

Air traffic control is the equipment used in controlling and monitoring air traffic for smooth aircraft operations within a particular area. It is very necessary in ensuring the safety and efficient movement of aircraft through the process and to account for intentions and positions in the operations of aircraft in an airport to avoid aircrafts collisions. Due to this, airports are classified into towered and non-towered airports.

- i. **Towered Airports:** It refers to airports which have an Air Traffic Controller (ATC) with the flexibility and utility of flying to prevent collision and coordinate air traffic flow for proper take-off and landing of airplanes (Lin, Y. et al., 2021).
- ii. **Non-towered Airports:** A non-towered airport refers to an airport without an ATC but follows recommended process of communications and operations to take off and land in an airport having no ATC (Fürstenau, N., Jakobi, J., & Papenfuss, A. 2022) and these procedures differ from one country to another.

#### 2.1.4.2 Classification Based on Functions

Classification of Airports based on function distinctly explains types of services and facilities obtainable by the aerodrome. Therefore, they are classified into reliever, commercial, cargo service and general aviation.

#### 2.1.4.3 Classification based on Passenger movement

Airport categories based on passenger movement and flight per year are generally divided into three broad categories; International, Regional and Local.

- i. **International:** It is an airport operates by international airline with control facilities for Immigration and Customs officers to move passengers from one country to another.
- ii. **Regional:** This type of airport has no common agreed definition but its purpose is to serve medium and short ranges of routes from one place to another within a very light populated geographical area (Nierstadt M., 2021).
- iii. **Domestic:** It is an airport which offers services in the same country with no control facilities for Customs and Immigrations officers.

#### 2.1.4.4 Classification based on type of ownership

1. **Military airports-** It is a type of airport classification which is operated by the appropriate Federal Government Agencies and Military.
2. **Civil airports-**These type of airports are opened to the public.
3. **Private airports-**These airports are not open to the general public and are assigned for private use and are highly restricted.

#### 2.1.5 Components of Airport

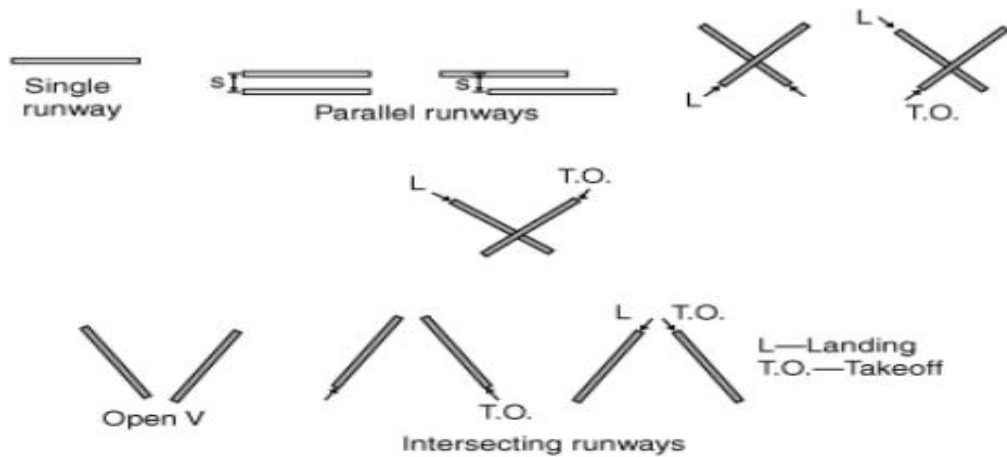
According to Chen S.J, (2019), the term ‘airport’ means the geographical area of the airfield comprising the airside, terminal and landside.

#### 2.1.5.1 Airside

This is a zone which is after the terminal building in an airport involved directly in the arrivals and departures of aircraft covering an area of leveled land that to allow aircraft embark and disembark which encompass smooth surfaces for runway, taxiway and maintenance building for planes. (Chen S.J, 2019).

The airside components in an airport are runway, taxiway and ramp;

- 1.—**Ramp:** It is can also referred to as Apron and this is an area where aircraft used for parking, loading, unloading, refueling and also for boarding and alighting the aircraft and these activities are known as ramp operations (Aviation, L., 2020) The apron size depends on the number of planes serviced. Figure 2.4 shows typical ramp in an airport's airside.
- 2.—**Taxiway:** It is the path on which aircraft travels to and from the ramp to runway, connecting aircraft to hangars, terminal, apron and other services. It provides fluent and safe surfaces for expeditious movement of airplanes. Figure 2.4 shows typical taxiway in an airport's airside.
- 3.—**Runway:** It is a designated zone for embarking and disembarking of airplanes made of either asphalt grass or concrete surface with white markings in order to guide pilots to land and take off. Runway configuration can be single, parallel or intersection. Figure 2.5 shows typical types of runways configuration.



Figure

2.4: Taxiway, Runway and Ramp activities  
Source: Aviation Management Resources

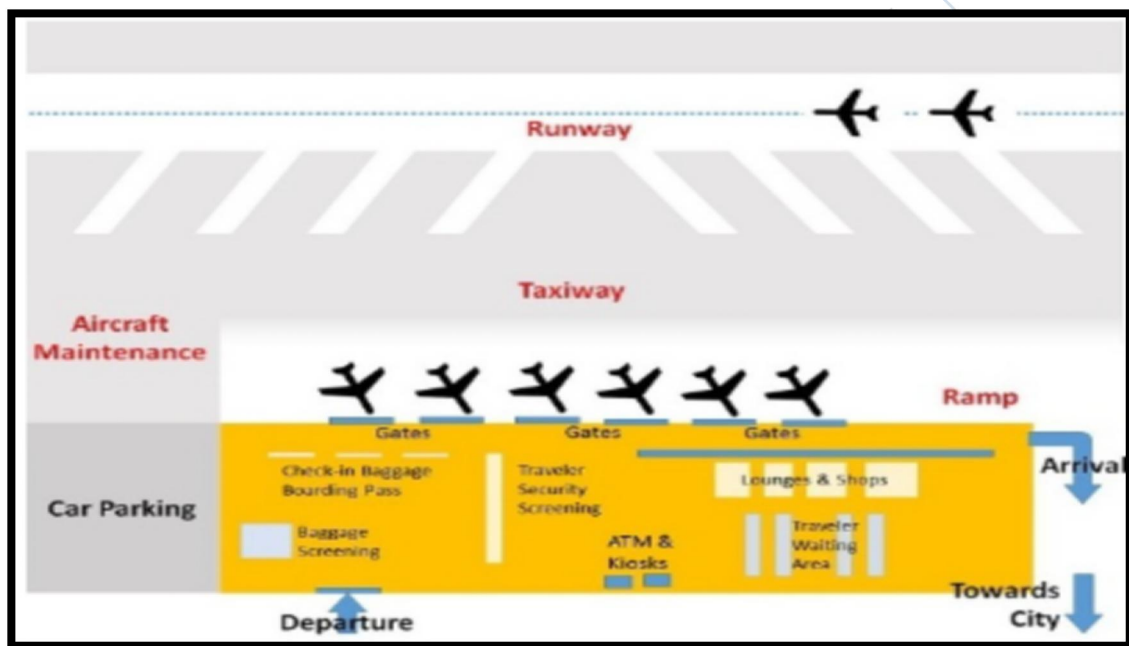


Figure 2.5: Typical runway configuration types  
Source: John C.S. (2019)

#### 4.—Airside Support facilities

These are facilities which facilitate aircraft operations around an airside. They include, Aircraft maintenance facilities, Fauna control, control tower, De-icing and anti-icing facilities, airfield lighting, facilities for fueling planes, and fuel farms depot.

### 2.1.5.2 Landside

It is an area to accommodate ground-based vehicles, departures and arrivals curbs, passengers, and transfer of cargo from its specific flight to other means of transportation as well as landside freight component. It comprises public access, airport cities, processing of passengers, and commercial areas. Landside components area are as follow:

- 1. Ground Transport and Parking:** This is the means linking passengers and goods within the curbside and aviation processes. The rate at which airports continues to enlarge, it is necessary to have a detailed multi-mode ground transportation design to support its long-term development.
- 2. Landside Support Facilities:** These include fuel farm, access roads, parking spaces, Fire services facilities, ground support equipment facilities, Water conservation services, power plants and intermodal facilities.



Figure 2.6: Delhi Indira Gandhi International Airport Terminal 1 Landside Improvement Concept

Source: L& B (2020)

### 2.1.5.3 Terminal Building

It is a building designed to facilitate the embarking and disembarking of passengers from aircrafts and it is considered the airport's gateway serving the boundary between the landside and airside components. Within this building, the processing interface of

passengers' movement to board occur through the purchase of tickets, regular or self-check-in, security checking zones and transfer of luggage in and out of the aircraft, duty free shops, concourses, restaurant and many other facilities for passengers' satisfaction. Usually, big airports have more than one terminal building connected to the other using link bridge while small airports have single terminal equipped with necessary facilities. The design of this facility is determined by the passengers' flow of traffic and its operation type.

Guiding factors for designing terminal are as follow:

1. Location and number of terminals.
2. Number and layout of facilities.
3. Service efficiency
4. Passenger flow
5. Signage
6. Maintenance of facilities
7. Community concerns

#### **2.1.6 Airport planning layout and design**

Theoretically, the design of airports and management of the entire aviation system is a joint and linear process, however, the complex sophistication and skill required makes the task difficult in practice (Uysal, M.P., & Sogut, M.Z. (2017). The design of airport facilities consists proper planning, designs, operations and methods of construction, and means of navigation are done by Consultants like Architects, Civil, Electrical, Mechanical, Geo-technical, Structural Engineers, Acoustic Engineers and specialists, Quantity Surveyors, and Land Surveyors.

The design and implementation of an airport system has significant challenges both at the design and management stages. Predicting the service and traffic levels is extremely



difficult because of the fluctuating passenger requirements, growth rate that is unpredictable and advancement in technology brought about by industrialization, ever changing government policies and airline regulations by the requisite bodies (Devoto, R., Meloni, I., Rassau N., & Teulada, B.S.D. (2017).

Most parts of airport design need to consider the depth understanding of many interconnected factors and these are size and performance of aircraft, air traffic management, safety demand and effective operation, impact of noise on societies, and airways obstruction. Different engineering specialization are requested to design and plan airport.

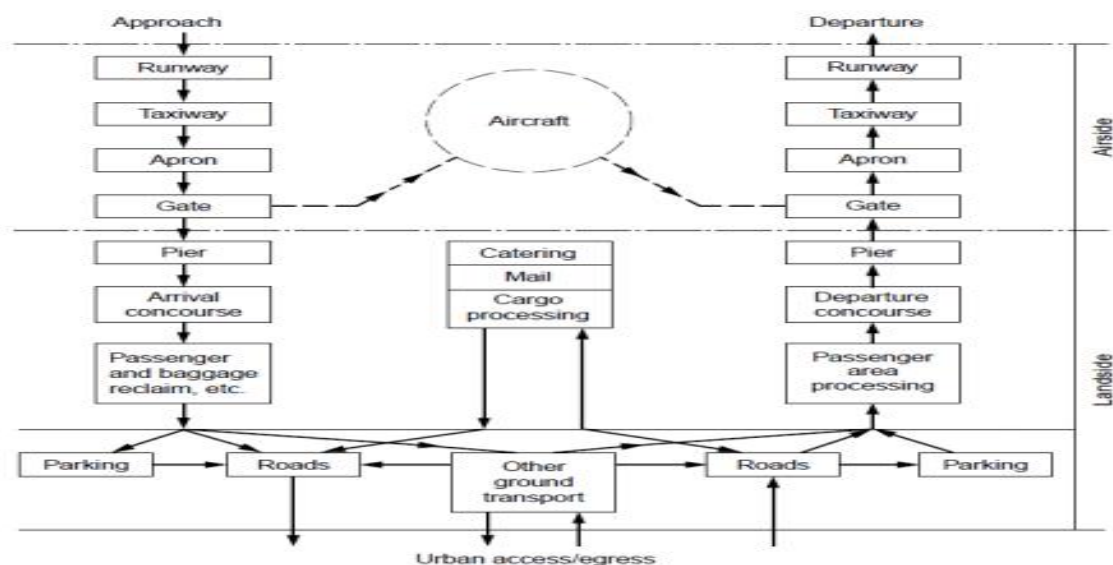


Figure 2.7: The Airport System

Source: Ashford, N., Stanton, H., and Moore, P., Airport Operations, Pitman, London

The term aircraft size is categorized into groups according to their wingspan length which is known as Aircraft Design Group (ADG) and are:

1. Group 1: It is not exceeding 15m.
2. Group 2: This is up to 15 m but not exceeding 24 m.
3. Group 3: Up to 24 m not exceeding 36 m
4. Group 4: Up to 36 m but not exceeding 52 m
5. Group 5: This is up to 52 m but not exceeding 65 m

6. Group 6: 65 m up to but not exceeding 80 m

### **Determination of Airport site and its considerations**

The site selection of airport is of great importance to have perfect design of airport project and its interrelation with airspace services like runway, apron, taxiway in order to achieve proper takeoff and landing environment. The followings are factors necessary for site selection:

1. Where safe landing of aircraft for over 95% of the wind conditions must occur
2. Where obstacles projecting into the flight path must be eliminated.
3. Where houses, buildings, and recreation sites could be subjected to unacceptable levels of aircraft noise.

With the gravity of airplane crashes occurrence around community hall buildings, and neighborhoods are stimulated to monitor use of land about 3 miles away from the Airport Reference Point (ARP), restricting the building of any such buildings (Nguyen, D. M. (2017). The soil type of the airport is a major concern to site selection for locating airport requiring grading and earthwork, wetlands, and suitable access to link the airport.

#### **2.1.6.2 Characteristics of Aircraft**

The features of Aircraft are of great importance to the airport designer and planner with the following features to be studied: Figure 2.8 shows typical parts of aircraft.

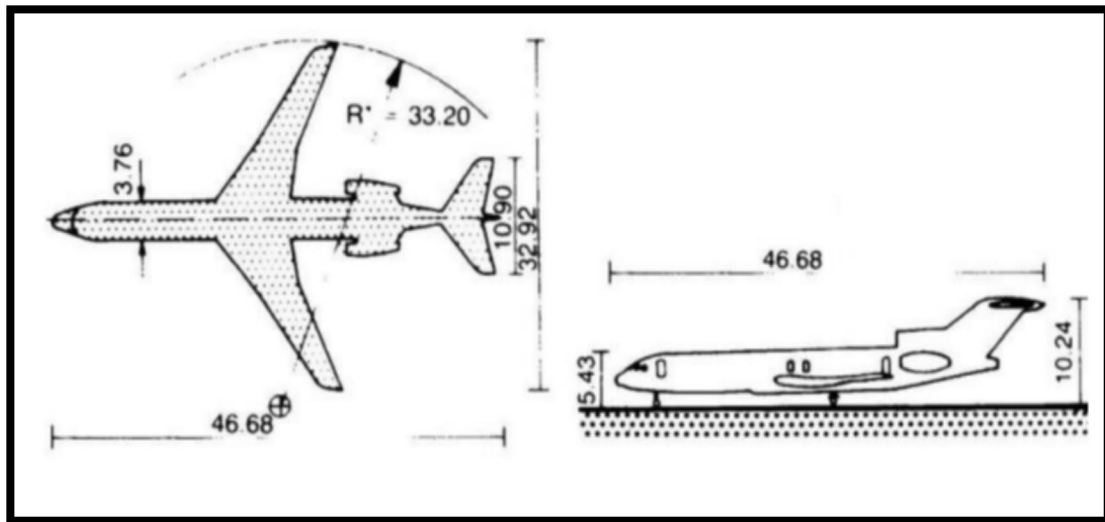


Figure 2.8a: F50 Aircraft size

Source: Neufert Architects' Data pg 447 (3rd Edition)

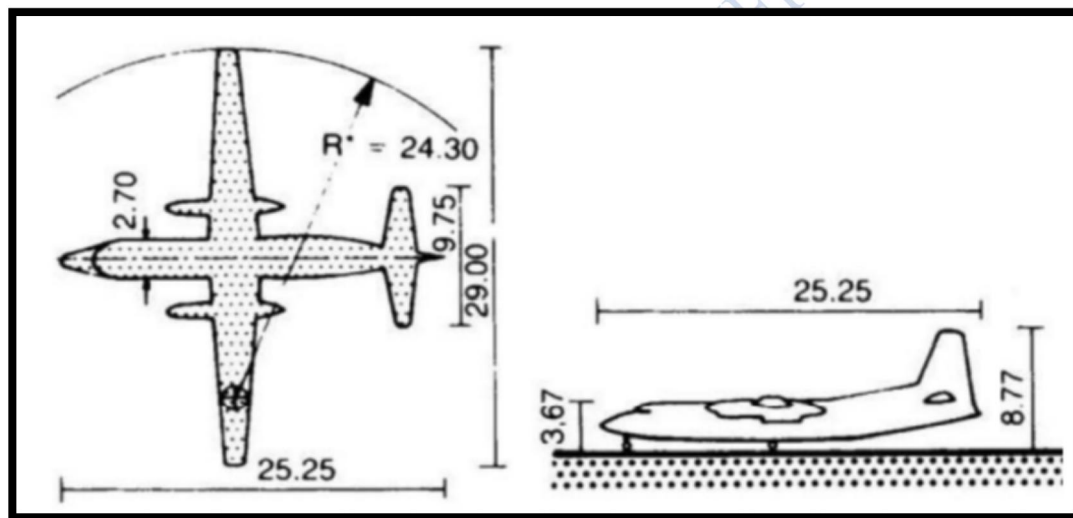


Figure 2.8b: B727 - 200 Aircraft size

Source: Neufert Architects' Data pg 447 (3rd Edition)

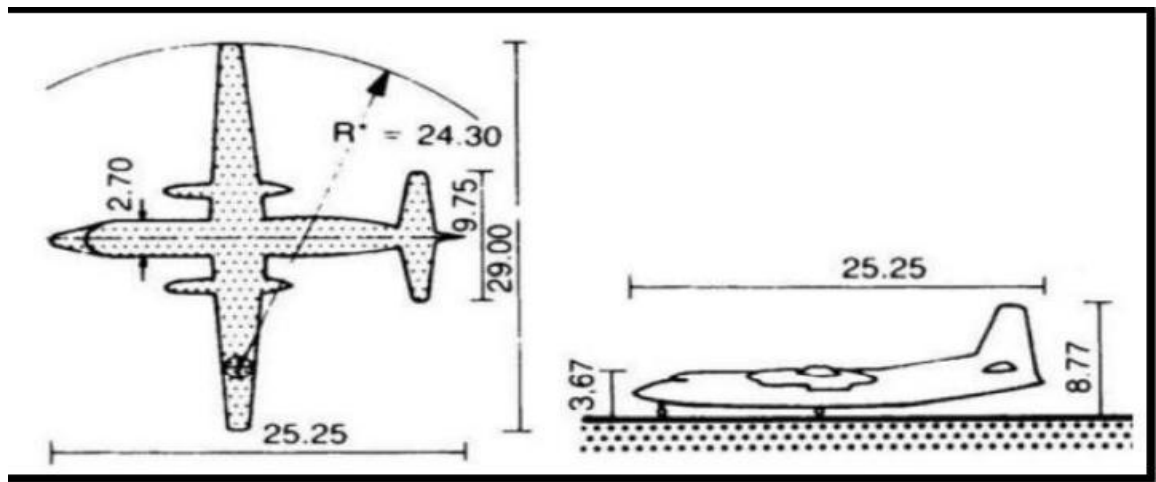


Figure 2.8c: B757 - 200 Aircraft size

Source: Neufert Architects' Data pg 447 (3<sup>rd</sup> Edition)

1. **Type of propulsion:** Aircraft size, circling radius, weight carrying capacity, noise, nuisance, speed characteristics etc. depend upon the type of population of the aircraft. The performance characteristics of aircrafts, which determine the basic runway length, also depend upon the type of population.

Table 2.1: Typical Passenger aircraft Turning Radii

Source: Planning and Design of Airports, pg.81

| AIRCRAFT | MAXIMUM<br>Steering angle° | RADII, M <sup>2</sup> |       |       |
|----------|----------------------------|-----------------------|-------|-------|
|          |                            | Wing tips             | Nose  | Tail  |
| DC-9-32  | 82.00                      | 16.92                 | 18.66 | 5.94  |
| B727-200 | 78.00                      | 21.67                 | 24.23 | 24.38 |
| DC-8-63  | 67.00                      | 33.65                 | 30.18 | 33.44 |
| DC-10-10 | 68.00                      | 34.26                 | 31.88 | 30.79 |
| B747A    | 70.00                      | 42.67                 | 33.22 | 41.76 |

- 2. Size of aircraft:** This comprises hangar gate depth, aircraft wings span, height of hangar gate and in the hangar, wheel base, tail width for parking and apron and following important dimensions.
- 3. Minimum turning radii:** Each taxiway has its own turning radii towards its end and this determines the position of apron and hangars in order to know the movement path (Uysal, M. P., & Sogut, M. Z. (2017)). The geometry study of aircraft rotational movement is very crucial in the design and planning stage. The maximum nose gear steering angle varying from  $60^\circ$  to  $80^\circ$  is specified by the aircraft manufacturers which correspond to the minimum turning radius the table below shows the maximum turning radii of some aircrafts.
- 4. Minimum circling radius:** Aircraft has recommended radius to turn in a space which depend on the following:
- Aircraft type
  - Volume of traffic
  - Weather condition
  - Radii of aircrafts
  - Aviation gear for small aircraft (1.6 Km),
  - Piston engine (3.2 Km or 13 Km)
  - Jet engine (80 Km)
- 5. Speed of aircraft:** It is divided into two areas and they are cruising speed and air speed. The term air speed is referred to as the aircraft speed measured against the air speed it travels while cruising speed is the aircraft speed regarding the ground it travels in its highest speed.

- 6. Aircraft weight and wheel configuration:** This has great impact on the runway length and the requirements of the infrastructures such as apron, hangars, runway thickness and taxiway.
- 7. Jet blast:** Aircraft at high velocity emits hot exhaust gases with its velocity up to 300 kmph and this reduces passengers' level of satisfaction but to curb these challenges different jet blast deflectors should be introduced.
- 8. Fuel spillage:** Fuel spillage is hard to stop at the loading aprons and hangars zones with its effect on the asphalt surface and this should be reduced to the minimum. Therefore, continuous inspection is recommended at the fuel areas.
- 9. Noise:** Noise from aircrafts results in decision making problem of on layout & capacity. This should be greatly reduced as regulated by FAA.
- 10. Aircraft Capacity:** The capacity of aircraft determines the passengers' number, cargo, luggage and fuel that the aircraft can house.

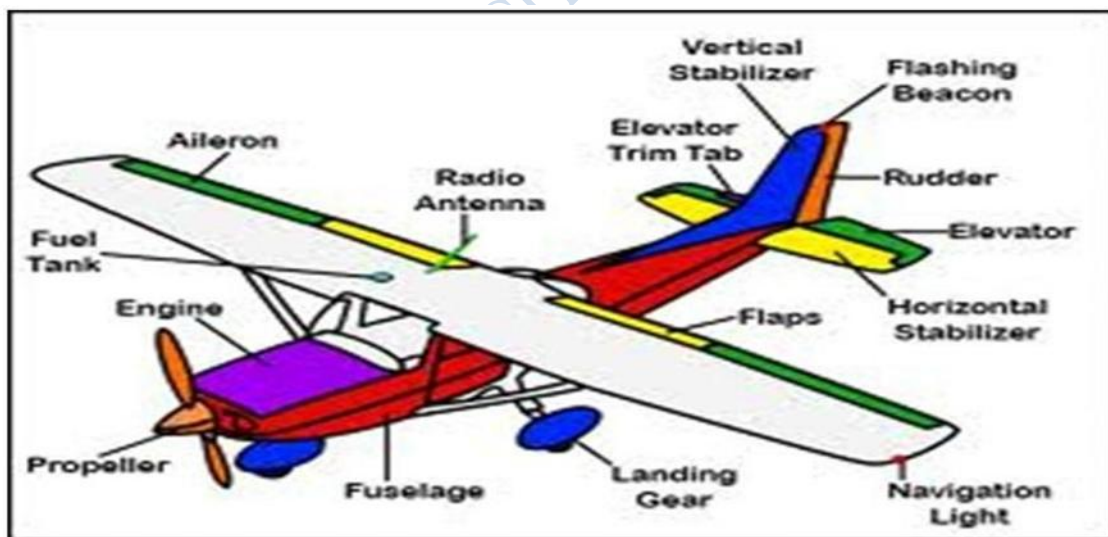


Figure 2.9: Parts of Aircraft

Source: <https://www.quora.com/Describe-various-aircraft-characteristics-How-do-they-affect-the-design-elements-of-an-airport>

#### 2.1.6.3 Airport Design Standards

Generally, the design guidelines of airport facilities for aircraft operations have been prepared by aviation organizations like the FAA (Howard, J., Murashov, V., & Branche,

C. M. 2018) and ICAO, IATA (Alabi, B. N. T., et al. 2021), FAA, Director General of Civil Aviation (DGCA), National Airports Authority (NAA), FAAN, International Airports Authority of India (IAAI) and other building regulatory codes (Batuwangala, E., Silva, J., & Wild, G. 2018). Their operations must be within the framework of international agreements, regulations, guidelines and programs that create operating environment for the commercial air transportation industry.

#### 2.1.6.4 Terminal Building Design Categories

Airports have different terminal geometries with its geographical limitations and diverse configurations are initiated and are proven by the current terminals. Terminal building design concepts are grouped into four in accordance to its configuration and these are pier, satellite, linear and transporter.

Terminals design concepts are categorized into three and they are: Centralized, Decentralized and Semi-Centralized.

##### 2.1.6.4.1. Configuration concepts

**Pier:** Aircrafts are parked on either side and passenger access the aircraft gate through the axis of the pier (Figure 2.10a)

#### **Advantages of Pier**

1. It uses centralized resources, economies of scale (human, facilities, amenities)
2. It eases passenger's movement.
3. It is cheap to construct.
4. It has well organized land use.

#### **Disadvantages of Pier**

1. It has long walking distances
2. It reduces curbside congestion.
3. It has limited expansion capability.

4. It reduces circulation and maneuverability of aircraft.
5. The future compatibility design development of aircraft is limited.

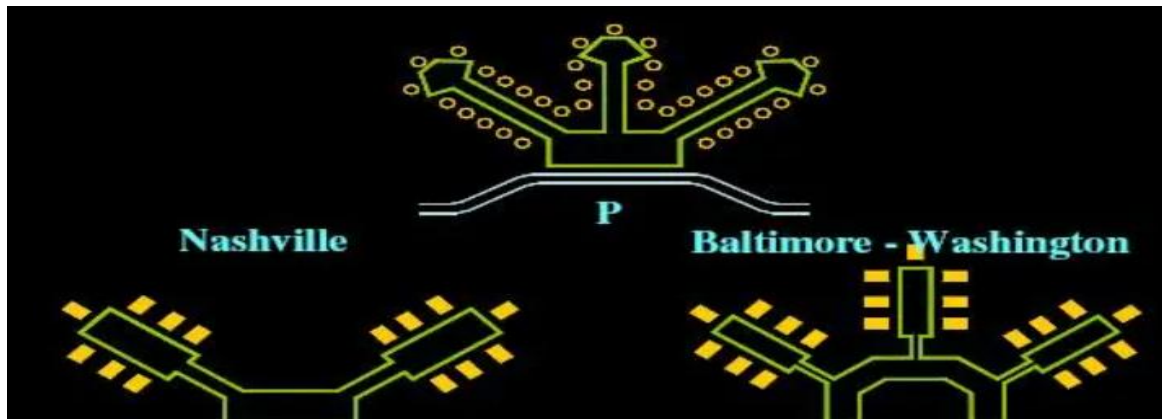


Figure 2.10a: Typical Pier terminal concept

Source: <https://kekanaan.wordpress.com/2013/09/16/airport-design-passenger-terminal-concepts/>

**Linear:** Aircrafts are parked singly on the terminal side of the concourse which extends from the terminal block and aircrafts are arranged on each side of the concourse like the pier concept (Figure 2.10b)

#### Advantages

1. It has short walking distances
2. It has clear orientation
3. It has simple construction and economical
4. It has adequate curb length
5. Its baggage systems cost low

#### Disadvantages

1. It duplicates terminal facilities or amenities
2. Its connecting time is long.
3. Its walking distance is long for passengers that are connecting.
4. The changing operation of terminal and apron has less flexibility.



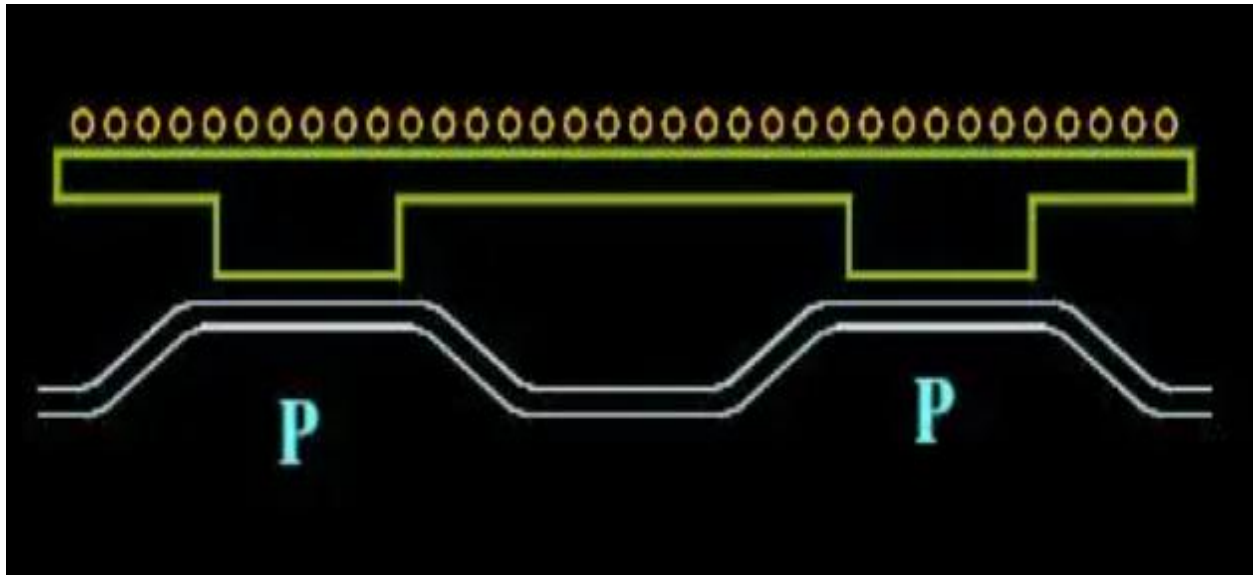


Figure 2.10b: Typical Linear concept

Source: <https://kekanaan.wordpress.com/2013/09/16/airport-design-passenger-terminal-concepts/>

**Transporter:** This type of concept park aircraft at remote parking position. In transporter concept, passengers make use of special means of conveying them to and from the aircraft. (Figure 2.10c)

#### Advantages

1. Terminal apron geometry compatibility and development of new aircraft design development easy.
2. It eases the maneuverability of aircraft.
3. The aircraft stands capability expansion is easy.
4. Its central terminal is small and simple.
5. It saves cost.

#### Disadvantages

1. It has high passenger delay instances.
2. It closed out time is early.
3. The maintenance, capital and operating cost is high.
4. There are industrial conflicts with operators of vehicle.
5. Curbside congestion

6. Increased minimum transfer times.

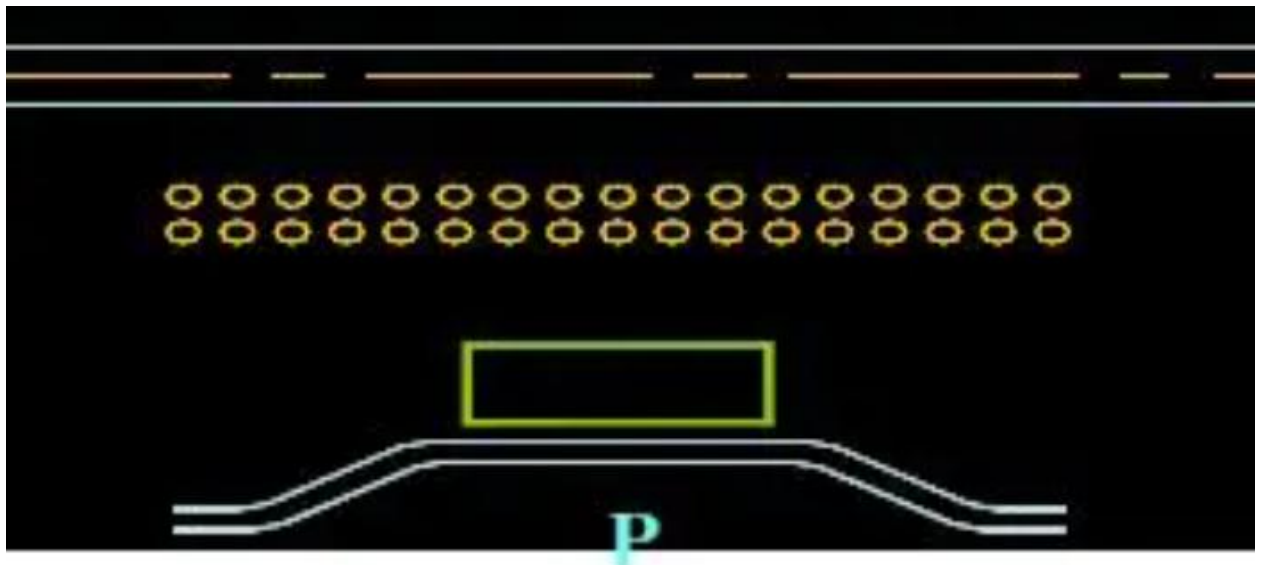


Figure 2.10c: Typical transporter concept

Source: <https://kekanaan.wordpress.com/2013/09/16/airport-design-passenger-terminal-concepts/>

**Satellite:** In this type of concept, airplanes are stationed around a structure that is separate from the terminal strip and are linked to the terminal strip through grade, above or sub-grade connections (Figure 2.10d)

#### **Advantages**

1. It has central resources.
2. It facilitates passengers' movement.
3. There is room for more designed satellites to receive newly developed aircraft design.

#### **Disadvantages**

1. Underground transportation and high technology are required.
2. High maintenance and operating costs
3. Congestion of curbside.
4. The connecting time increases.
5. The close out time is early.

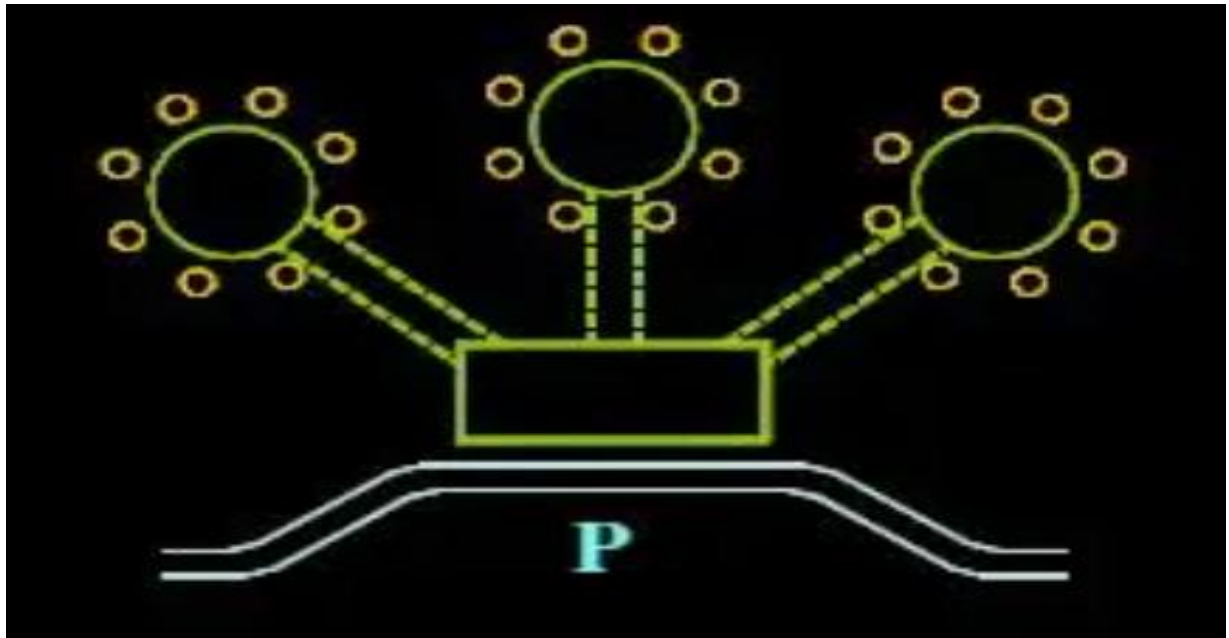


Figure 2.10d: Typical Satellite concept

Source: <https://kekanaan.wordpress.com/2013/09/16/airport-design-passenger-terminal-concepts/>

#### 2.1.6.4.2 Operational Concepts

**Centralized:** In this concept, passengers and luggage claim platform, check-in area, and other passenger processing zones are centrally situated in a building having access to boarding. This type of concept allow passenger to make maximum use of all the provided facilities within the terminal and provide good level of satisfaction.

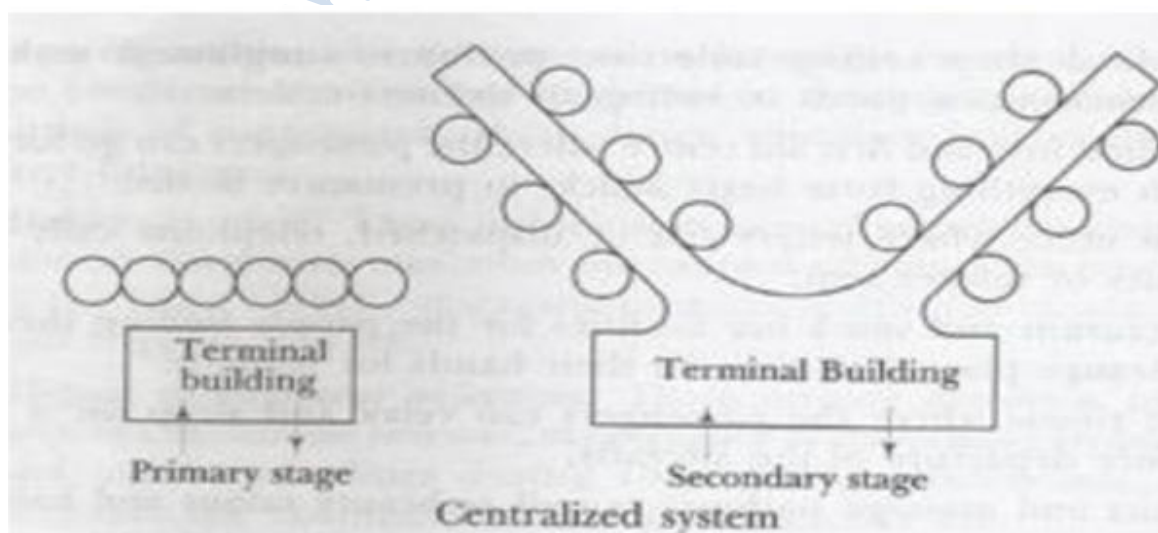


Figure 2.11a: Typical Centralized System

Source: <https://slideplayer.com/slide/11842327/>

**Decentralized:** This type of terminal operational concept in which its administrative and facilities are arranged in more than one building within a smaller modular part having access to the boarding gate and cost of operation is more. Decentralized terminal concept provides short arriving and departing walking distances each but not favorable to the connecting passengers.

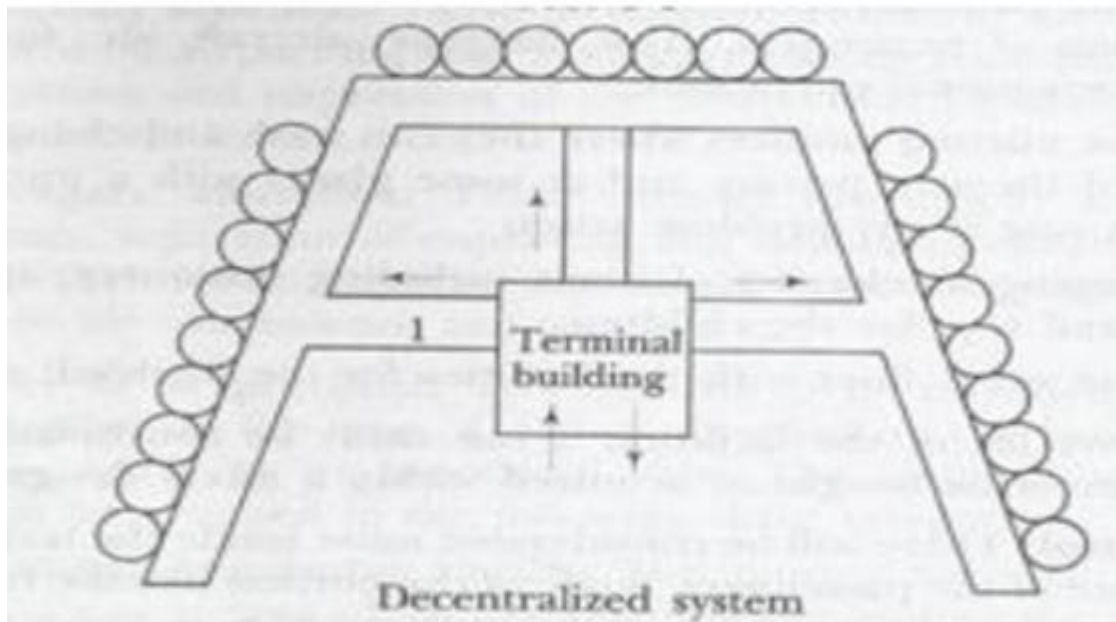


Figure 2.11b: Typical Decentralized System  
Source: <https://slideplayer.com/slide/11842327/>

**Semi-Centralized:** In this concept, different terminal processing facilities for passenger are divided to clusters of aircraft gates and consists of single or several terminal blocks depending on the degree of decentralization.

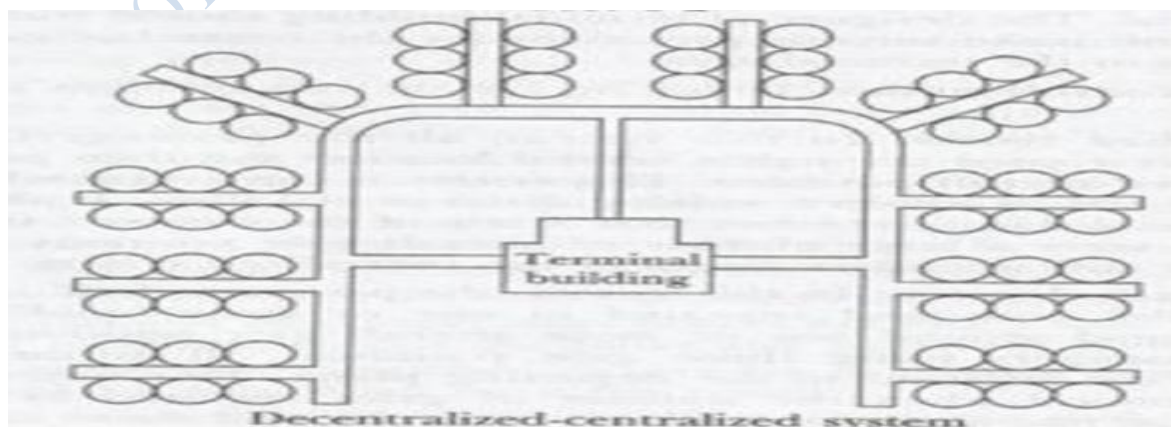


Figure 2.11c: Typical Semi-Centralized System  
Source: <https://slideplayer.com/slide/11842327/>

There is possibility of having hybrid of configurational concepts such as satellite and pier terminals while there are concepts that configurational concepts may not have other operational concepts (Table 2.2).

Table 2.2: shows the possible combinations of configurational and operational concepts.  
Source: <http://dl.lib.uom.lk/bitstream/handle/123/800/chapter%203.pdf?sequence=7&isAllowed=y>

| Configurational Concept | Operational Concept |                  |               |
|-------------------------|---------------------|------------------|---------------|
|                         | Centralized         | Semi-Centralized | Decentralized |
| Pier                    | Yes                 | Yes              | Nil           |
| Satellite               | Yes                 | Yes              | Nil           |
| Linear                  | Yes                 | Yes              | Yes           |
| Transporter             | Yes                 | Yes              | Nil           |

#### 2.1.6.5 Airport Circulation Design

The complexity of airport and features necessitate consideration for spaces but in advance it space must showcase the quality of airport services being offered thus the categorization of airport is a great help to achieve this goal. Different airports have different circulation designs and designers need to set up proper circulation routes which allow free flow of passengers and further create a relationship between the space and user. The circulation in the airport includes the following:

1. It has easy accessibility to airport by various public transportation.
2. It predicts appropriate location stops or suitable destination
3. There should be direct, avoiding and clear interference routes having long haul passengers, baggage claims and other vehicles.
4. It does not create different levels in walking sides

5. It improves the landscape with the addition of architectural works
6. Installation of appealing signs and thus help passengers to appreciate scenes.
7. There should be separation between the flow of domestic and international (IATA, 1995).

The architectural form of airport and its circulation is very crucial in creating a smooth flow and calm atmosphere for passengers which help them in preparing for their trip.

#### 2.1.6.6. Spatial Organization of Airport Terminal

Airport terminal spatial organization are in two different layers and they are program zones and circulation loops (Mehta, Y. (2020). Program zones can be defined as the areas with concentration of certain activities, whereas circulation loops may not have a physical area defined to all of the spaces but it stands for the sequence in which certain areas need to be connected with the other areas in the terminal building.

Loops is the flow sequence with different types of sequences need to be defined for effective functioning of any airport terminal building.

##### 2.1.6.6.1. Spatial Analysis of Activities

**Departing Lobby Activities** - security checkpoint, waiting, eating, drinking, boarding airplanes, and restrooms

**Arriving Lobby Activities** - greeting people, baggage claim, renting car, getting food and drinks, restrooms.

**Ticket Counter Activities** - waiting in line, paying for/picking up tickets, checking baggage. **Airline offices Activities** - record keeping, balancing receipts, scheduling flights and employees

**Baggage Processing Activities** - x-ray baggage, load/unload baggage to/from planes, sorting of baggage, tractor and cart storage

**Baggage Claim Activities** - loading bags onto carousel, waiting for baggage, sorting through bags for your own.

**Restaurant/Lounge Activities** - food/drink preparation, ordering, waiting, eating/drinking, clean-up of dishes, glasses and utensils.

**Airport offices Activities** - coordinating with airlines, overseeing maintenance of facility, public relations

**Security offices Activities** - watching closed circuit monitors, making reports, temporary holding for troublemakers

**Press room Activities** - operation of camera and sound equipment, movable seating, podium for speeches.

#### **2.1.7 Sustainable Architecture**

The term “sustainability” is originated from the Latin word *sustinere* (*tenere*, to hold; *sub*, under) which means to maintain, support, uphold, or endure (Borgaonkar, A. D., & Marhaba, T. F. 2021). According to Poodineh, 2017, sustainability was described as a means of preserving the originality of things for the future generations.

Tamur, S. T., & Erzaij, K. R. (2021) quoted the Environmental Protection Agency (EPA) the meaning of Green Architecture as the “practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building life-cycle from siting to design, construction, operation, maintenance, renovation, and deconstruction.

The commonest definition of sustainability globally is the fulfillment of future generation needs without compromising the ability of future generations to meet their needs while ensuring the balance between economic growth, environmental care and social well-being. Dimensions of sustainability comprise environmental, economic and social as shown in figure 2.12



1. Environmental sustainability

- It reduces effect on man's health
- It uses renewable raw materials
- It eliminates toxic substances

2. Social sustainability

- It boosts staff's health and safety
- It is of great advantage to physically challenged people
- It cheers people's quality of life and impacts on local communities.

3. Economic sustainability

- It creates new opportunities and markets for sales growth
- It creates additional added values
- Reduction in energy and raw materials inputs and cost reduction through efficiency improvements.



Figure 2.12: Dimensions of Sustainability

Source: <https://www.architecture-student.com/sustainable-design/three-dimensions-of-sustainable-environmental-architecture/>



Eco friendly, Green or Sustainable Architecture can be interchangeably used with the same concept by different authors (Rheude, F., Kondrasch, J., Röder, H., & Fröhling, M. 2021). In Architecture, Engineering and Construction (AEC) industry, authors have different perception of the word sustainability.

It is the architecture that is utilized in consciously reducing the negative environment effect on the built environment via the contemporary use of building materials, construction methods, energy conservation flexible use of space and the ecosystem and heavily reliance on natural resource like timber, metal, and stone (Lima L. et al., 2021).

Sustainability plan ensures that the use of obtainable resources have no harmful impacts on man's well-being and its environment. There are some key aspects of sustainable architecture and they are as follow:

1. Energy efficient lighting fixtures and appliances
2. Water conserving plumbing fixture
3. Rainwater harvesting
4. Efficient heating, cooling and ventilation systems
5. Windows placed strategically to maximize natural light
6. Landscaping with native vegetation
7. Grey-water reuse
8. Use of locally sourced materials to reduce transportation distance and its cost.
9. Incorporating old structures and using recycled materials.

Specialists in sustainable design constantly research for new innovations, initiatives and techniques to increase the quality of sustainability and not compromising its goals.

#### 2.1.7.1 Background History of Sustainable Architecture

Sustainable Architecture began at inception of man's history and his three basic needs such as shelter, food and clothing for survival are key to him; therefore, the relationship

between man, ecology and environment was established (Idiagi, E. 2021). Due to the nomadic nature of man in his earliest days made it impossible to have permanent homes, thereby, he lived in shelter built with available materials like stones, wood, leaves, animal hides and so on. Between 100,000 to 35,000 BC (Idiagi, E. 2021), man's resilience was proven when the Ice Age was very cold but man survived it; though, man moved to non-inhabited areas. This experience made man to develop lighter and more efficient tools and weapons necessary for shelter. Changes in climatic conditions increased the population of man with the developed measures to endure during the Ice Age. Habitation of animals and plants occupied wide areas around the globe like America, Africa and Europe and this also led to gentle increase of man's population.

Exposure of man to agricultural society changed the environment suitable for his settlement being affected by the changes in its ecological system (Hassell, J. M., Begon, M., Ward, M. J., & Fèvre, E. M. 2017). This modification of man's settlement necessitated required resources to meet his various needs from cooking of food and shelter to rest and warm up his body temperature. These requirements led to deforestation, soil erosion and other ecological challenges where he lived (Živković, J. 2020). Destruction of our ecological systems has resulted in environmental challenges and this has created environmental protection awareness in 18<sup>th</sup> century.

Industrial revolution began in the mid-eighteenth century increasing the technological advancements and radical departure from manual to machine and this resulted in new building materials like iron, steel, steam engine, coal, petroleum and electricity were initiated (Attaman, 2010). Exposure to new technologies increase exploitation of natural resources, stimulate huge population growth in the urban settlements.

After World War II, serious challenges of environmental movement arose and activities on how to shield mankind and nature from destruction. Increase in ecological challenges,

global pollution, increase in population growth, scientific discoveries, limited resources, and economic differences globally led to new agenda of environmental movement.

In 1987, World Commission on Environment and Development organized a summit which was centered on the definition of sustainability as the ability to meet the need of the present generation and not to compromise the need of the future generations and this led distinguishing Architecture as a direct solution. This summit birthed new building design approach to minimize negative environmental effects and thus increase the word Sustainable Architecture.

2.1.7.2 Benefits of Sustainable Architecture (Source: Zhang, L. et al., 2018). Turning green into gold: A review on the economics of green buildings. *Journal of cleaner production*, 172, 2234-2245.

There three different categories of benefits for implementing sustainable architecture and they are: Economic, Social and Environmental benefits.

#### **Economic Benefits**

1. Its advantages are competitive.
2. It has property values and increased assets.
3. There is development in the human performance productivity.
4. The life cycle cost decreases and continues to depend on traditional sources of energy.

#### **Social Benefits**

1. It enhances the health, comfort and living conditions of our population.
2. The air and water quality improves.
3. There is reduction on the demand of local utility infrastructure.

#### **Environmental Benefits**

1. Our natural resources are being are conserved and restored.

2. There is reduction in waste, water and energy consumption.
3. Ecosystems and environmental biodiversity is protected.
4. There is improvement of water and air quality.

#### 2.1.7.3 Principles and Strategies of Sustainability

Sustainable design strategies are essential in guiding architects, appropriate professionals and specialists to create buildings that are carbon free or minimally reduced and reduction in energy consumption, waste management in construction and maintenance (Idiagi, E. 2021). Comprehensive and integrated design approach is required to achieve its principles from the inception planning of each project phases.

In general, there is a consensus that the breadth of the principle of sustainable building mirrors those of sustainable development, which is about synergistic relationships between economic, social and environmental aspects of sustainability. Each of these three pillars and their related principles is over-arched by a set of process-orientated principles, including:

1. The undertaking of assessments prior to the commencement of proposed activities assists in the integration of information relating to social, economic, biophysical and technical aspects of the decision-making process
2. The timeous involvement of key stakeholders in the decision-making process (Purvis, B., Mao, Y., & Robinson, D., 2019).
3. The promotion of interdisciplinary and multi-stakeholder relations (between the public and private sectors, contractors, consultants, nongovernmental) should take place in a participatory, interactive and consensual manner
4. The recognition of the complexity of the sustainability concept in order to make sure that alternative courses of action are compared. This is so that the project objectives and the stakeholders are satisfied with the final action implemented

5. The use of a life cycle framework recognizes the need to consider all the principles of sustainable construction at each stage of a project's development (*i.e.*, from the planning to the decommissioning of projects)
6. The use of a system's approach acknowledges the interconnections between the economics and environment. A system's approach is also referred to as an integrated (design) process;
7. That care should be taken when faced with uncertainty
8. Compliance with relevant legislation and regulations
9. The establishment of a voluntary commitment to continual improvement of (sustainable) performance
10. The management of activities through the setting of targets, monitoring, evaluation, feedback and self-regulation of progress. This iterative process can be used to improve implementation in order to support a continuous learning process
11. The identification of synergies between the environment and development.

These principles will form a framework for achieving sustainable building that includes an environmental assessment during the planning and design stages of building projects, and the implementation of sustainable practices.

#### 2.1.7.4 Sustainability Building Rating Systems

It is a set of guided principles in ensuring that sustainable practices are ensured in how we plan, design, construct, operate and maintain sustainable communities for national development. Green building design and its rating systems have been developed globally and making efforts to reduce the pressure on energy, water resources and be environmentally responsible throughout the its life cycle.

The benefits of using a green rating system include:

1. Environmental aspiration can be set.

2. Clear goals can be worked towards.
3. Environmental performance can be verified.
4. Environmental performance can be demonstrated to the third parties.
5. Improvement can be measured and demonstrated.
6. Green education can be facilitated and encourage.
7. Positive marketing can be generated.

Table 2.3: Some commonly used sustainability building rating systems  
Source: [https://www.designingbuildings.co.uk/wiki/Green\\_rating\\_systems](https://www.designingbuildings.co.uk/wiki/Green_rating_systems)

| BUILDING RATING OR CERTIFICATION SYSTEM | TYPE OF STANDARD OR CERTIFICATION                                                                                                                                                                   | MANAGING ORGANISATION                                                      | ISSUES/AREAS OF FOCUS                                                                                                                                                                                                                                                                  |
|-----------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| BCA Green Mark Scheme (Singapore)       | Benchmarking scheme that aims to achieve a sustainable built environment by incorporating best practices in environmental design and construction, and the adoption of green building technologies. | Building and Construction Authority (BCA)                                  | <p>1 Rates buildings according to five key criteria:</p> <p>2 Energy efficiency.</p> <p>3 Water efficiency.</p> <p>4 Environmental protection.</p> <p>5 Indoor environmental quality.</p> <p>6 Other green and innovative features that contribute to better building performance.</p> |
| CASBEE (Japan)                          | <p>Building assessment tools for</p> <ol style="list-style-type: none"> <li>1. Pre-design.</li> <li>2. New construction.</li> <li>3. Existing building.</li> <li>4. Renovation.</li> </ol>          | JSBC (Japan Sustainable Building Consortium) and affiliated sub-committees | <p>Assessment areas include:</p> <ol style="list-style-type: none"> <li>1. Energy efficiency.</li> <li>2. Resource efficiency.</li> <li>3. Local environment.</li> <li>4. Indoor environment.</li> </ol>                                                                               |
| Energy Star (USA)                       | Government certification using a benchmarking method.                                                                                                                                               | U.S. EPA and U.S. DOE.                                                     | Building energy and water use.                                                                                                                                                                                                                                                         |

|                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                             |                                                                                                                                                                                                                                                                                                                                                                                                                             |
|------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Leadership in Energy and Environmental Design (LEED) (USA) | <p>Green building rating and certification system through independent third-party verification for:</p> <ul style="list-style-type: none"> <li>1 New Construction (NC).</li> <li>2 Existing Buildings, Operations &amp; Maintenance (EB O&amp;M).</li> <li>3 Commercial Interiors (CI).</li> <li>4 Core &amp; Shell (CS).</li> <li>5 Schools (SCH).</li> <li>6 Retail.</li> <li>7 Healthcare (HC).</li> <li>8 Homes.</li> <li>9 Neighborhood Development (ND).</li> </ul> | U.S. Green Building Council | <p>Performance in:<br/>Sustainable sites.</p> <ul style="list-style-type: none"> <li>1 Water efficiency.</li> <li>2 Energy &amp; atmosphere.</li> <li>3 Materials &amp; resources.</li> <li>4 Indoor environmental quality.</li> <li>5 Locations &amp; linkages.</li> <li>6 Awareness &amp; education.</li> <li>7 Innovation in design.</li> <li>8 Regional priority through a set of prerequisites and credits.</li> </ul> |
| CEEQUAL                                                    | Delivering improved specification, design and construction of civil engineering works, providing an evidence-based sustainability assessment, rating and awards scheme.                                                                                                                                                                                                                                                                                                   | BRE Global                  | <p>Stages:</p> <ul style="list-style-type: none"> <li>1 Project/Contract Strategy.</li> <li>2 Project/Contract Management.</li> <li>3 People &amp; Communities.</li> <li>4 Land Use &amp; Landscape.</li> <li>5 The Historic Environment.</li> <li>6 Ecology &amp; Biodiversity.</li> <li>7 Water Environment.</li> <li>8 Physical Resources Use &amp; Management.</li> <li>9 Transport.</li> </ul>                         |



|                                 |                                                                                                                                                                                                                                                                                                                                            |                                                                   |                                                                                                                                                                               |
|---------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Ska Rating                      | Environmental assessment method, benchmark and standard for non-domestic fit-outs.                                                                                                                                                                                                                                                         | Royal Institute of Chartered Surveyors (RICS)                     | <p>The Ska assessment process is broken into three stages:</p> <ol style="list-style-type: none"> <li>1 Design / planning</li> <li>2 Handover</li> <li>3 Occupancy</li> </ol> |
| WELL Building Standard (USA)    | <p>Performance-based standard and certification programme for new and existing buildings.</p> <ol style="list-style-type: none"> <li>1 New and existing interiors.</li> <li>2 Core and shell retail.</li> <li>3 Education facilities.</li> <li>4 Restaurant</li> <li>5 Commercial kitchen.</li> <li>6 Multi-family residential.</li> </ol> | Administered by the International WELL Building Institute™ (IWBI) | Measures attributes of buildings that impact occupant health by looking at seven factors: air, water, nourishment, light, fitness, comfort, mind.                             |
| Living Building Challenge (USA) | <p>Performance-based standard, and certification programme for:</p> <ol style="list-style-type: none"> <li>1 Landscape and infrastructure projects.</li> <li>2 Partial renovations and complete building renewals.</li> <li>3 New building construction.</li> <li>4 Neighborhood, campus and community design.</li> </ol>                  | International Living Future Institute                             | <p>Performance areas include:</p> <ol style="list-style-type: none"> <li>1 Site.</li> <li>2 Water.</li> <li>3 Energy.</li> <li>4 Materials.</li> <li>5 Equity.</li> </ol>     |



|             |                                                                                                                                                                                                                                                                                                         |                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Passivhaus  | An energy performance standard for dwellings, commercial, industrial and public buildings.                                                                                                                                                                                                              | Passivhaus-Institut | <p>The Passivhaus standard can be achieved by measures including:</p> <ol style="list-style-type: none"> <li>1 Shading.</li> <li>2 Pre-cooling of the supply air.</li> <li>3 Night purging.</li> <li>4 Natural ventilation.</li> <li>5 Airt-tightness.</li> <li>6 Mechanical ventilation heat recovery (MVHR).</li> <li>7 Insulation.</li> <li>8 Avoidance of thermal bridges.</li> <li>9 Passive solar gains.</li> <li>10 Exploitation of internal heat sources.</li> </ol> |
| BREEAM (UK) | <p>Certification system is a multi-tiered process with pre-assessment, third-party consultant guidance through an assessment organisation for:</p> <ol style="list-style-type: none"> <li>1. New construction.</li> <li>2. Communities.</li> <li>3. In-use buildings.</li> <li>4. Eco-homes.</li> </ol> | BRE Global          | <p>Assessment uses recognised measures of performance, which are set against established benchmarks in:</p> <ol style="list-style-type: none"> <li>1. Energy and water use.</li> <li>2. Internal environment (health and well-being).</li> <li>3. Pollution.</li> <li>4. Transport.</li> <li>5. Materials.</li> <li>6. Waste.</li> <li>7. Ecology.</li> <li>8. Management processes.</li> </ol>                                                                              |

## **2.2 Conceptual Framework/model**

### **2.2.1 Airport Sustainability**

A sustainable project is designed, built, renovated, operated or reused in an ecological and resource efficient manner to meet a number of certain purposes: resource and energy efficiency; CO<sub>2</sub> and GHG emissions reduction; pollution prevention; mitigation of noise; improved indoor air quality; harmonization with the environment (Keke, O. V., & Oladejo, E. I., 2017). Airport Sustainability involves responsive actions taken in minimizing the negative environmental effects of airport operation, maintaining the economic growth and providing social growth consistently to meet the need of man's immediate environment (John C.S., 2019). Airport sustainability practice covers a wide range of actions which include the design, management and operation of airports considering the ecosystem of the locality. Combination of this practice protects our environment such as natural resources conservation, social integration and maintenance of high levels of stable economic and employment growth of the airport and stakeholder's input (Maynard et al, 2015).

The aims of sustainability in environmental design as follow (Mehrab A., Mehdi S., 2018):

1. It increases the comfort of man
2. It is a mean of designing for change
3. It minimizes the wastage of spaces
4. It reduces buildings maintenance expenses.

### **2.2.2 Framework of Strategies and Methods: Sustainable Implementation**

To achieve sustainable future in the building sector, Oke, A., Aghimien, D., Aigbavboa, C., & Musenga, C. (2019) suggested adoption of multi-disciplinary approach covering a number of features like energy saving, improved use of materials, materials waste

minimization, pollution and emissions control, etc. Figure 2.13 shows three goals which form the implementation of sustainable building design and construction while considering the principles of sustainability challenges in terms of environmental, social and economic as identified before and these goals are as follow:

1. Resource conservation
2. Cost efficiency and
3. Design for Human adaptation



Figure 2.13a: Conceptual Framework for Implementing sustainability  
Source: <https://www.mdpi.com/2075-5309/2/2/126/htm#B38-buildings-02-00126>

#### 2.2.2.1 Resource Conservation

Resource conservation refers to achieving more with less and also the management of human use of natural resources to provide the maximum benefit to current generations while maintaining capacity to meet the needs of future generations (Akadiri, P. O., Chinyio, E. A., & Olomolaiye, P. O. (2012).

Different researchers have diverse opinions on the framework in figure 2.13a, Halliday observed that certain resources are becoming extremely rare and the use of remaining stocks should be treated cautiously while Bold viewed the necessity for radical increase in the use of materials and energy resources having achieved policy recognition (Haliday, S., 2008; Graham, P., 2003). He argued that the improvement on productivity is needed to

reduce the effects on the capacity of natural systems to understand waste materials and energy (Halliday, S., 2008). According to Durdyev, S., Zavadskas, E. K., Thurnell, D., Banaitis, A., & Ihtiyar, A. (2018), the building industry is a major consumer of natural resources, and therefore many of the initiatives pursued in order to create ecology sustaining buildings are focusing on increasing the efficiency of resource use. He stated that the ways in which these efficiencies are sought are varied. He cited examples ranging from the principles of solar passive design which aim to reduce the consumption of non-renewable resources, the consumption of energy production, life cycle design and design for construction. Methods for minimizing material wastage during building construction process and providing opportunities for recycling and reuse of building material also contribute to improving resource consumption efficiency. Resource conservation yields specific design strategies and methods, as defined in figure 2.13b.

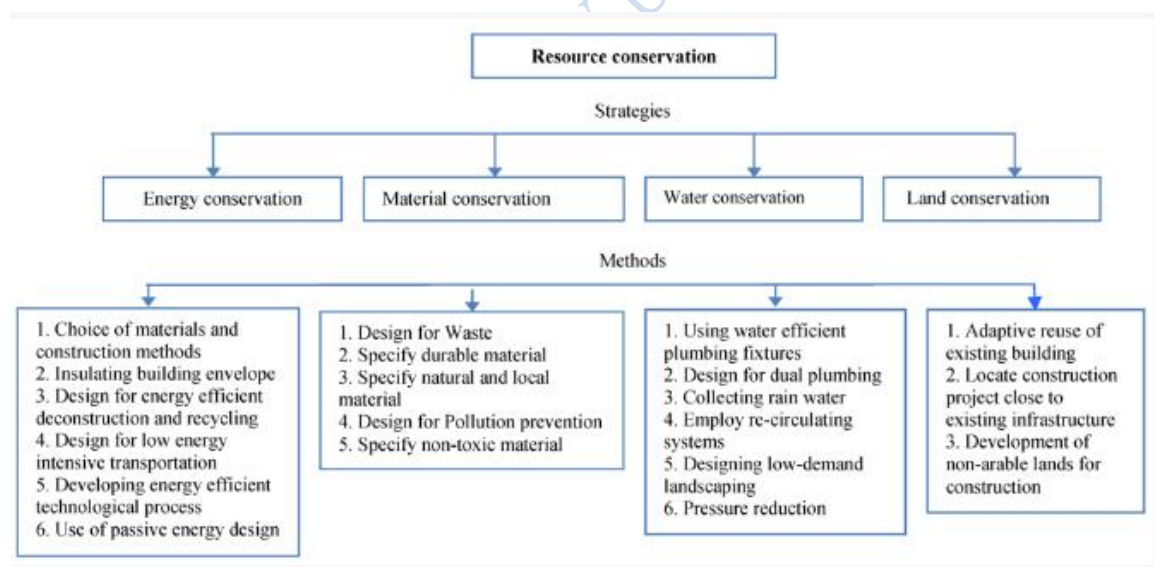


Figure 2.13b: Strategies and Methods to achieve resource conservation

Source: <https://www.mdpi.com/2075-5309/2/2/126/htm#B1-buildings-02-00126>

### 2.2.2.2 Energy Conservation

Energy use is one of the most important environmental issues and managing its use is inevitable in any functional society. Buildings are the dominant energy consumers and other resources at each stage of building project from design and construction through

operation and final demolition (Edwards, R. E., Lou, E., Bataw, A., Kamaruzzaman, S. N., & Johnson, C. 2019) shown in figure 2.13c. Also, Lenzen and Treloar (2002), the type and quality of energy use during the life cycle of any building from production process to its end life affect the flow of GHG to atmosphere in many ways having negative effects on the environment.

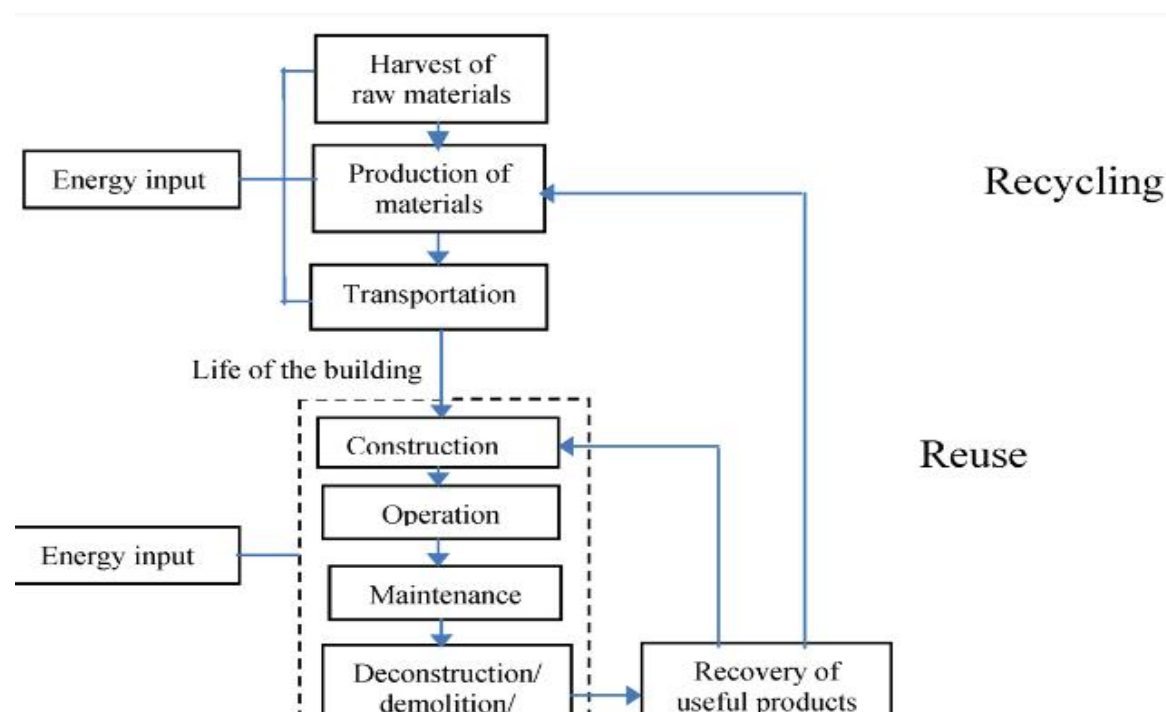


Figure 2.13c: Stages of energy input during the life of a building

Source: [https:// www.mdpi.com/2075-5309/2/2/126/htm#B1-buildings-02-00126](https://www.mdpi.com/2075-5309/2/2/126/htm#B1-buildings-02-00126)

Therefore, the main goal in energy conservation is to reduce the consumption of fossil fuels, as well as increasing the use of renewable energy sources. This could be achieved by the consideration of the following methods.

1. Choices of materials and construction methods.
2. Insulating the building envelope
3. Designing for energy efficient deconstruction and recycling of materials
4. Designing for low energy intensive transportation
5. Developing energy efficient technological processes
6. Use of passive energy design

### 2.2.2.3 Materials Conservation

Extraction and consumption of natural resources as building materials or as raw materials for production of building materials and building materials production itself in implementing construction works has a direct impact on natural bio-diversity due to the fragmentation of natural areas and ecosystems caused by construction activities (Akadiri, P., Chinyio, E., & Olomolaiye, P., 2012). Built environment consumes global energy of about 40% and human activities of GHG emissions consumes about 30% (Bonoli, A., Zanni, S., & Serrano-Bernardo, F. 2021) and this should be integrated in project design considerations right from each stage of the design phases. Methods to be considered in selecting materials efficiency in construction are as follow:

1. To design for Waste Minimization by recycling, reusing and reducing construction waste also proper disposal and storage of construction waste
2. To prevent pollution from the design processes
3. To identify materials that is durable.
4. Local and natural materials should be stated.
5. Specification of non-toxic or less toxic material should be clearly noted.

### 2.2.2.4. Land Conservation

Land is an important resource upon which the construction industry depends. Land use through urban expansion has been identified as a growing problem in both developed and developing worlds. Although more land may be reclaimed from the ocean, land reclamation on a large scale is undesirable since it could severely interfere with ecosystems. Soil erosion, groundwater contamination, acid rain and other industrial pollutants are damaging the health of plant communities, thereby intensifying the challenge and necessity to restore habitats. Sustainable design must develop a respect for

the landscape and expend more effort understanding the interrelationships of soils, water, plant communities and associations, and habitats, as well as the impacts of human uses on them. Land can be conserved by adopting a policy of zero expansion of existing urban areas which could be achieved by adaptive reuse of an existing building, thereby eliminating the need for new construction and placing sustainable building project within easy access of public transportation, medical facilities, shopping areas and recreational facilities, to prevent the expansion of built environment and occupation of agricultural and eco-sensitive areas.

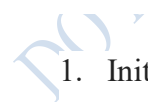
### **Water Conservation**

With the fast development of the global economy, depletion of water resources is becoming an environmental issue of the utmost concern worldwide. The United Nations World Water Development Report (WWDR) indicates that water for all our uses is becoming scarce and is leading to a water crisis (Odhiambo, G. 2017). The effects a sector can have on the environment are nowhere more apparent than in the building industry. Building construction and its operations draw heavily on water from the environment. Growth in urban water use has caused a significant reduction of water tables and necessitating large projects that siphon supplies away from agriculture. Water used to operate buildings is a significant component of national water consumption. However, this is not the only form of water consumed throughout a building's life cycle. Water is also consumed in the extraction, production, manufacturing, and delivery of materials and products to site, and the actual on-site construction process (Liu, S., Wang, Z., Han, M., & Zhang, J. 2021). There are several numbers of strategies that can be employed to reduce the amount of water consumed through the life cycle of a building and these methods are:

1. Utilizing water-efficient plumbing fixtures such as ultra-low flow toilets and urinals, waterless urinals, low-flow and sensed sinks, etc.
2. Design for dual plumbing to use recycled water for toilet flushing or a gray water system that recovers rainwater or other non-potable water for site irrigation.
3. Collecting rainwater using rainwater and grey water storage for irrigation greatly reduces the consumption of treated water.
4. Employ re-circulating systems for centralized hot water distribution, which conserve water which is typically wasted by users while waiting for warm water to flow from a warm water faucet.
5. Designing low-demand landscaping using plants native to the local ecosystem
6. Pressure Reduction.

### *Cost Efficiency*

Construction clients are demanding assurance of their buildings' long-term economic performance and costs. In addition, the construction project supply chain of developers, suppliers, manufacturers, design and construction teams are under increasing pressure from clients to minimize total project cost and consider how much a building will cost over its life cycle and how successfully it will continue to meet user's requirements. There are three principal life cycles cost to be considered at inception of a construction project are:



#### 1. Initial cost

- The design should optimize the use of locally-available materials.
- Use of cost saving construction technology
- Identify opportunities to minimize initial construction costs, through use of modular designs and standardized components



- Use common, readily available components, where appropriate, to minimize replacement costs and stocking of custom components.
- Using recycled and reclaimed materials.

## 2. Cost in Use

- Taking adequate measures within the design of key building elements
- Ensuring that the skills required are within the competence of available labor supply.
- Choosing minimum-maintenance materials.
- Adopting an appropriate process during the design stage to protect materials from destructive elements
- fully meeting the operational requirements

## 3. Recovery Cost

- Recycling potential and ease of demolition
- The adaptive reuse of an existing project
- Reusing building materials or components

### *Design for Human Adaptation*

One of the main purposes of a sustainable building is to provide healthy and comfortable environments for human activities (Ding, Z., et al., (2018)). A building must accommodate the activities it is built for and provide floor-space, room volume, shelter, light and amenities for working, living, learning, curing, processing *etc.* Furthermore, the building must supply a healthy and comfortable indoor climate to the people using it. In meeting these basic requirements, the building should not cause harm to its occupants or the environment and must, for example, be structurally stable and fire safe. Sustainable development requires that the building does not cause unnecessary load or risk to the

environment, for example in the form of energy use. To promote and enhance human adaptation the following two design methods should be considered

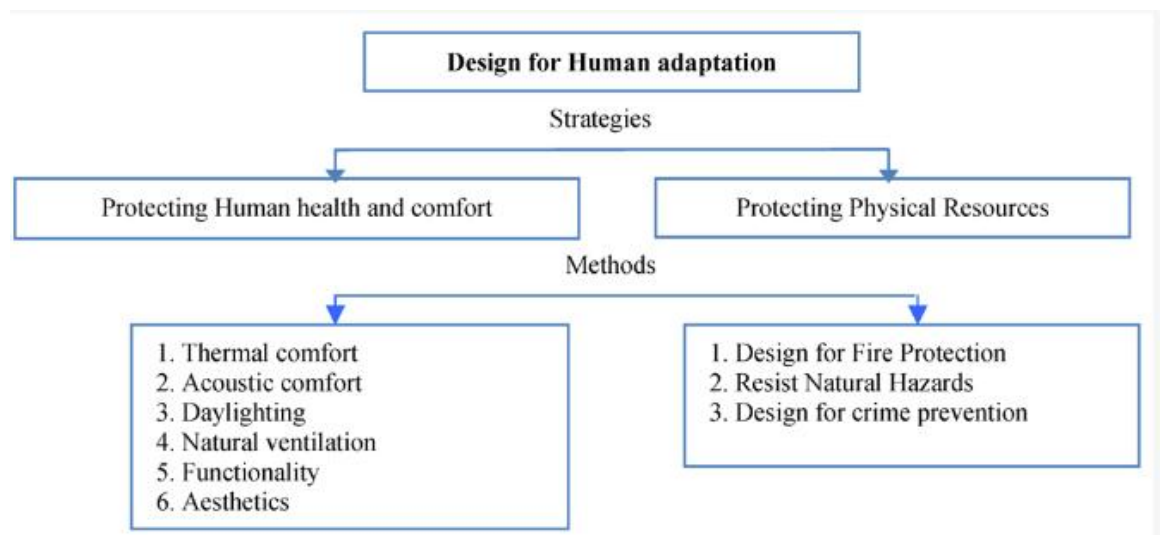


Figure 2.14: Strategies and methods to achieve human adaptation

Source: <https://www.mdpi.com/2075-5309/2/2/126/htm#B1-buildings-02-00126>

The following are considered to achieve design for human adaptation:

### 1. Protecting Health and Comfort

- Thermal comfort
- The acoustical environment of a workspace
- Day lighting
- Natural ventilation
- Building functionality
- Building aesthetics

### 2. Protecting Physical Resources

- Plan for Fire Protection.
- Resist Natural Hazards
- Crime prevention through architectural Design

## 2.3 Empirical Review

### 2.3.1 Sources of Carbon Emission

According to Law-Insider dictionary (2022), Carbon Emissions is defined as CO<sub>2</sub> emitted through the burning of fossil fuels in vehicles, buildings, industrial processes and many others. Over a period of time, carbon emissions mean sum amount of carbon equivalent GHG emissions related to energy consumption in that time is expressed in metric tons of equal carbon dioxide.

Research has shown that carbon is in the air man breathe, the food, the product and man is made up of carbon (EarthHero, 2017). Sources of carbon emissions are both natural and human sources. Human sources emerge from different activities such as deforestation, production of cement and burning of fossil fuel like natural gas, oil, and coal while natural sources are decomposition, respiration and ocean release. The carbon generated from fossil fuels is essentially different in its relative sum of heavier and lighter carbon atom than carbon from other sources. The smaller the ratio of carbon atom which is from heavier to lighter, the higher the proportion of carbon from fossil fuels will be.

**2.3.1.1 Sources of emissions by gas** are CO<sub>2</sub>, Methane (CH<sub>4</sub>), Nitrous Oxide (N<sub>2</sub>O), Industrial gases, Water Vapor, and Ozone while sources by economic sector are Electricity and heat production, Industry, Agriculture, forestry and other land use, Transportation, buildings and other energy.

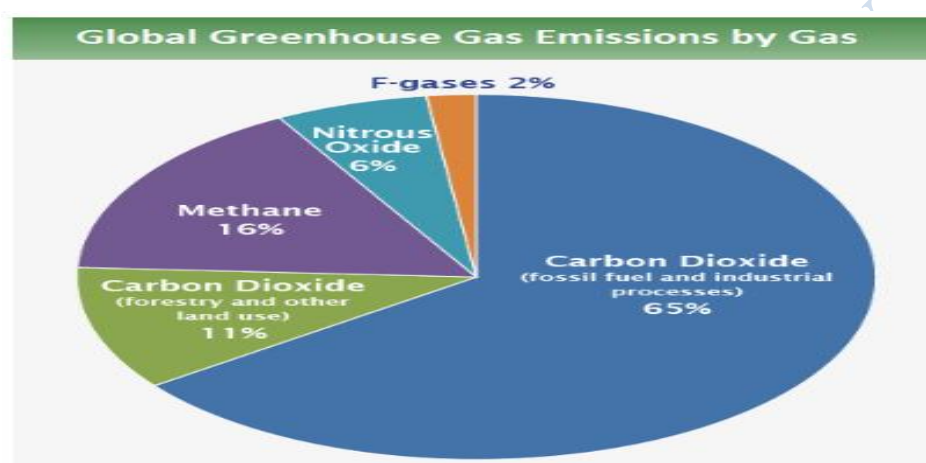
**CO<sub>2</sub>:** The use of fossil fuel is the elementary cause of carbon emissions. Human activities induced impact on land clearing for agriculture; jet gasoline from aircraft, power plants, degradation of soils, deforestation, forestry and other land use emit carbon. Though, land removes via reforestation, soils improvement and other activities.

**CH<sub>4</sub>:** Methane is a major component of natural gas which is discharged from landfills, petroleum industries agriculture activities waste management and natural gas.

**N<sub>2</sub>O:** This takes small quantity of global GHG emissions about 6 percentage and has lifetime in the atmosphere more than a century, according to IPCC. Examples of Nitrous Oxide are Agriculture and livestock, including manure, fertilizer, burning of fuel and agricultural residue.

**Industrial gases:** This consists of fluorinated gases like chlorofluorocarbons, Sulfur hexa Fluoride (SF<sub>6</sub>), perfluorocarbons, and Nitrogen trifluoride (NF<sub>3</sub>) with heat trapping potential thousands of times greater than CO<sub>2</sub>.

**Contrails:** Jet fuel consumption



**Figure 2.14a: GHG emission by gas**

Source: IPCC (2014) based on global emissions from 2010

### 2.3.1.2 Sources of carbon emission by Economic Sector

Generally, GHG emissions can be as a result of economic activities yielding from their production output (IPCC, 2014) such as Electricity and heat production, Industry, Transportation, Buildings, other energy and Agriculture, Forestry and other Land Use.

**Electricity and Heat Production:** Generally, about 25% of 2010 GHG emissions via burning of coal, natural gas, oil for electricity and heat in the IPCC 2014 pie chart shown in figure 2.14b. In the pie chart, it has the largest percentage among other sources of GHG emission.

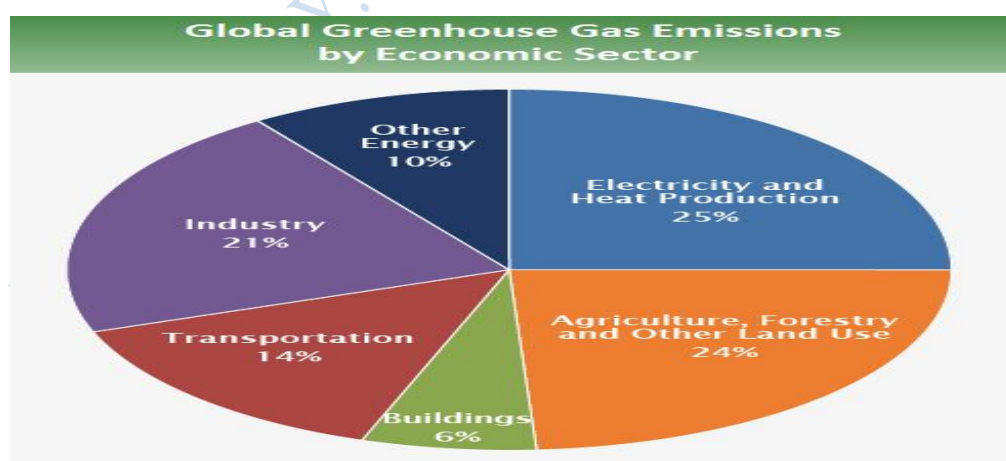
**Industry:** This contributes 21% of 2010 global emission of GHG as revealed in figure 2.14b below. This emission generated includes fossil fuels, aircrafts, metallurgical, chemical and mineral transformation processes, waste management activities.

**Agriculture, Forestry and other Land Use:** This takes 24% of 2010 in the IPCC (2014) pie chart for GHG emission by economic sector. The source of this emission is commonly from agriculture and this does not consist of CO<sub>2</sub> that ecosystems remove from the atmosphere.

**Transportation:** This type of emission includes fossil fuel used for air, road and marine transportation and this is about 14% of 2010 in the IPCC (2014) pie chart below (figure 2.14b).

**Buildings:** This is up to 6% of 2010 global GHG emissions in the pie chart shown in figure 2.3.2 below. GHG emissions from this industry arises from onsite energy generation and burning fuels for heat in building or cooking on homes.

**Other energy:** 10% of 2010 global GHG emissions is contributed and the source refers to all emissions from energy sector which are not directly associated with electricity or heat production such as fuel extraction, refining, processing and transportation.



**Figure 2.14b: Global Carbon Emission by Economic Sector**

Source: [https://www.epa.gov/sites/default/files/201605/global\\_emissions\\_sector2015.png](https://www.epa.gov/sites/default/files/201605/global_emissions_sector2015.png)

### **2.3.1.3 Global Emissions by Country**

In 2014, the top carbon dioxide (CO<sub>2</sub>) emitters were China, the United States, the European Union, India, the Russian Federation, and Japan. These data include CO<sub>2</sub> emissions from fossil fuel combustion, as well as cement manufacturing and gas flaring and the sum of these sources represent a large proportion of total global CO<sub>2</sub> emissions.

Emissions and sinks related to changes in land use are not included in these estimates. However, changes in land use can be important: estimates indicate that net global greenhouse gas emissions from agriculture, forestry, and other land use were over 8 billion metric tons of CO<sub>2</sub> equivalent, (FAQ, 2014) or about 24% of total global greenhouse gas emissions.(IPCC, 2014) In areas such as the United States and Europe, changes in land use associated with human activities have the net effect of absorbing CO<sub>2</sub>, partially offsetting the emissions from deforestation in other regions.

### **2.3.1.4 Sources of Carbon Emissions in Airport Facilities**

The transportation sector is the third largest emitter of GHGs among the global economy's sources and activities. Air transport is the only source that emits directly into the higher levels of the atmosphere, causing greater climate damage. According to Giuffrè, O., et al., (2019), there are three “scope” categories of emissions sources: GHG emissions from sources owned or controlled by the airport operator (scope 1); GHG emissions from off-site generation of electricity purchased by the airport operator (scope 2); and GHG emissions from airport-related activities from sources not owned or controlled by the airport operator (scope 3).

Scope 1: This is on-site emissions from the combustion of fossil fuels, such as natural gas, oil, LPG, and company-owned vehicles. The emissions here are the result of activities that the company can directly influence through its actions.

Scope 2: These are emissions obtained from the use of imported electricity from the grid or the third-party supplier of energy in form of electricity or heat. The airport can influence the amount of electricity it uses; however, it has little control over the generation of the electricity and these emissions are therefore classed as Scope 2.

Scope 3: These are emissions resulting directly from the use of the company's goods and (or) services. These sources could be the airport's operation, aircraft movements, and passenger and staff at the airport, airside activities, waste disposal, and water. The airport has some influence over Scope 3 emissions, but it has no control over the activities.

### **2.3.2 Carbon Footprint**

The phrase "carbon footprint" and its related ideas are now frequently used in discussions about personal accountability and the need for preventative measures against the threat of climate change (Marlon, J. R., 2019; Carbon T., 2008). The total amount of gaseous emissions caused directly and indirectly by an individual, organization, event, or product is referred to as a carbon footprint (Rivera-Méndez, Y. D., et al., 2017). For example, flying from London to New York has a carbon footprint of 0.68 tons of CO<sub>2</sub>e while the UK's carbon footprint in 2006 was 653 million tons of CO<sub>2</sub>e. The carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions caused by an activity or accumulated over the lifecycle of a product, companies, industry sectors, and many more are inclusive and products are both goods and services (Wicker, P. (2018).

### **2.3.3. Environmental Effects of Carbon Emissions on our Environment through airport facilities**

The major causes of emissions in airports are by means of electricity generation facilities, vehicles, ground support equipment, functioning in landside and airside of the airport (Dimitriou, D., & Karagkouni, A. (2022). Airport being one of the main contributors to air

pollution in a community and air travel growth has extensive consequences of climate change globally resulting in global warming (Ajibade, F. O., et al, (2021). The impact of global warming on the environment having negative effect on water and food supplies, weather pattern, and sea levels.

Carbon monoxide, particulate matter, nitrogen oxides, hydrocarbon and many others contaminate the air quality (Dimitriou et al., 2014; Postorino and Mantecchini, 2014). Exposure to human has negative effects such as respiratory disease, blood disorder, asthma and many others. 2 – 3% of anthropogenic CO<sub>2</sub> emissions are accounted from aviation and its increasing yearly because the industry's growth is outpacing the rate of airframe and the engine development (Cokorilo, 2016). Several factors influence local air quality in the vicinity of airport. Generally, the main purpose of local air quality and emissions management is to achieve and maintain compliance with the local pollutant concentration restrictions (Grewe et al., 2021; Dimitriou et al., 2019)

Figure 2.15 represent the rising global temperature's effect on CO<sub>2</sub> emissions. The emissions of CO<sub>2</sub> change the seasons of harvesting and water supplies. For example, climate change threatens marine and coastal areas by sea levels rise, and thus increases demand for food crops. CO<sub>2</sub> also causes acid rain, which harms trees and the built environment. These effects and consequences of CO<sub>2</sub> emissions are already visible. They go far beyond the effects of rising global temperatures on ecological systems and communities around the world.



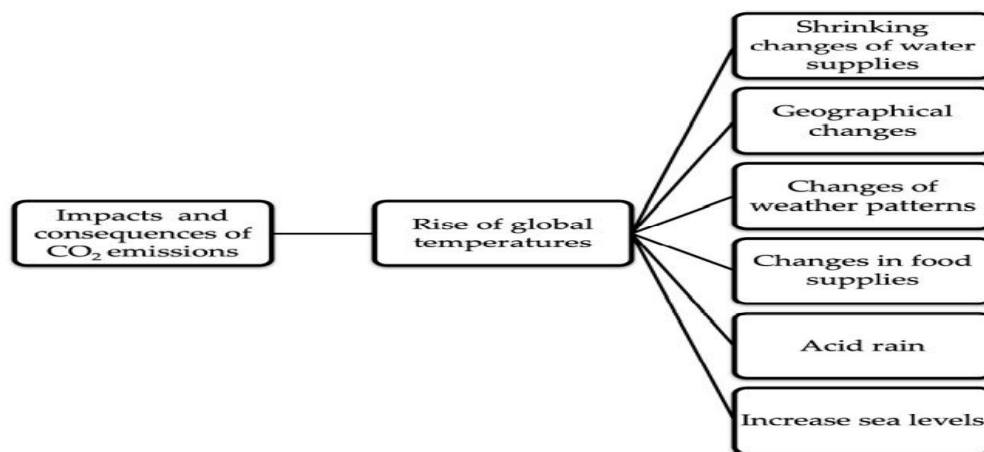


Figure 2.15: Impacts and consequences of CO<sub>2</sub> emissions on the environment  
Source: Sustainability (2020)

#### 2.3.4. Physiological Effects of Carbon Emissions on Airport staff, passengers and visitors

In recent ages, all industrial sectors have shown an interest in calculating the effect of carbon emissions on the environment; the transportation industry is a significant polluter. Average oil consumption daily by global aviation is estimated to be more than 5 million barrels (7.95 108 L). The deadly aircraft emissions are great of concern because they are related to exposing man to pollutants which have negative effect on his health (Sher et al, (2021).

The most single critical issue influencing the operation and expansion of airports and consequently their capacity frequently is aircraft noise nuisance at the local level (Dimitriou and Voskaki, 2010; Asensio et al., 2010). Noise pollution has a significant impact on residents and airport personnel (Sreenath et al, (2021). Furthermore, aircraft noise has been linked to an increased risk of health problems such as hypertension. Aviation emissions are responsible for 5% of the world's human-induced radiative forcing, and poor air quality is responsible for approximately 16,000 premature deaths each year. Particulate matter (PM) emitted by aircraft has been linked to a variety of health problems, including cardiovascular disease, respiratory disease, and lung cancer. Many studies have

found that PM, along with other pollutants emitted by aircraft, has harmed global air quality and harmed the health of communities near airports (Sher et al, 2021).

### 2.3.5 Measures of Reducing Carbon Emissions Adopted in Airports

More than two decades, policymakers and governments have been admonished to take action to lessen CO<sub>2</sub> emissions in various sectors (Langevin, J.; Harris, C.B.; Reyna, J.L. 2019). This part explains various strategies to minimize CO<sub>2</sub> emissions in response to the global warming challenge in the building industry (Figure 2.14 below).

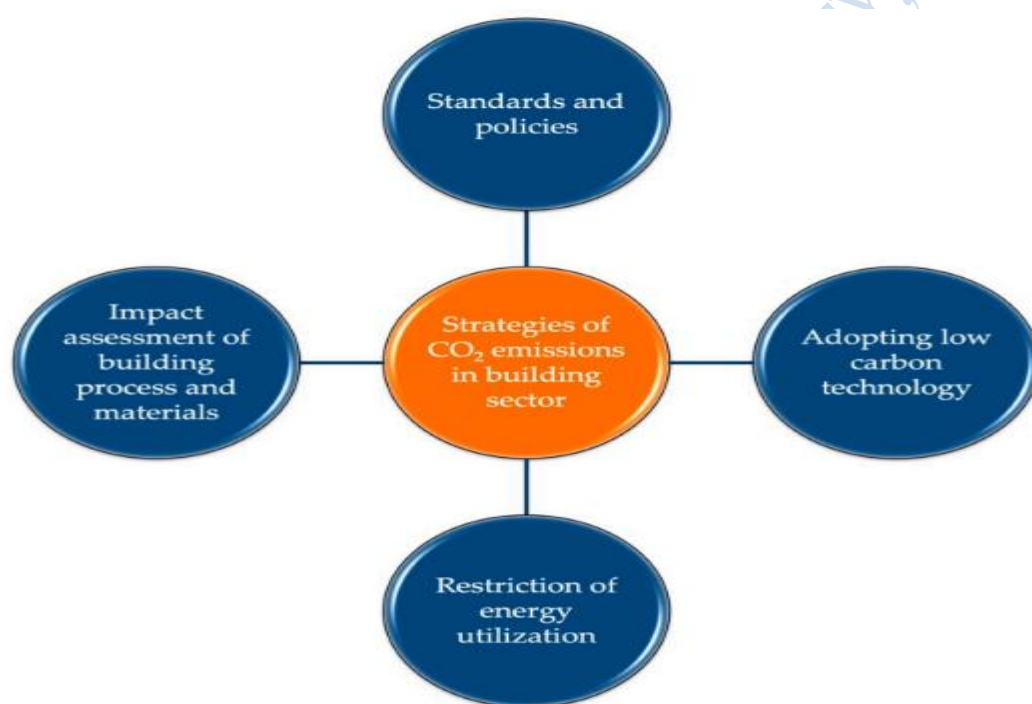


Figure 2.16: Strategies in reducing CO<sub>2</sub> emissions in the building sector  
Source: <https://www.mdpi.com/2071-1050/12/18/7427/pdf>

#### 2.3.5.1 Standards and Policy

Many sustainable building standards, codes, policies, and guidelines packages have been introduced in many countries across the world, which aim to improve building energy performance and reduce CO<sub>2</sub> emissions. A total of 184 countries participated in the Nationally Determined Contribution (NDC) where governments have taken initiatives in

the decarbonization of the building sector through the establishment of policies and standards. Table 2.3 summarizes current standards and policies committed by selected countries under this strategy that incorporate the reduction of CO<sub>2</sub> emissions in their goals and objectives which was set in 2015 under the Paris Agreement commitment and the United Nations Sustainable Development Goals.

**Table 2.3:** Existing standards associated with the reduction of CO<sub>2</sub> emissions in buildings

Source: <https://www.mdpi.com/2071-1050/12/18/7427/pdf>

| Country        | Standards or Policies                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| China          | The Energy Consumption of Buildings standard was introduced by the Ministry of Housing and Urban-Rural Development in 2016. This standard covers indicator of energy use for various building types. It aims is to limit the amount of building sector energy consumption of the country and simultaneously limit the total CO <sub>2</sub> emissions.                                                                                                                                                                                                                                                                                                                                                                    |
| Australia      | The Australian Federal Government launched the National Carbon Offset Standard for Buildings in 2017. It was established in collaboration with the Green Building Council Australia. The main objective of the standard is to provide to measure, reduce, offset, report, and audit CO <sub>2</sub> emissions from building operations.                                                                                                                                                                                                                                                                                                                                                                                   |
| India          | A policy was introduced in 2016 as part of the Energy Conservation Act of 2001, which is aimed at commercial buildings under the Perform, Achieve, and Trade (PAT) program. It had saved about 9 million tons of oil equivalent (Mtoe) of final energy, thereby reducing annual CO <sub>2</sub> emissions by nearly 23 MtCO <sub>2</sub> . The Energy Conservation Building Code (ECBC) was updated in 2017 for commercial buildings that recognized improvement efforts towards decarbonization. In 2018, the first national model building energy code called the Energy Conservation Building Code for Residential Buildings was introduced with simple enforcement of thermal comfort and passive system improvement. |
| European Union | As part of the Clean Energy for all European policy package set in 2016, the European Commission targets to combat climate change contributed by GHGs, including CO <sub>2</sub> emissions, through proposals on energy efficiency, energy market, and renewable energy strategies. An amendment to the Energy Performance of Buildings Directive (EPBD) was published in 2018 to achieve high-energy efficiency and be decarbonized by 2050.                                                                                                                                                                                                                                                                             |
| Sweden         | In 2016, the Centre for Sustainable Construction was created under a Swedish Government policy to promote the usage of sustainable materials and energy-efficient renovations, which could also reduce CO <sub>2</sub> emissions. In 2019, a certification scheme addressing the environmental impact of a new building was introduced.                                                                                                                                                                                                                                                                                                                                                                                   |
| Japan          | In 2017, the act on the Improvement of Energy Consumption Performance of Buildings (Building Energy Efficiency Act) was introduced, which includes regulatory measures for mandatory compliance with energy                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

|             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|             | efficiency standards for non-residential buildings. This act is part of the Japanese government policy on the zero-energy-building [ZEB]/zero-energy-house [ZEH] system to be achieved by 2030.                                                                                                                                                                                                                                                                                    |
| Canada      | In 2016, tighter energy performance standards for energy-using product categories in buildings were introduced. New building energy codes have been planned to be introduced in 2022 as part of the Pan-Canadian Framework on Clean Growth and Climate Change to increase energy efficiency in existing buildings. In 2019, the Government of Canada was working to develop a net-zero-energy-ready building code to support the aim of implementing building energy use labeling. |
| Germany     | In 2019, a package of emission mitigation measures by the German government was formed to meet the requirement of Agenda 2030 in the building sector.                                                                                                                                                                                                                                                                                                                              |
| USA         | In 2018, the California 2019 Building Energy Efficiency Standards was introduced as the first code in the USA. The New York State Energy Research and Development Authority was established in 2018 to increase the overall efficiency and sustainability of buildings.                                                                                                                                                                                                            |
| Nigeria     | In 2017, the first building energy code was introduced with a partnership between the German Development Agency (GIZ) and the Nigerian Energy Support Program with the aim of a set of minimum standards for energy-efficient building construction in Nigeria.                                                                                                                                                                                                                    |
| Singapore   | In 2016, the Code on Environmental Sustainability Measures for Existing Buildings was launched in 2016 for existing non-residential buildings within Singapore's Building Control Regulations.                                                                                                                                                                                                                                                                                     |
| Switzerland | In 2018, Switzerland's new Energy Act came into force, intending to increase energy efficiency in buildings towards decarbonization. Including the use of a CO <sub>2</sub> tax on stationary fuels (heating and industry). Under the Act, CO <sub>2</sub> tax and subsidizing of geothermal energy have been introduced. A Federal Act on Reduction of CO <sub>2</sub> Emissions was revised in 2019 to implement NDC in the building sector.                                     |

#### 2.3.5.2 Adopting Low Carbon Technology

Low carbon technology is one of the technical strategies that can be adopted in buildings to reduce carbon dioxide emissions. Low carbon technology refers to the technology that has a minimal output of GHG emissions into the environment, specifically for CO<sub>2</sub> emissions (Tan, Y.C.; Ismail, M.; Ahmad, M.I , 2016). Examples of renewable and sustainable energy technologies are evaporative cooling, passive ventilation and cooling, solar photovoltaic, dehumidification, and energy recovery systems. These technologies have been proven to significantly help to decrease emissions and promote energy savings in buildings. Through low carbon technology, the development of basic strategy

requirements of innovation-driven development in the building can also be achieved (IPCC. 2007).

#### 2.3.5.3 Restriction Strategy

It is the practice in buildings where closing down operation in some areas and shutting down associated devices is a straightforward approach to minimizing the CO<sub>2</sub> emissions and energy utilization. The most accessible practice is to keep the doors closed and switching off the lights and electrical appliances of vacant rooms. Research showed by Chen, Y.; Liu, H.; Shi, L (2018) that the linkage between building occupant rate and energy consumption in their study decline in lighting and heating energy consumption per capita with the increase of occupant rate has displayed.

#### 2.3.5.4 Impact Assessment of Building Process and Materials

Adequate understanding of entire building process is crucial in reducing CO<sub>2</sub> emissions and these processes are manufacturing, transportation, extraction, construction, maintenance and disposal. Varieties of utilized building materials use energy and release CO<sub>2</sub> through its life cycle which is regarded as embodied energy and embodied carbon. The selection of appropriate sustainable building materials can reduce about 30% of embodied CO<sub>2</sub> emissions over a lifespan of the building Chastas, P.; Theodosiou, T.; Kontoleon, K.J.; Bikas, D (2018), González, M.J.; Navarro, J.G (2006). Through this assessment, it has been reported that reinforced concrete and clay bricks are the most carbon-emitting materials leading to approximately 60% to 70% of the total embodied carbon Robati, M.; Daly, D.; Kokogiannakis, G. (2019), Kumanayake, R.; Luo, H.; Paulusz, N (2018), [31,32]. Therefore, low carbon cement, timber, straw and compressed earth having lower carbon footprint are excellent alternatives for building materials.

### 2.3.6 Major Sustainable Design Elements for Airport facilities

The following are required in achieving the goal of designing and building sustainable architecture: passive design, life cycle carbon footprint, energy efficiency, water efficiency, materials impact and conservation, waste management, site planning, sustainable building materials, health and wellbeing.

1. **Wellbeing and health:** It has been discovered that man spends 75% of his moment in an enclosed space (indoor) (Wheeler, 2015). Architects, professionals and specialists realize the significance of indoor environmental quality affecting the comfort level of users within a space to create a healthy and satisfactory indoor environment quality with the use of proper ventilation, thermal comfort, natural daylight, noise control and the use of sustainable building materials. Its architecture should not only be aesthetically pleasing but to contribute actively to man wellbeing psychologically and physiologically.
2. **Sustainable Building Materials:** Architects and Engineers select the use of Eco-friendly building materials mostly from those that are recycled or renewable requiring those with minimal energy to produce, durable materials and easy to maintain (Shadab, M., 2017). There is often a focus on using locally-obtained woods and stone, reducing the distance that materials travel before being used in the construction process and supporting local trades. There is a preference for wood that is harvested responsibly from certified forests and all other materials are non-synthetic and non-toxic. Materials with high content of Volatile Organic Compound (VOC) should be avoided to boost indoor air quality. Recycling is at the heart of a sustainable architect's design.
3. **Site Planning:** Feasibility study of site is essential in that each site is totally different from the other, therefore, Architects and other professionals and

specialists need to visit the site for proper planning and analysis and to reduce negative impact of elements on our environment and man.

Proper positioning of building and site layout is crucial to maximize the use of daylight and good ventilation. Landscaping of site can be by planting deciduous trees, shrubs, and grasses that are found and grow in the area used as part of a passive strategy to shade roof and windows during hot season and to reduce the heat gained within the space.

4. **Waste Management:** It is the strategy an organization uses to dispose, reduce, reuse, and prevent waste. In the life cycle of a building liquid and solid waste are generated from users activities. Waste management is an approach used to manage waste throughout its life cycle from waste generation to disposal or recovery. The possible waste disposal methods are recycling, composting, incineration, landfills, bio-remediation, waste to energy, and waste minimization (figure 2.13a). Figure 2.13b shows waste management life cycle below. Sustainable waste management reduces pollution, conserves energy, create enabling environment and employment.



Figure 2.16a: Waste Management Disposal Method

Source: <https://www.conserve-energy-future.com/waste-management-and-waste-disposal-methods.php>



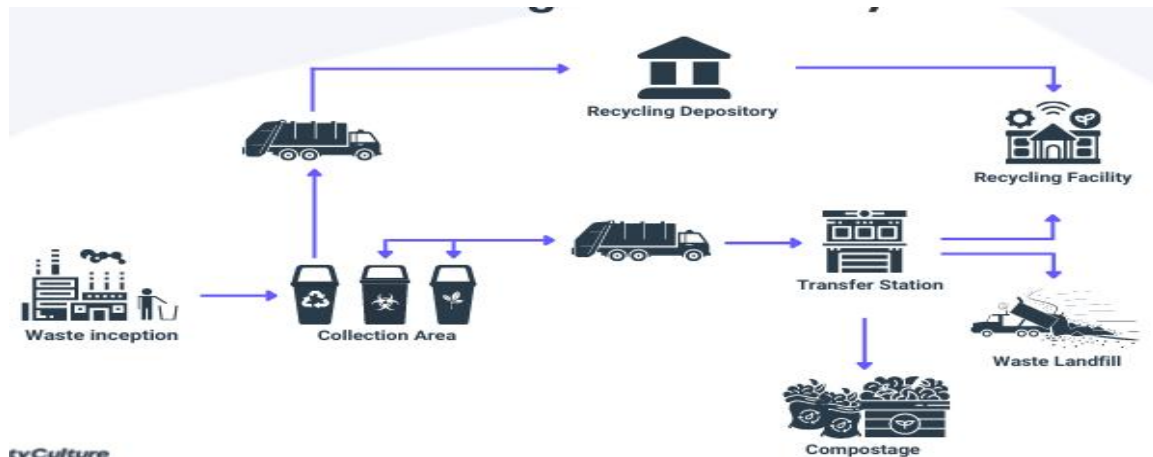


Figure 2.16b: Waste Management Life Cycle

Source: <https://safetyculture.com/topics/waste-management-system/>

5. **Water Efficiency:** Water is very essential for survival in life with its efficiency to improve water quality, maintain aquatic ecosystems and protect drinking water resources. It is the smart use of our water resources through water-saving technologies, recycling of grey from showers and appliances by using energy star rated equipment, plumbing fixtures and fittings that are efficient. This to help us ensure reliable water supplies today and for the future generations.

Harvesting rainwater will assist in minimizing the quantity of water that flows to the storm water system installed and maintained local authority and can be used for irrigation. The use of planted green roof soaks up rainwater and reduces the flow of storm water. Water resources are liable to pollution and this creates a serious environmental problem. Water foot print of buildings can be reduced by strategies like re-use/recycle, low flow fixtures and landscaping (to conserve water),

6. **Energy Efficiency:** This is a means of fusing less energy to eliminate energy waste, bills and reduces pollution. Heating and cooling are the largest consumers of energy in a building and reducing this need therefore reduces carbon emissions. The energy-efficient siting and design of buildings are beneficial in terms of economy (cost savings), social (poverty reduction in fuel), and the ecosystems



(Reduction in resource exploitation and emission of greenhouse gases), (SABD, 2005). Passive design strategy can be maximally utilized the benefit seasonal changes achieved through the use of renewable energy sources like wind turbine, solar power, blue energy and geothermal (Attaman, 2010).

Energy conservation is also critical: buildings can be ‘weatherized’ for maximum protection against the loss of warm or cool air, and appropriate insulating materials and window glazing can be installed to reduce heat loss in ways that do not cause indoor humidity.

7. **Life Cycle:** Every building’s life cycle is grouped into three phases namely: pre-building, building and post building phases (figure 2.13c) and it’s also made up of a linear process which includes four phases; design, construction, operation, maintenance and demolition. One of the goals of sustainability is to create buildings that a low carbon or carbon neutral footprint throughout their life cycle from construction to operation and maintenance.

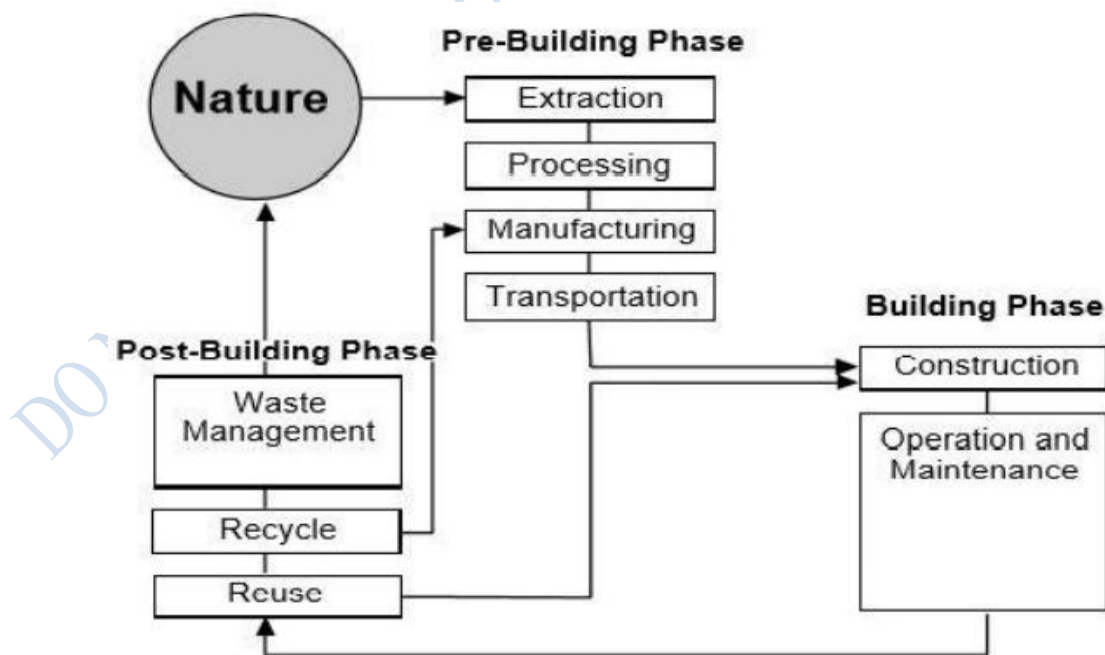


Figure 2.16c: Sustainable building life cycle Source: Kim (1998)

Pre building phase involves site assessment and selection, design of the building, analysis and processing of the materials to be used during the building phase; The building phase is a stage of a building's life cycle when the building is constructed and operated by occupants while the post building phase of a life cycle begins when the useful life of a building comes to an end.

8. **Passive Energy:** Passive design utilizes resources such as sun, wind and shade (free natural resources) by working with the specific conditions and climate of a site and is used to light, heat and cool spaces. Architects purposefully and carefully positioned and designed building for the movement of sun and wind and building envelopes (walls, floor, roof and windows) to control sun, air, shade the building. It is an approach used to design buildings that depends on the architecture of the building to minimize the energy consumption of the buildings (Ragheb, El-Shimy & Ragheb, 2015). Passive solar design uses the following methods to achieve energy efficiency in buildings: Shape and form of buildings, Orientation of the facades to enable cooling and heating, Space planning, Natural day lighting and ventilation, Responsible landscape to reduce heat island effect, Thermal insulation, thermal storage of roof and walls and efficient site planning based on bioclimatic conditions. Figure 2.16d shows passive design strategies.

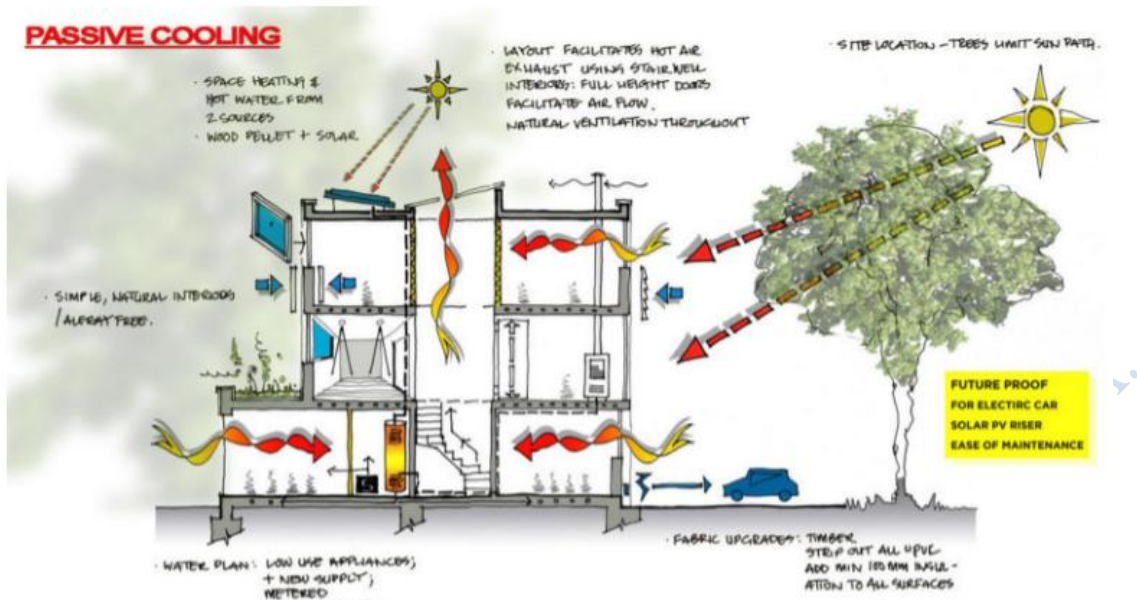


Figure 2.16d: Passive Energy Design Strategy

Source: <https://www.re-thinkingthefuture.com/sustainable-architecture/a3992-what-are-passive-design-strategies/>

9. **Active Energy:** Engineers and Architects work together to execute high efficiency HVAC, electrical, plumbing and other systems designed to have little environmental footprints. The best strategy is to minimize the demand and design the active system that will meet it.

## Chapter Three

### Methodology

#### 3.1 Introduction

This chapter discusses the methodology adopted in pursuit of the research objectives this study summarized in chapter one. This explains the philosophical background of the study, study population, sources of primary and secondary data and its method of collection.

Research philosophy comes as a result of different perceptions of humankind and the procedures necessary based on different situations surrounding them. It is a set of beliefs and assumptions guiding the development, analysis and usage of data pertaining to a particular phenomenon (Saunders, 2009). Research philosophy focuses on knowledge, existence, reality, and it is categorized into five and they are; modernism, pragmatism, critical realism, interpretivism and positivism.

Study population refers to the sum of all the elements used in the study that have to be identified listing definite principles based on the scope of the research. The first group consists of airports in Nigeria while the second group comprises airports terminals dedicated to sustainability measures. In table 3.1, the list of domestic airports in Nigeria is shown.

Table 3.1: Domestic Airports in Nigeria

| S/N | Names of Airport            | Location | Category         |
|-----|-----------------------------|----------|------------------|
| 1   | Akure Airport               | Akure    | Domestic Airport |
| 2   | Akwa Ibom Airport           | Uyo      | Domestic Airport |
| 3   | Asaba International Airport | Asaba    | Domestic Airport |

|    |                                     |              |                  |
|----|-------------------------------------|--------------|------------------|
| 4  | Bauchi Airport                      | Bauchi       | Domestic Airport |
| 5  | Benin Airport                       | Benin        | Domestic Airport |
| 6  | Gombe Lawanti International Airport | Gombe        | Domestic Airport |
| 7  | Ibadan Airport                      | Ibadan       | Domestic Airport |
| 8  | Ilorin Airport                      | Ilorin       | Domestic Airport |
| 9  | Jalingo Airport                     | Jalingo      | Domestic Airport |
| 10 | Kaduna International Airport        | Kaduna       | Domestic Airport |
| 11 | Kastina Airport                     | Kastina      | Domestic Airport |
| 12 | Kebbi international Airport         | Birnin Kebbi | Domestic Airport |
| 13 | Magaret Ekpo International Airport  | Calabar      | Domestic Airport |
| 14 | Maiduguri International Airport     | Borno        | Domestic Airport |
| 15 | Makurdi Airport                     | Makurdi      | Domestic Airport |
| 16 | Minna Airport                       | Minna        | Domestic Airport |
| 17 | Sam Mbakwe Airport (Cargo)          | Owerri       | Domestic Airport |
| 18 | Sir Abubakar Tafawa Balewa Airport  | Bauchi       | Domestic Airport |
| 19 | Sultan Saddik Abubakwa Airport      | Sokoto       | Domestic Airport |
| 20 | Warri Airport                       | Warri        | Domestic Airport |
| 21 | Yakubu Gowon Airport                | Jos          | Domestic Airport |
| 22 | Yola Airport                        | Yola         | Domestic Airport |

|    |               |       |                  |
|----|---------------|-------|------------------|
| 23 | Zaria Airport | Zaria | Domestic Airport |
|----|---------------|-------|------------------|

Table 3.2: International Airports in Nigeria

| S/N | Names of Airport                          | Location | Category              |
|-----|-------------------------------------------|----------|-----------------------|
| 1   | Akanu Ibiam International Airport         | Enugu    | International Airport |
| 2   | Mallam Aminu Kano International Airport   | Kano     | International Airport |
| 3   | Nnamdi Azikiew Internaternational Airport | Abuja    | International Airport |
| 4   | Port Harcourt International Airport       | Rivers   | International Airport |
| 5   | Murtala Muhammed International Airport    | Lagos    | International Airport |

Source: Nigerian Infopedia (2020)

Population study is based on the above tables 3.1 and 3.2 which shows that Nigeria has five functional international airports (5) and twenty-three (23) domestic airports. In the above listed study population, it was virtually impossible (due to timing, location and current security issues) to realize the purpose of this research, hence, a purposive sampling method was suitably considered.

Purposive sampling is a technique which consists of all elements relating to the features that are most appropriate for the objectives of this study. Table 3.3 shows current airports both national and international practicing Sustainable design strategies in a measure to

minimize carbon emission in the design of airport facilities. The final selected airports used for purposive sampling are taken from table 3.3 in this research.

Table 3.3: List of selected Airports currently practicing sustainable design strategies

| S/N | Names of Airport                          | Location         | Category      |
|-----|-------------------------------------------|------------------|---------------|
| 1   | Murtala Muhammed International Airport    | Lagos, Nigeria   | International |
| 2   | Nnamdi Azikwe International Airport       | Abuja, Nigeria   | International |
| 3   | Ibadan Airport                            | Oyo, Nigeria     | Domestic      |
| 4   | Port-Harcourt International Airport       | Rivers           | International |
| 5   | Shenzhen Baoan International Airport      | Guangdong, China | International |
| 6   | Denver International Airport              | Colorado         | International |
| 7   | Seymour Galapagos Ecological Airport      | Ecuador          | International |
| 8   | Singapore Changi Airport                  | Singapore        | International |
| 9   | Mactan Cebu International Airport         | Philippine       | International |
| 10  | Heathrow International Airport terminal 5 | London           | International |
| 11  | Zurich International Airport              | Switzerland      | International |
| 12  | Marrakech Menara Airport                  | Morocco          | International |

Source: Researcher Field work (2022)

Types of data used to achieve the objectives of this research are divided into primary and secondary data.

Primary data is the actual data put together research for a specific goal. In this research, primary data collected directly from the field survey by careful observations of the sustainable element in some of the purposive sampled airports, interviews of airport workers and case study surveys.

Secondary data is the gathering of data by appropriate person for a particular goal to be used by the researcher to meet up the objectives of a study. In this research, the secondary data collected from review of pertinent literature on airport terminal designs and its sustainable strategies which were obtained from magazines, journals, books and other internet sources that were properly verified and referenced accordingly.

### **3.2 Case Studies Analysis**

#### **3.2.1 Case Study 1: Murtala Muhammed International Airport Terminal 2 (MMA 2), Ikeja-Lagos, Nigeria**

##### **3.2.1.1 Description of the building**

Murtala Muhammed International Airport is a public airport and one of the main airports in Nigeria located in Ikeja in Lagos State. The airport itself was built during World War II (1938 – 1976). It is fully operated by (FAAN) with a code name LOS by International Air Transport Association (IATA) and DNMM by ICAO (FAAN, 2017).

It has an international terminal wing built on 56,000 square meters landmass with six entries and exit points each because of its nearness to both commercial and residential areas in Lagos State.

The new international terminal modeled after Amsterdam Airport Schiphol was opened on March 15, 1979 (Tubi, 2013). Forty-one years after, a new terminal (terminal 2) was



added. This new facility was constructed by the Chinese Civil Engineering Construction Company (CCECC). It has 66 check-in counters, 5 baggage collection carousels, 16 immigration desks at arrival, 28 immigration desks at departure, 6 boarding bridges and 8 security screening points. It also consists of 2 food courts, 4 premium lounges, 22 guest rooms and spa, 16 airline ticketing offices, port health unit, visa on arrival, playing area and more than 3,000 square meters of duty-free shops. MMA 2 comprises of a level main Terminal Building, three-storey building, two-storey Cargo terminal building, 82,925m<sup>2</sup> apron, together with ancillary and external works.

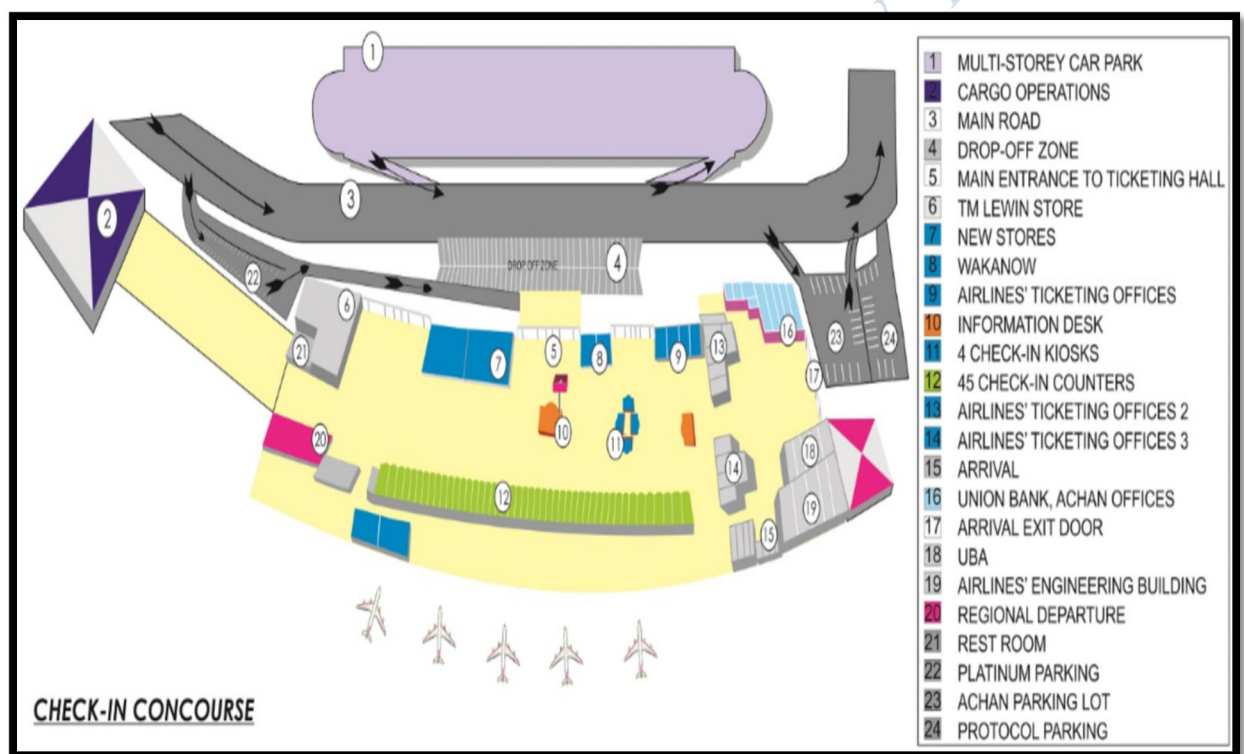


Plate 3.1: Check –in Concourse of MMA 2 terminal building  
Source: Researcher Field Work (2022)

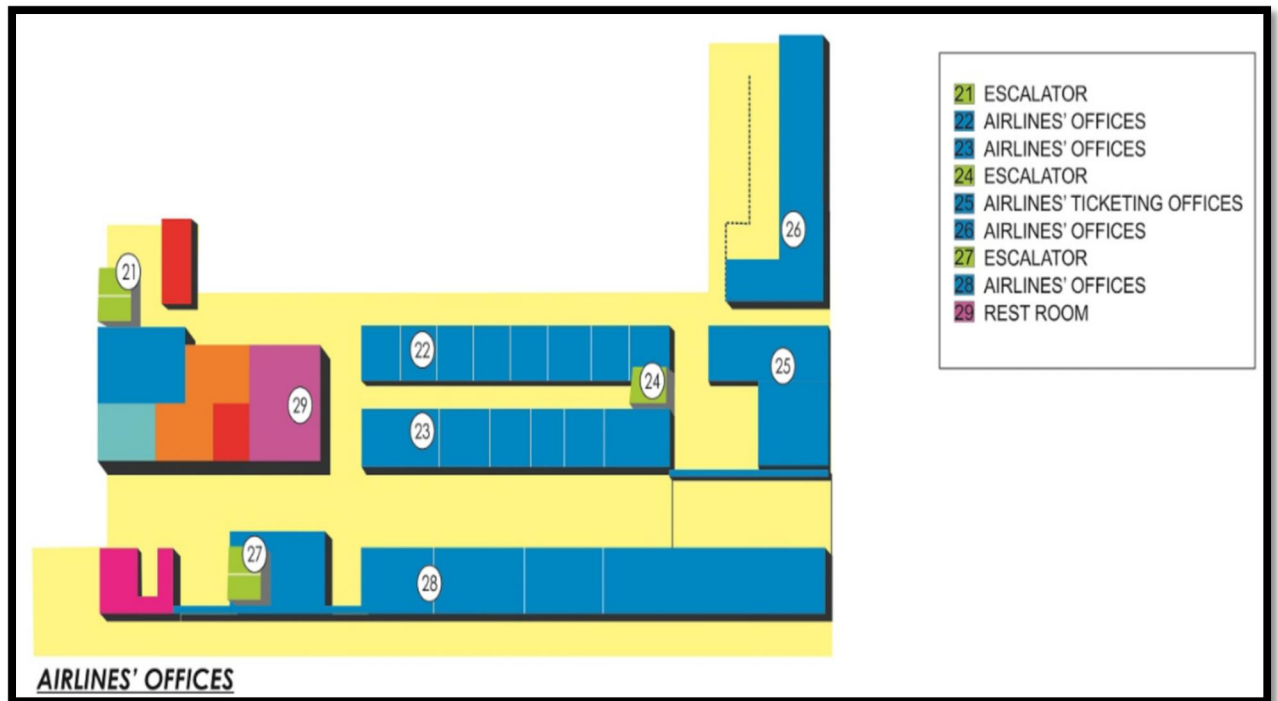


Plate 3.2: Check –in Concourse of MMA 2 terminal building  
Source: Researcher Field Work (2022)

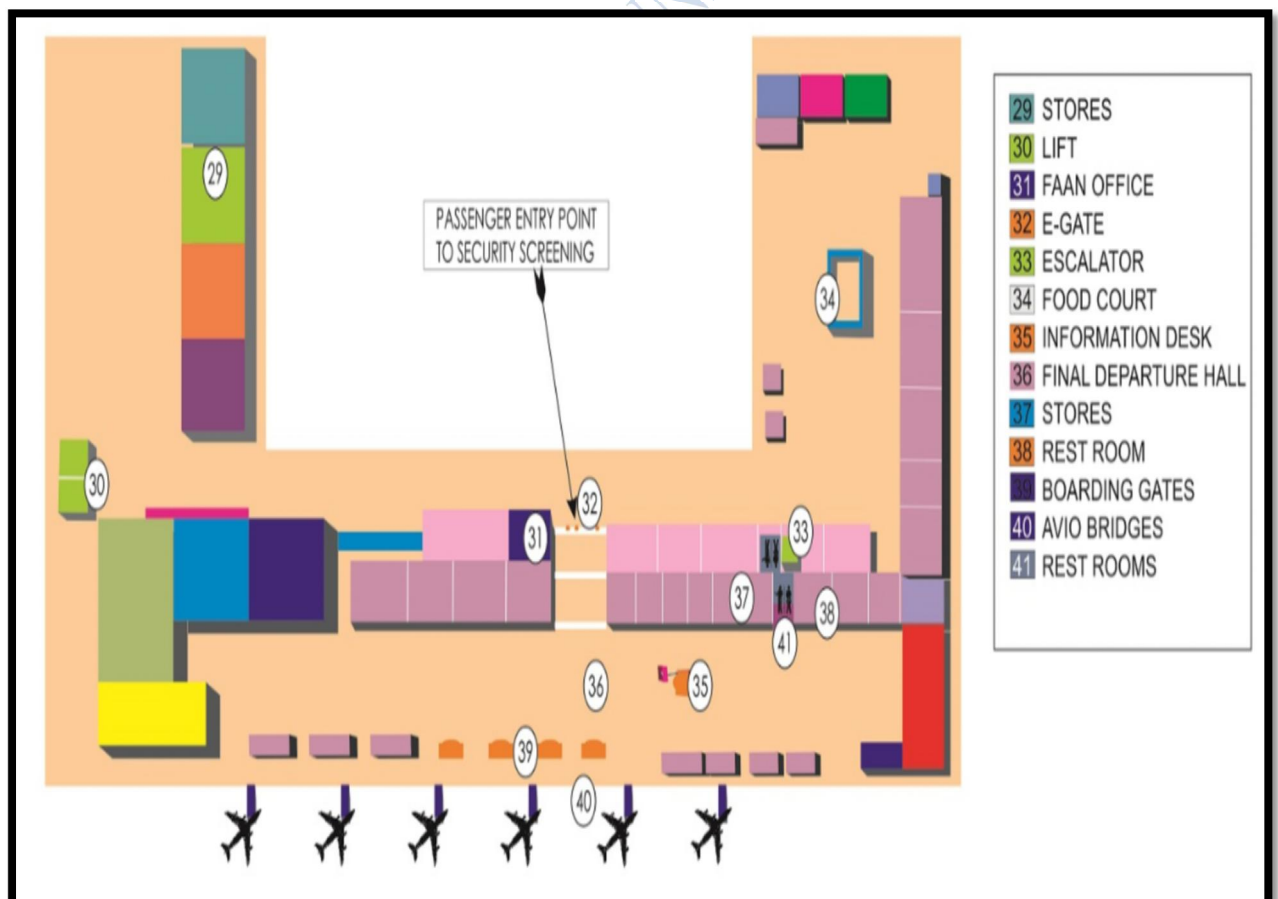
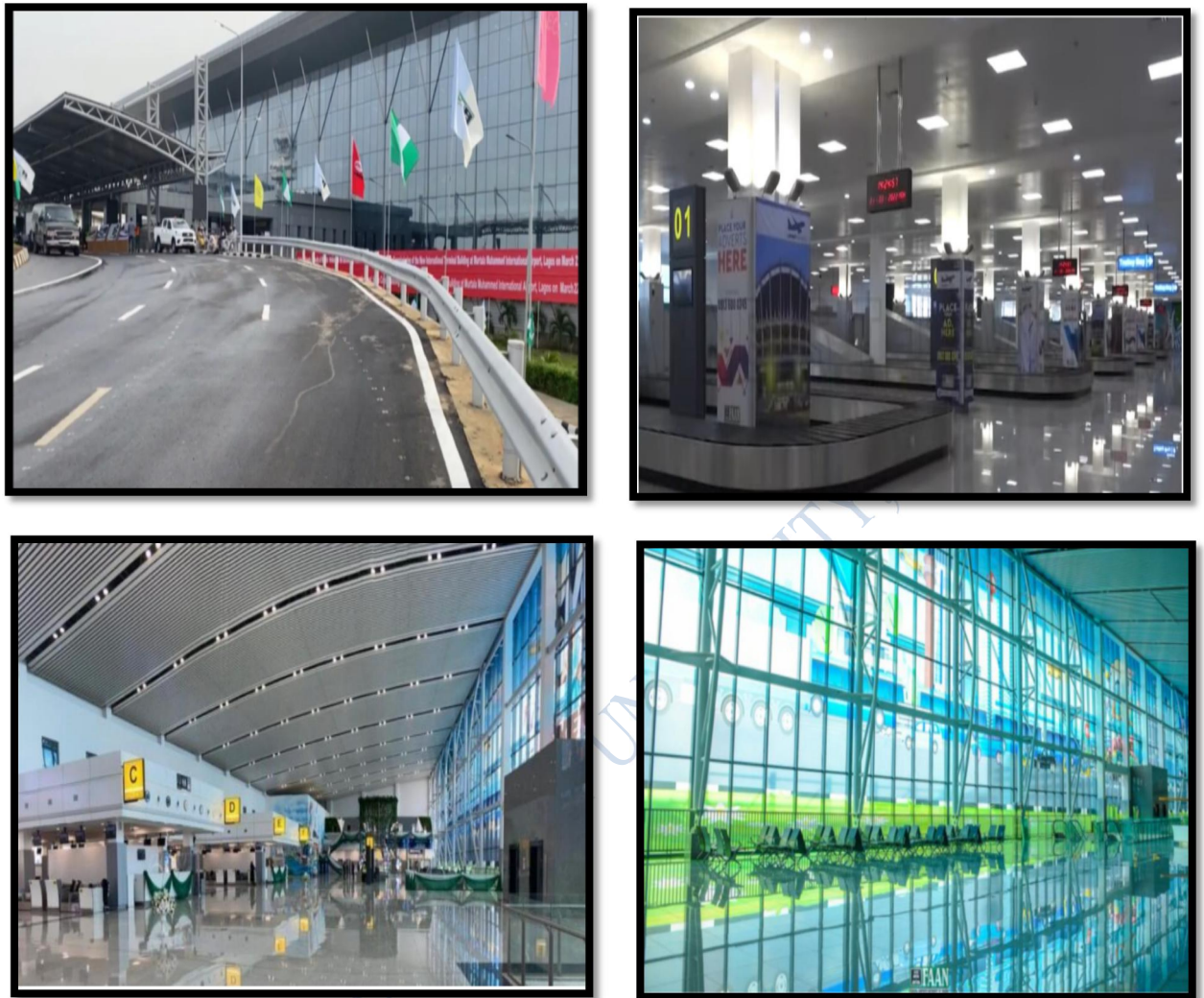


Plate 3.3: Departure Concourse of MMA 2 terminal building  
Source: Researcher Field Work (2022)

Plate of Pictures 3.4: External and internal pictures of MMA 2 Source: Researcher Field Work



Materials and finishes used for floor are ceramic tiles, the soffit of the roof covering is exposed showing the steel space frame structures holding the roof members, the walls are made of sandcrete blocks and reinforced concrete with art work display in some parts while some parts are double glazed curtain walls with steel frames members. MMA 2 used solar panels to reduce GHG emitted in the airport and also reduces the dependence of fossil fuels while it balances the footprint of energy within the airport facilities.

### 3.2.1.3 Sustainable Strategies

Both active and passive green approaches are used in the design of this terminal building. The exterior façade material of the terminal building is clad with aluminum composite panels material to improve its thermal insulation and its ability to resist fire and weather while double glazing in the façade and office windows allow natural lighting and ventilation to minimize the usage of HVAC units. Indoor green are used to boost air quality of the space on passengers, visitors and airport staff.

### 3.2.1.4 Design Appraisal

MMA 2 terminal building used double glazed curtain walls to permit natural lighting and hence trim down the dependence artificial lighting. The use of self-service check in equipment facilitates ease of processing the volume of passengers' volume from 7 million to 14 million annual passengers.

The airport is equipped with a category 1 navigational equipment, safety facilities and infrastructure.

Sustainable materials are used to boost thermal insulation and as weather and fire proofs.

The use indoor plants help to produce good indoor air quality.

Its terminal configuration concept is a centralized linear design.

### 3.2.1.5 Critique

MMA 2 terminal building has no integrated link from the domestic terminal to international terminal without using a car and has no direct link to train station.

The apron is not wide enough to accommodate wide bodied aircraft like Boeing 777s, 747s, A380s, Dreamliner, among others and it is facing the wrong direction.

Its number of boarding gates is too small for such a busy international airport.

Despite the use of solar system, the airport relies on diesel powered generator to supply power as a means of alternating supply of power.

There is inadequate display of way finding signage for visitors within airport.

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### **3.2.2 Nnamdi Azikiwe International Airport, Abuja**

#### **3.2.2.1 Descriptions of the building**

Nnamdi Azikiwe airport (IATA: ABV, ICAO: DNAA) is an international airport located in Abuja, the Federal Capital Territory (FCT) of Nigeria which was named after the first Nigerian President. The airport site is located approximately 20km West of Abuja and is far from human environment and activities. It is owned by FAAN and Federal Government of Nigeria (FGN) and can accommodate 22,000 passengers per year. Its construction started in year 2000 and was completed in 2002. The airport terminals consist of domestic and international sharing one runway and both terminals are separated from each other and thus make it uncomfortable walking distance to cover. No provision of circulation links from domestic wing to international wing or vice versa. The parking lot is located close to the terminal buildings and thus allows easy movement of passengers without obstruction or delay.

The airport terminal is a centralized linear building having its car park near it. Terminal facilities are 72 check-in counters, 5 baggage claim carousels, immigration desks each at arrivals and departure, boarding bridge and walkway to link FCT metro rail and additional apron for remote parking of aircraft.



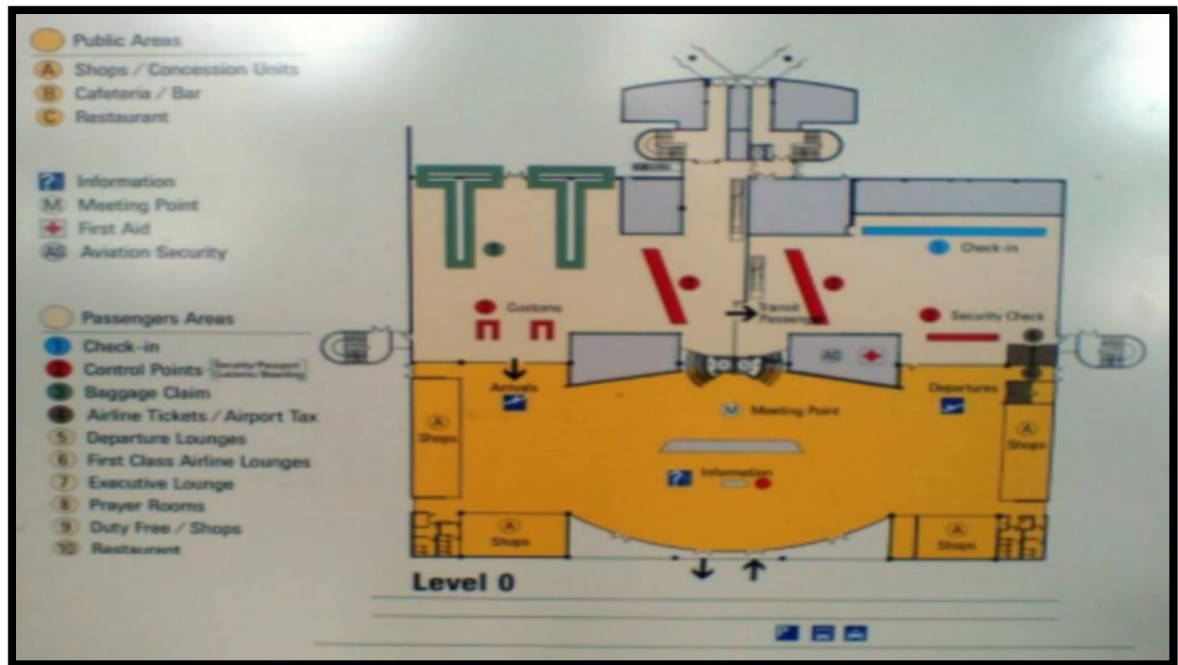


Plate 3.5a: Nnamdi Azikiwe International Airport Terminal – level 0 Plan  
Source: Researcher Field Work (2022)

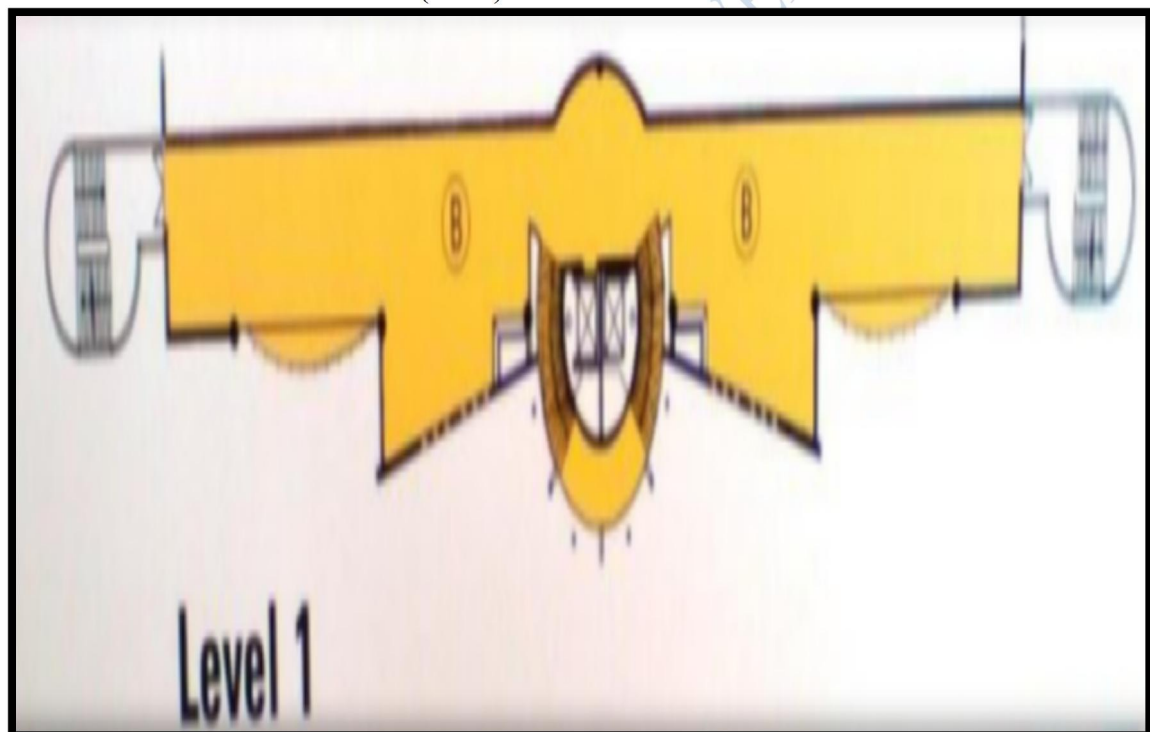


Plate 3.5b: Nnamdi Azikiwe International Airport Terminal – level 1 Plan  
Source: Researcher Field Work (2022)

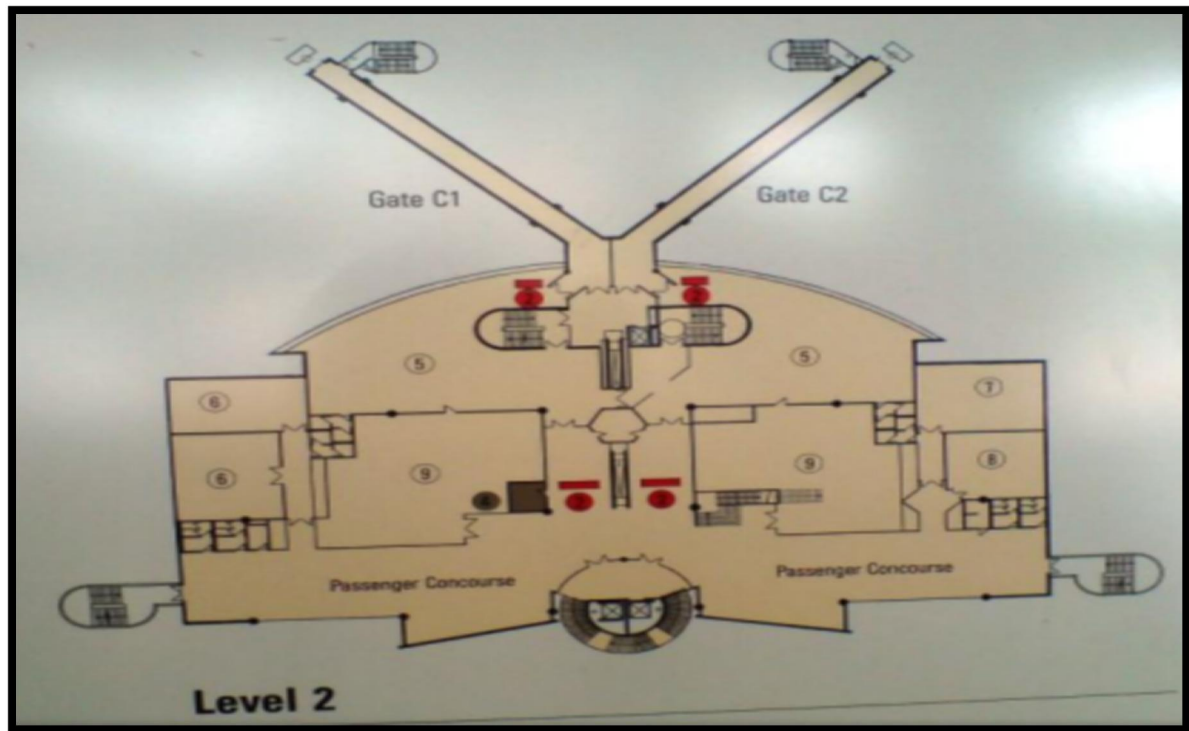


Plate 3.5c: Nnamdi Azikiwe International Airport terminal – Level 2 Plan  
Source: Researcher Field Work (2022)

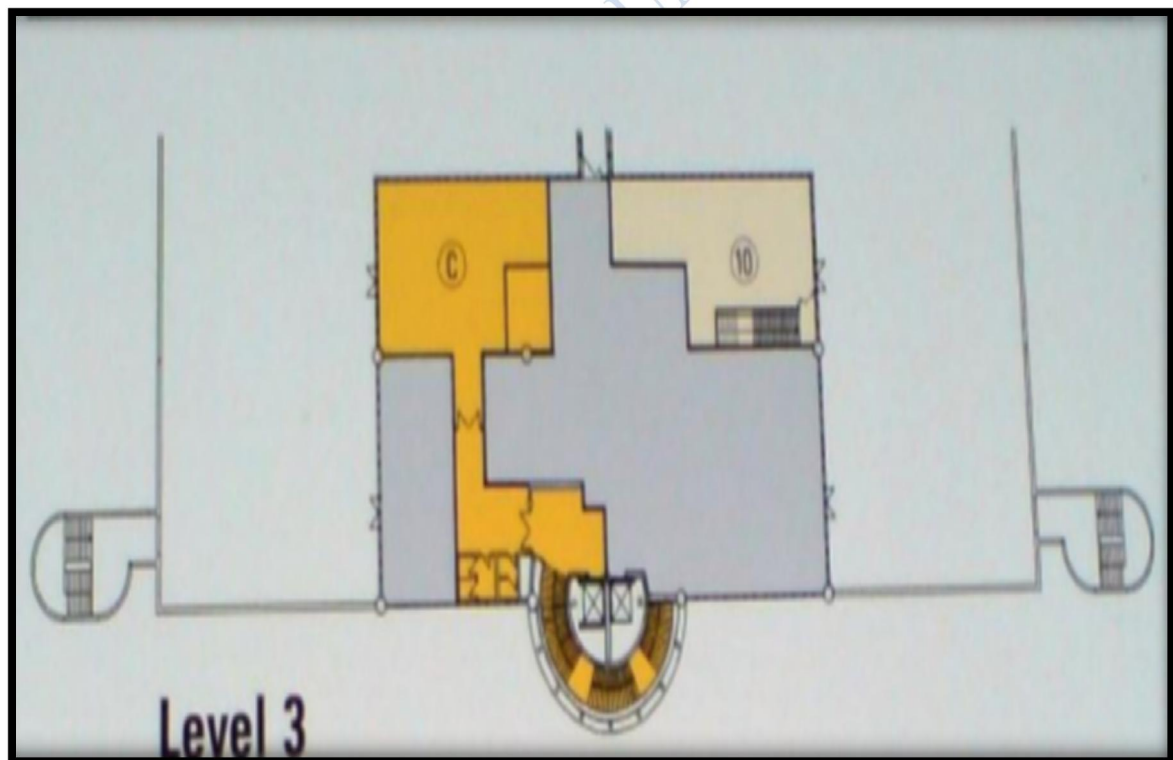


Plate 3.5d: Nnamdi Azikiwe International Airport terminal – level 3 Plan  
Source: Researcher Field Work (2022)

The basic materials used on its exterior facades consist of double glazed panels, gray Aluminum composite panels and concrete masonry walls while the internal walls are



painted with satin and emulsion paint and with the display of artworks in the waiting areas. The terminal floor finish materials are different pattern of terrazzo and marble tiles in different areas. Polyester acoustic panels are used in the large hall with double volume and some sections are aesthetically exposed to the roof members.



Plate 3.6a: 3D View



Plate 3.6b: Terminal Building

Source: [www. Googleimages.com](http://www.Googleimages.com)

The sustainability measures used in Nnamdi Azikiwe International Airport include active and passive strategies. These strategies improve thermal insulation; allow daylight in the terminal building and increase good air quality.

#### 3.2.2.2 Design Appraisal

There is an easy and continuous flow of passengers at the departure and arrival location and this removes collision and confusion that may likely occur. The direct link from the departure to the arrivals with airport security for connecting passenger facilitates their movement.

#### 3.2.2.3 Critique

Internal zoning of activities and facilities is highly low and there is need for more parking spaces. Facilities at the airport totally rely on Abuja Electricity Distribution Company (AEDC) and the use of generator. There are insufficient conveniences and no visitors waiting area for deplaning passengers. The use of too much hardscape in the surrounding area of airport generates radiation in the building.

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### 3.2.3 Port Harcourt International Airport, Port-Harcourt, Rivers State

#### 3.2.3.1 Description of the building

Port Harcourt International (ICAO: DNPO, IATA: PHC) is an international airport situated in Omagwa along Owerri-Port Harcourt expressway in the capital city of Rivers State with site coordination of 05°01' North and 06°57' East and it is quite a distance from the man's habitation and his activities. The airport terminal was commissioned in 2018 by President Muhamadu Buhari and this terminal served 1, 081, 587 passengers in 2009 making it one of the busiest airport in Nigeria. The design scope was to have one terminal accommodating both international and domestic wing meeting airport international standards.

It is a linear centralized terminal designed building having one apron with open arrivals and departure gates system. It has 361m<sup>2</sup> conveyor belts, security check equipment, kitchen facilities, offices and check in counters. Control tower of seven floors is 24.6 meter high.

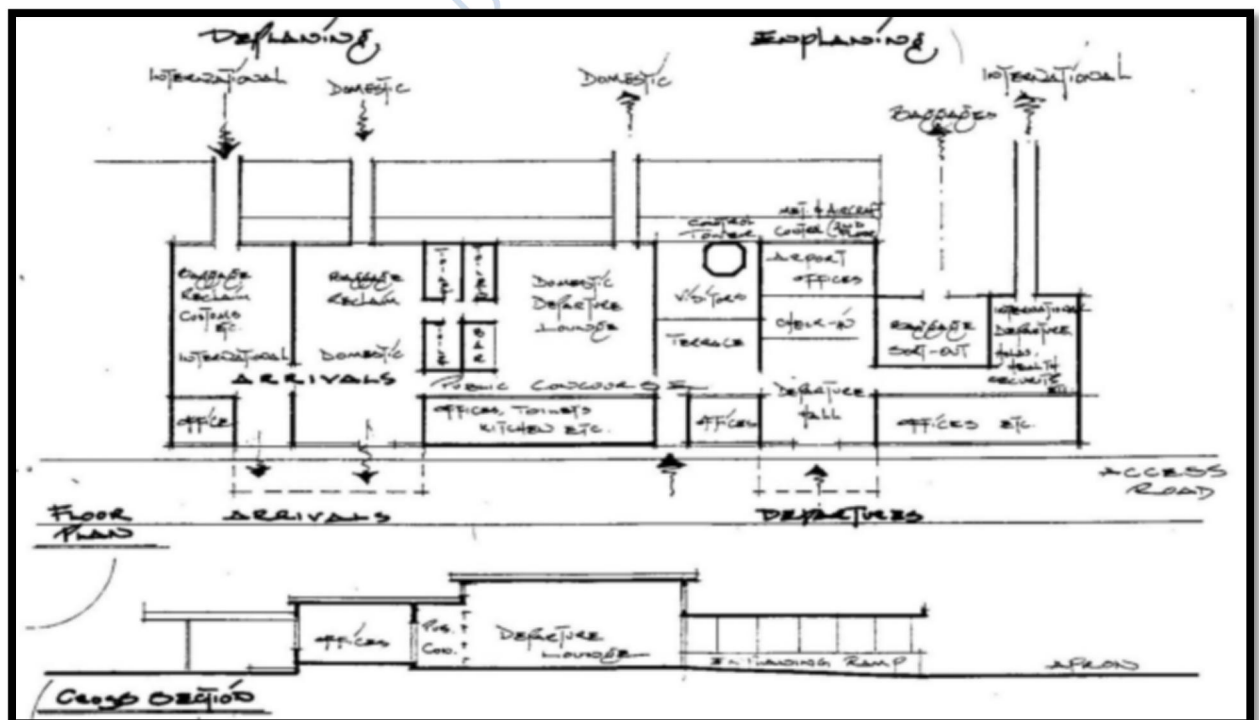


Figure 3.7a: Ground Floor plan of Port – Harcourt International Airport  
Source: Researcher Field Work (2022)



Figure 3.7b: PHC Airport Terminal building with the control tower  
Source: [www.googleimages.com](http://www.googleimages.com)



Figure 3.7c: Ticketing and Baggage Check-in Area, PHC International Airport  
Source: [www.googleimages.com](http://www.googleimages.com)

Port- Harcourt International has domestic waiting area of 567m square together with a restaurant and the international arrivals halls of 503 meter square and a combined check-in hall of 207m<sup>2</sup>. The length of the runway is 3000 meters, width of 60 meters and the width of its taxiway is 30 meters and the angle of the taxiways is 90° in the direction of 03/21. The airport apron is 265 by 120 meters and has a space for helicopters. It has a dedicated cargo handling facility

The roof is decked with reinforced concrete to support both external and internal steel columns.

Surface of the runway is made up of asphalt while the façade of landside has concrete wall partitioning having general offices areas partitioned with asbestos.

#### 3.2.3.2 Design Appraisal

The airport permits links between the country and main destination around the world especially from and to Western countries. Separation of arrivals and departure for both domestic and international wings suffice for efficient flow system of baggage claim, passengers and staff. Noise pollution from the airside is being reduced with the use of thick plate glazed and aluminum frames materials

#### 3.2.3.3 Critiques

The airport has no sufficient parking lots for travelers and visitors and no public facilities like post office, telephone and no Wi-Fi.

There is no loading bridge to shelter passengers from weather elements.

The entrance of both arrivals and departure causes confusion and the walking distance is long.

### 3.2.4 Foreign Case Studies

#### **Marrakech Menara International Airport Terminal 1, Morocco**

##### 3.2.4.2 Description of Building

Marrakech international airport (IATA: RAK, ICAO: GMAX) is an international airport serving Marrakech situated 6km southwest of downtown city center and 7km of the Djemaa el-Fna. Its facility receives European, Casablanca and some of the Arab countries which served more than 6.3 million passengers in 2019 designed by Swiss Architects,

E2A Architecture. Project construction of the terminal started in 2006 and was commissioned in 2008 having floor area of 15,300m<sup>2</sup> and its height is 15.80m<sup>2</sup>. The airport has two terminals accommodated in a single large building on a space of 42,000m<sup>2</sup> designed to receive 9 million passengers annually and has a cargo terminal separated from the air terminal. It has a single runway laid in the direction 10/28 is 3100m by 45m and the parking space of the aircraft is 125,000m<sup>2</sup> supporting Boeing 737s and Boeing 747s to accommodate all jetliners up to Boeing 747 in size. The terminal facilities have parking capacity of 360 vehicles, a chapel, airport clinic, prayer room, currency exchange offices, ATMs (at arrivals hall), restaurant and café, duty free shops and many others. Their design concept is based on the ideas below:

1. To present the Moroccan architecture to the world and not forgetting the traditions.
2. To have a welcoming and secured space.
3. To use past and present materials and techniques with sense and feel of new modernity.

The exterior facade consists of 24 diamonds and 3 triangles located above the entrance doors as the lozenges are filled with ornaments of glass in Islamic style while the interior follows the pattern of the façade with the white aluminum covered grating that allow natural light in the building. Its roof has a steel skeleton material flying outward which provide shade through an overhang of 24 meters and this covers 72 supports photovoltaic pyramids in a package that represent some 15,300 meters square.



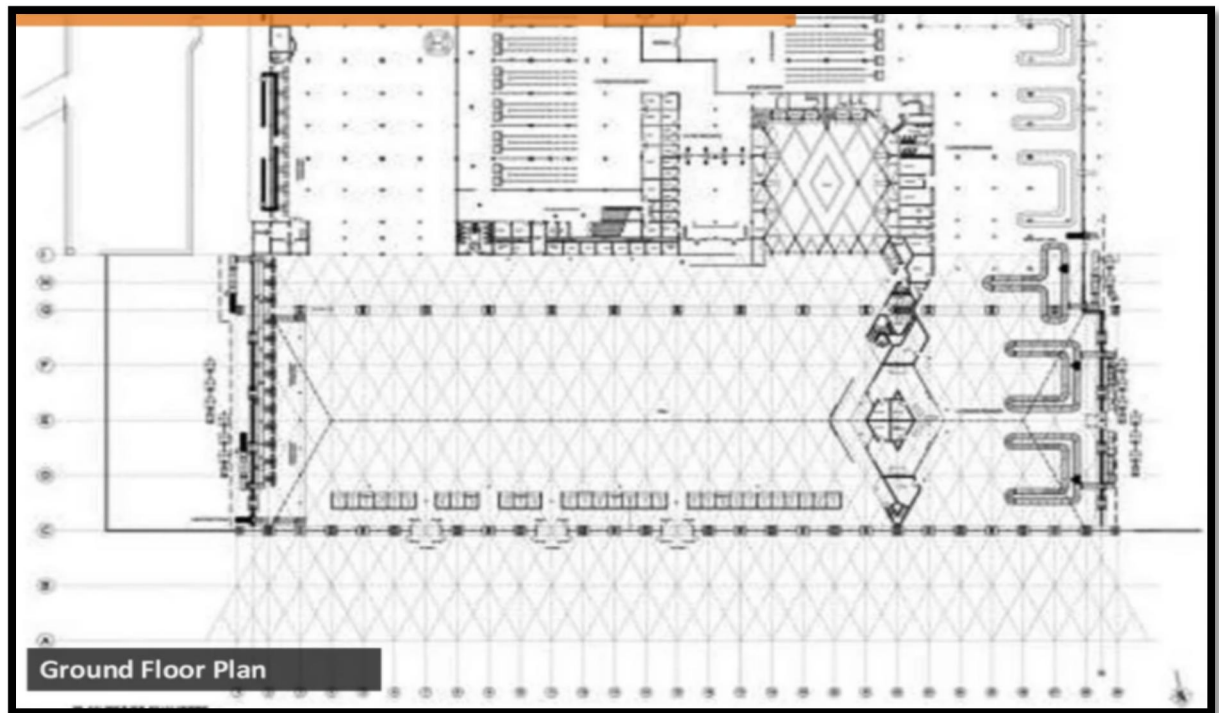


Figure 3.8a: Marrakech International Airport Terminal –Ground Floor Plan

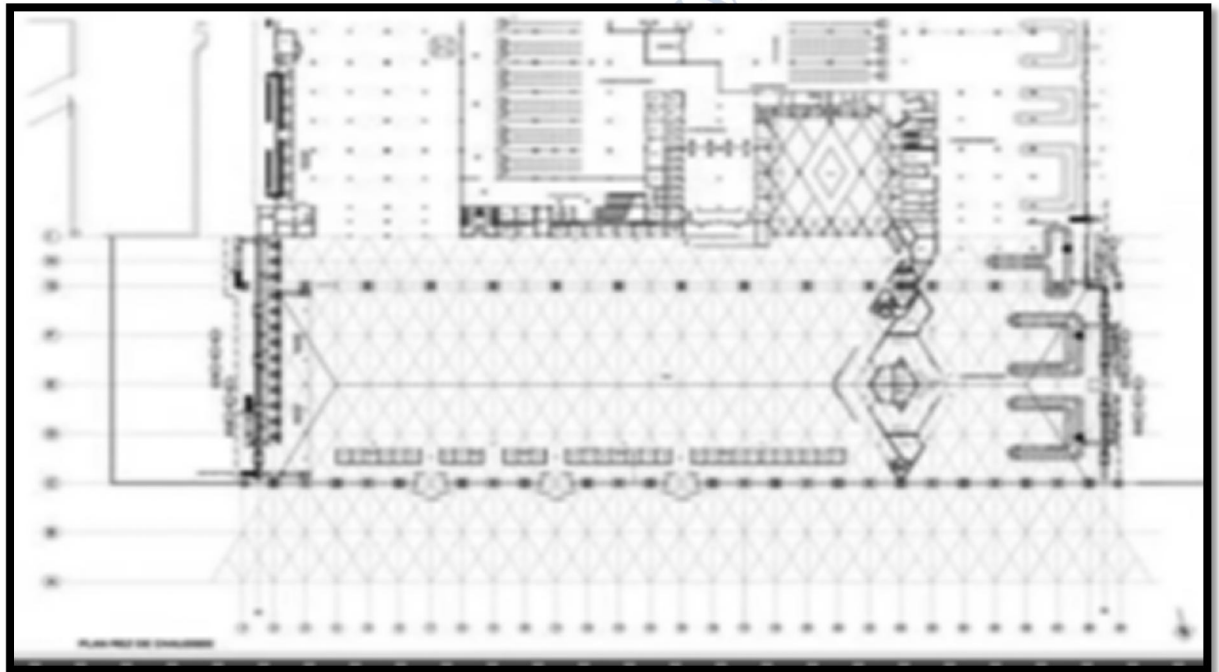


Figure 3.8b: Marrakech International Airport Terminal –First Floor Plan

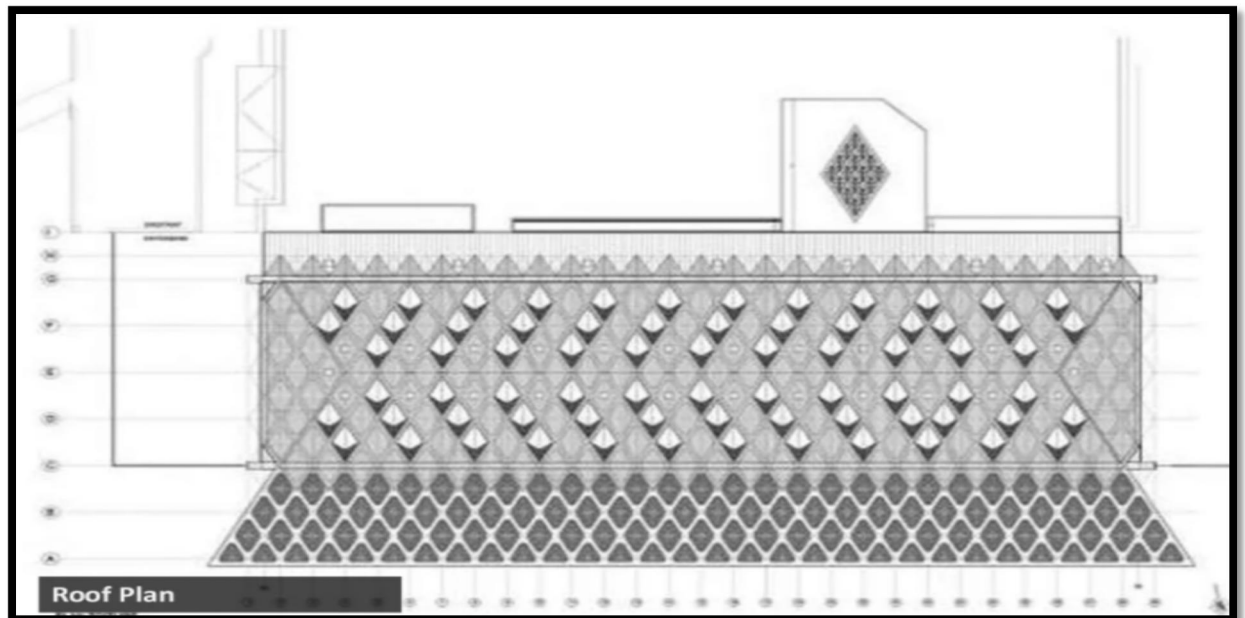
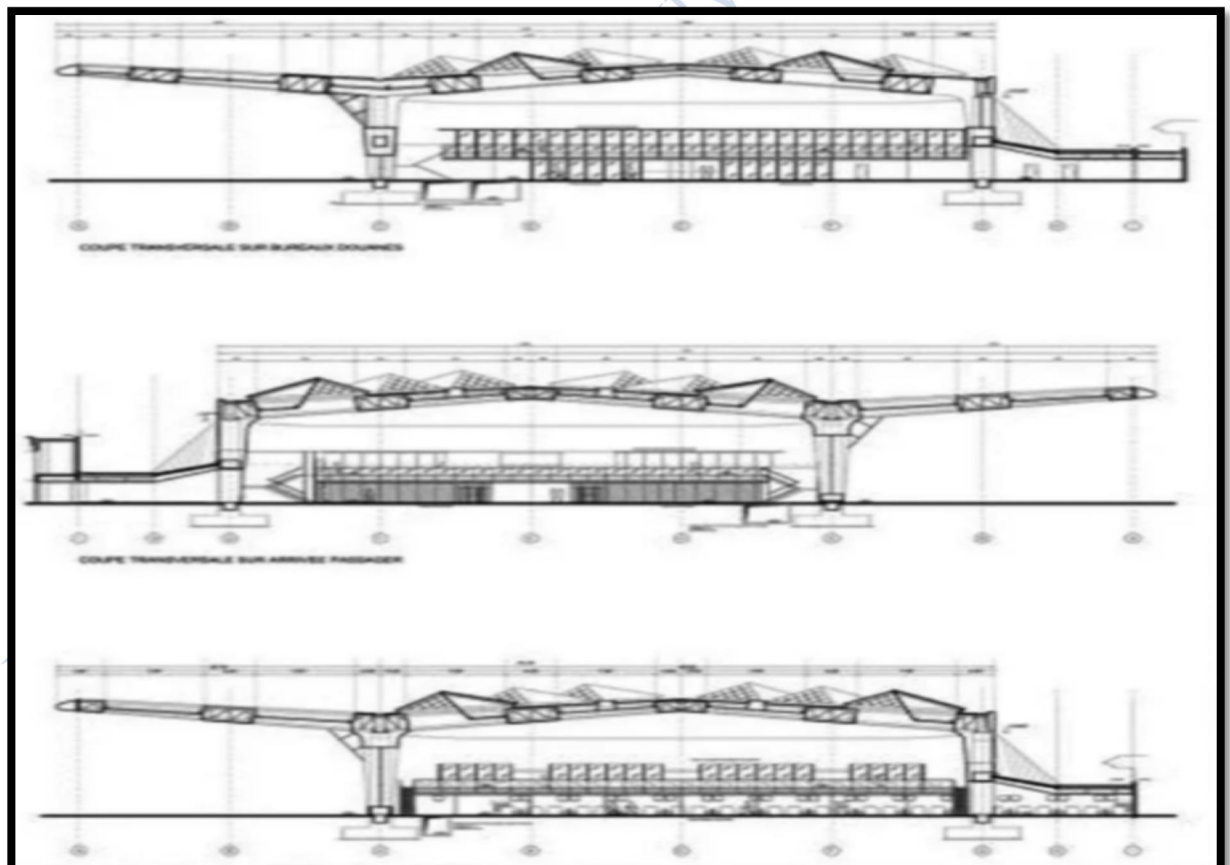


Figure 3.8c: Marrakech International Airport Terminal –Roof Plan  
 Source:[https://www.slideshare.net/banasaldhruv/the-international-airport-of-marrakech\(2022\)](https://www.slideshare.net/banasaldhruv/the-international-airport-of-marrakech(2022))  
 Figure 3.8d: Marrakech International Airport Terminal –Sections

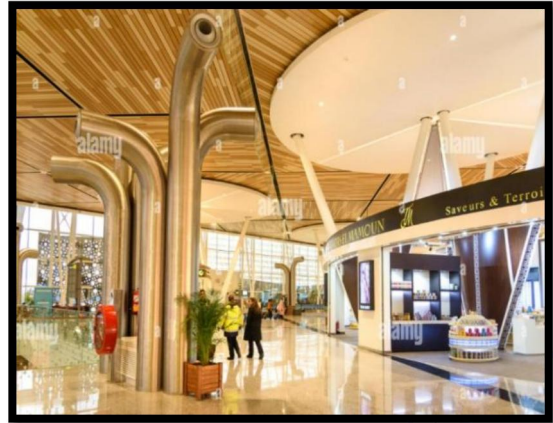


Source:[https://www.slideshare.net/banasaldhruv/the-international-airport-of-marrakech\(2022\)](https://www.slideshare.net/banasaldhruv/the-international-airport-of-marrakech(2022))





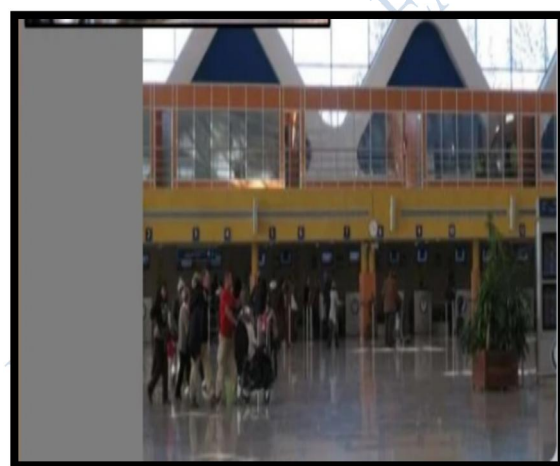
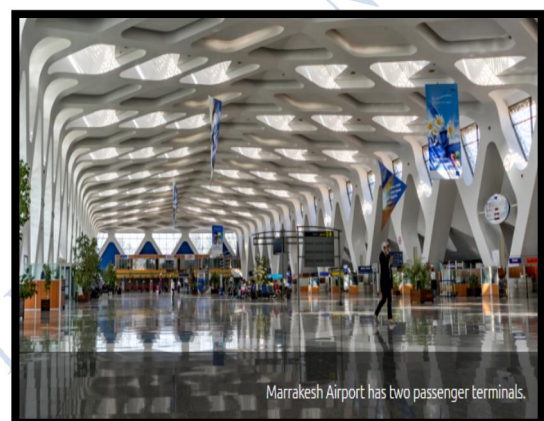
Front view



Interior view



Vehicular Access



Interior view

Back view



internal hall

### 3.8: Plates of Pictures

Source: Wikipedia (2022)

#### 3.2.4.3 Sustainable Strategies

Both active and passive green approaches are used in the design of this terminal building. Introduction of sets of lights and shadows in every one hour during the day to brighten the terminal and the use of Moroccan's purest and most traditional materials which merge smooth designed styles. The roof has overhang of 24 meters to create a patch of shade for both people and vehicles and availability of greenery around the facilities to produce good air quality.

#### 3.2.4.4 Design Appraisal

Marrakech Menara International Airport new innovation of light filter screen using arabesque to cover the window and eye contact with the outside and introduction of their tradition and religion style into the terminal design. There is provision of ramp connecting floors for reduced mobile people. Application of past and present used of materials and techniques employed to generate modernity in their design of the terminal building. Roof overhang of 24 meters at the front façade provides a patch of shade and mosaic style

#### 3.2.4.5 Critique

The provided parking space is not adequate compare to number of passengers coming in to the airport. There is no posh walkway directly from the door to the plane of the airport therefore, short walks across the tarmac to the entrance of the arrival terminal.

### **3.2.5 Shenzhen Bao'an International Airport Terminal 3, Guangdong, China**

#### 3.2.5.1 Description of the building

This airport is formerly called Shenzhen Huangtian (IATA: SZX, ICAO: ZGSZ) and serves as its province which is sited Huangtian and Fuyong villages within Bao'an

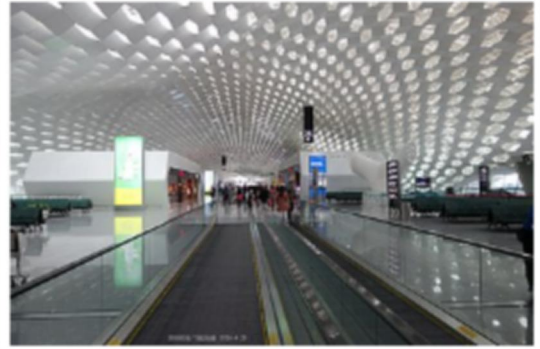
District. The concept of the building plan forms the image of a woman ray that breathes and transforms its own shape to form a celebrated bird and of a flight and it is designed by Massimiliano Doriana Fuksas. The terminal can accommodate 45 million passengers annually on five floor levels. The first floor leads to ground transportation center, the second is the arrivals hall and transfer of connecting passengers, the third floor has departure lounges, the fourth floor is the check-in area while its fifth floor is the commercial and dining hall.

Building materials used in this terminal are symbolic element especially the internal and external are double skin honeycomb motif which wraps up the building and allow in natural light creating effects of light within the terminal building. The metal used for cladding is made of alveolus shape while the glass panel is of different sizes and this can be opened halfway. Supporting columns in the terminal is characterized by white conical material from the ground to the roof level forming a cathedral.

The big stylized white trees designed to cool the terminal and the concourse mimicking the planning of amorphous forms which is inspired by nature.



Departure Hall



Interior view of new Terminal 3 in use



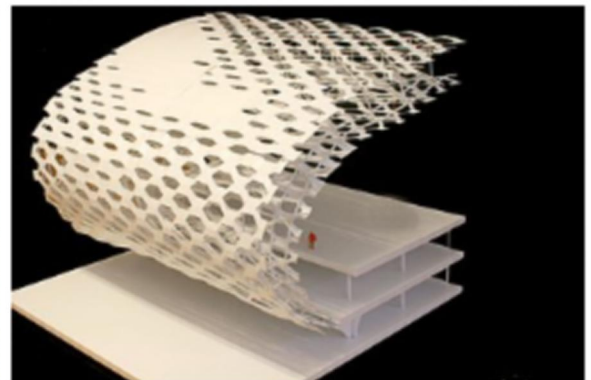
Waiting hall



Baggage Claim Hall



Building Site September 2012



Parametric developed structure and facade

### 3.9 Plate of pictures: Shenzhen International Airport interior views

Source: [https://en.wikipedia.org/wiki/Shenzhen\\_Bao%27an\\_International\\_Airport](https://en.wikipedia.org/wiki/Shenzhen_Bao%27an_International_Airport)



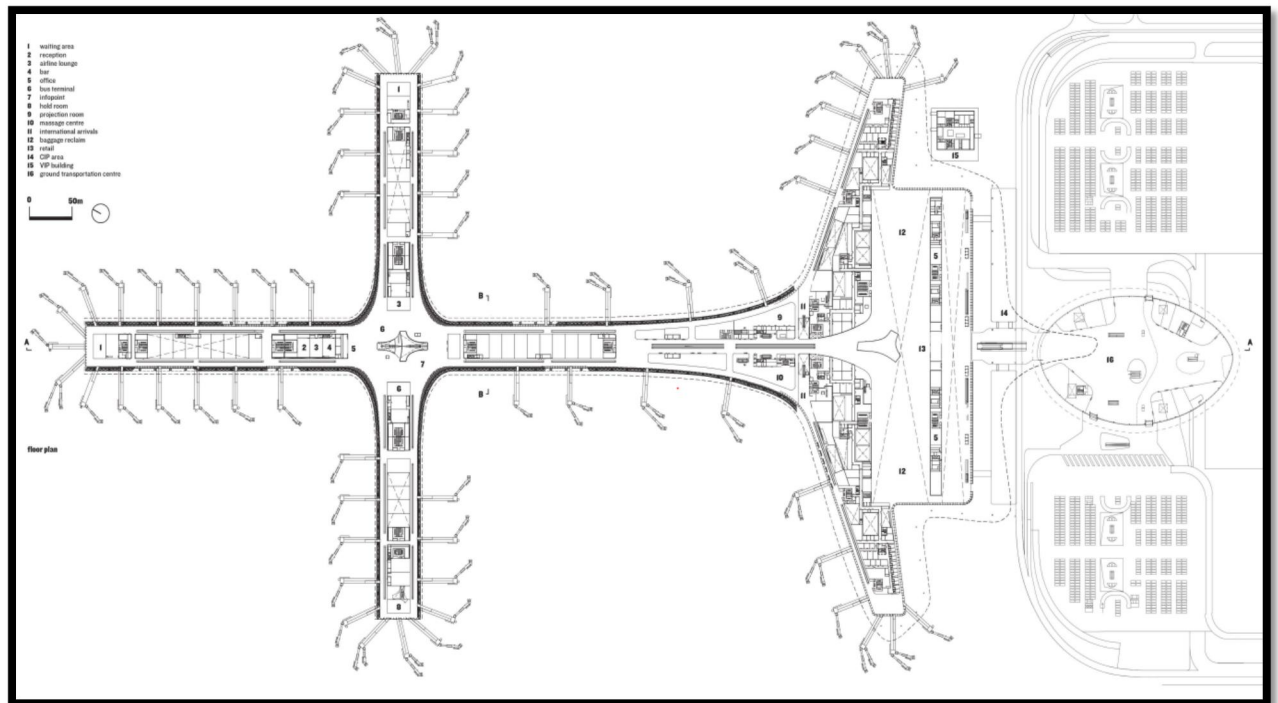


Figure 3.9a: floor level 1 Shenzhen Bao'an Airport

Source: <https://www.architectural-review.com/today/air-max-terminal-3-at-shenzhen-airport-by-studio-fuksas-architetto>

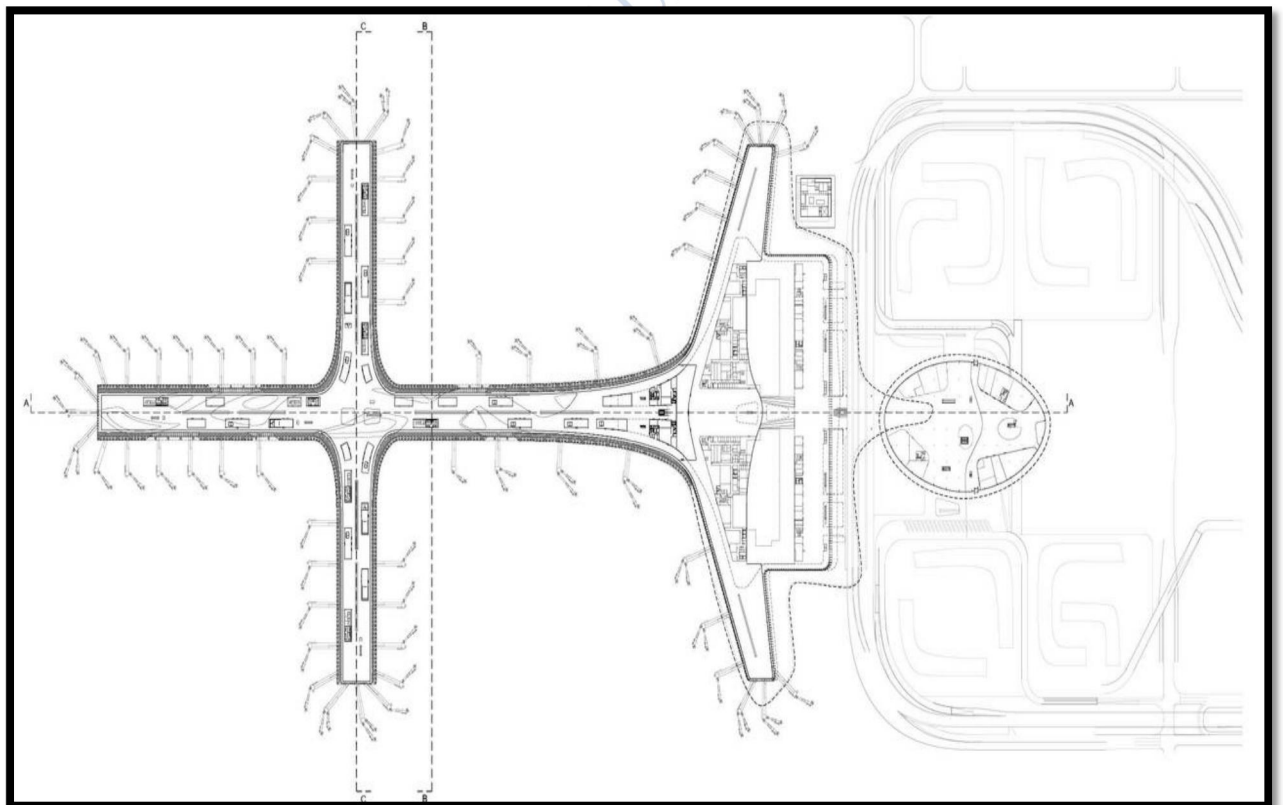


Figure 3b: floor level 3 Shenzhen Bao'an Airport

Source: <https://www.architectural-review.com/today/air-max-terminal-3-at-shenzhen-airport-by-studio-fuksas-architetto>

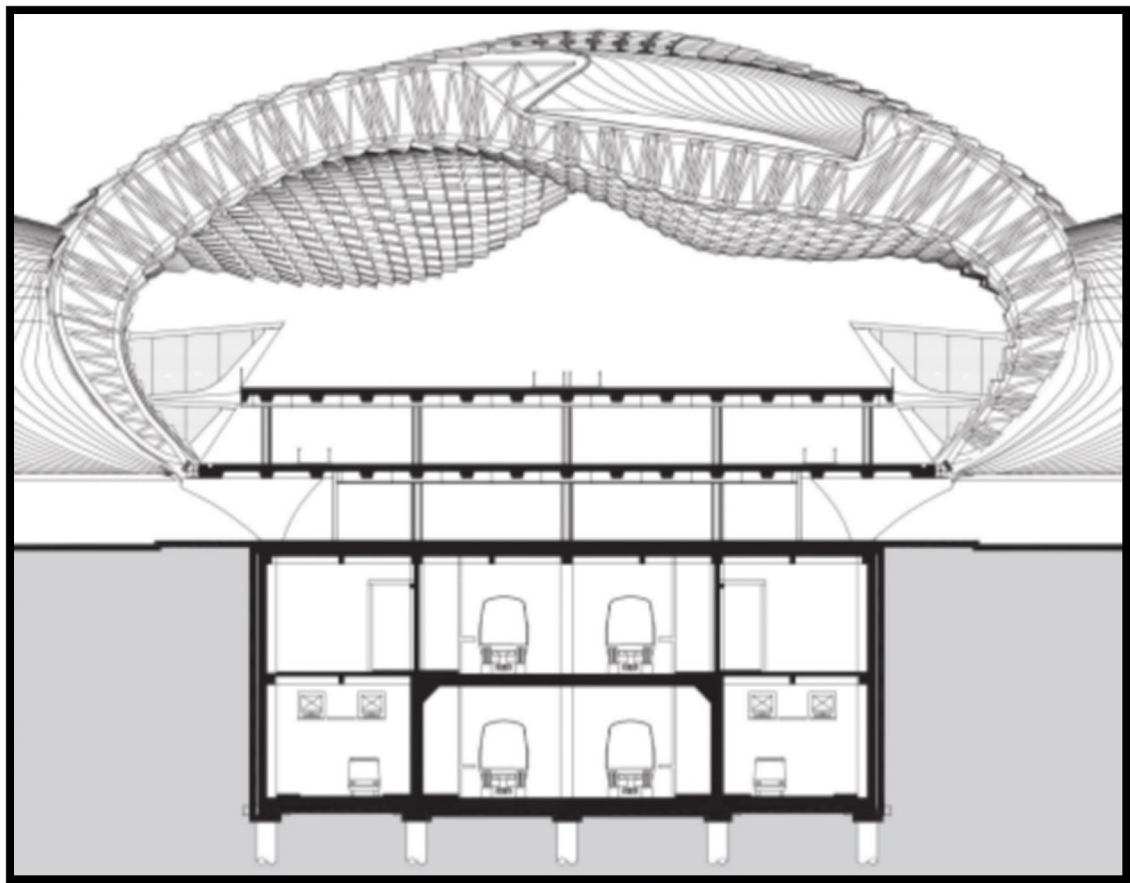


Figure 3c: section Shenzhen Bao'an Airport

Source: <https://www.architectural-review.com/today/air-max-terminal-3-at-shenzhen-airport-by-studio-fuksas-architetto>

### **3.2.6 Seymour Galapagos Ecological Airport, Ecuador**

#### **3.2.6.1 Description of the building**

Seymour Galapagos Ecological Airport (IATA: GPS, ICAO: SEGS) formerly called Seymour Airport serving the Baltra island in Ecuador built in 2012 and got the award of being the first green airport that same year. It also received award of the LEED gold certification by the United States Green Building Council and has also been able to go carbon neutral. Galapagos Ecological Airport achieved all these being 100% powered by renewable energy and is ISO 14001 certified meaning that it has worked on the identified environmental impact of airport to improve their environmental performance.

This terminal uses recycled steel tubes from operations of oil drilling and uses clean, renewable solar powered farm, wind farms, sea water desalination and other environmental innovations. It operates a non-directional beacon located at 1.0 nautical mile off the approach threshold of runway.

80% of its building materials are from old building and are recycled. Mechanical shutters are used to open or close depending on the heat and CO<sub>2</sub> level of the building. The local seawater is converted through the use of fresh water from airport desalination plant.



**Front view showing landscape**

**Side view**



**Photovoltaic panels**

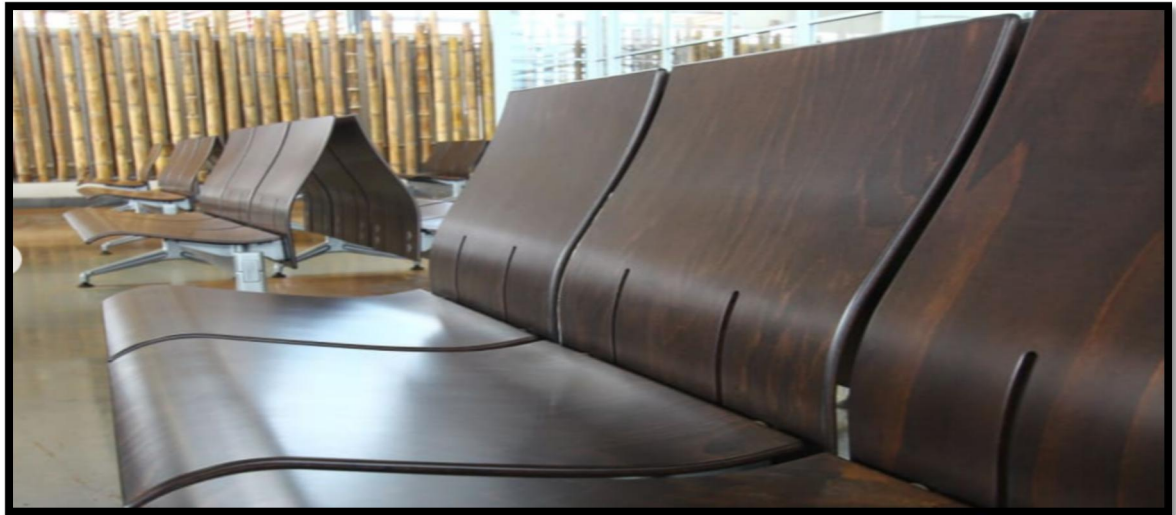


**Rear view**



**Aerial View**





**Certified green furniture**



**Wind turbine**



### **3.10 plate of pictures**

Source:<https://edition.cnn.com/travel/article/galapagos-ecological-airport-wind-and-solar-power/index/index.html>

### **3.2.6.2 Design Appraisal**

Galapagos Airport considers the environment effect having the facilities on global warming impact and initiated sustainable design strategies right from inception of its creation. The Airport had received various awards which helped to improve more on sustainability measures. Skylight was introduced to allow natural daylight in the terminal and the practice of 100% solar energy and wind turbine to power their equipment reduce the reliance of generator and energy consumption from electricity. Lightweight materials are used to make the building flexible and sustainable and these are recycled materials from old buildings.

### **3.2.6.3 Critique**

There is no addition of modernity to sustainability in the terminal building design to make it aesthetically pleasing and no signature of airport.

## **Chapter Four**

### **Site Analysis and Design Synthesis**

#### **4.1 Study Area**

Ibadan is the most populous city and the capital of Oyo State and also the third largest city by population in Nigeria with the population of 3,649,000 as of 2021. Ibadan is located in south-western Nigeria, 128 kilometers (80 mi) inland northeast of Lagos and 530 kilometers (330 mi) southwest of Abuja, the federal capital.

It lies completely within the tropical forest zone but close to the boundary between the forest and the derived savanna. The city ranges in elevation from 150 m in the valley area, to 275 m above sea level on the major north–south ridge which crosses the central part of the city.

Ibadan has a tropical wet and dry climate (Koppen climate classification Aw); with a lengthy wet season and relatively constant temperatures throughout the year. Ibadan's wet season runs from March through October, though August sees somewhat of a lull in precipitation. There are two peaks for rainfall, June and September. The mean daily temperature is 26.46 °C or 79.63 °F, the mean minimum 21.42 °C or 70.56 °F, and the relative humidity 74.55%.

##### **4.1.1. Site Location**

The proposed site by Federal Airport Authority of Nigeria for the upgrade of domestic to international standard is located along Ibadan – Ife expressway in Alakia area, Egbeda Local Government area of Nigeria.

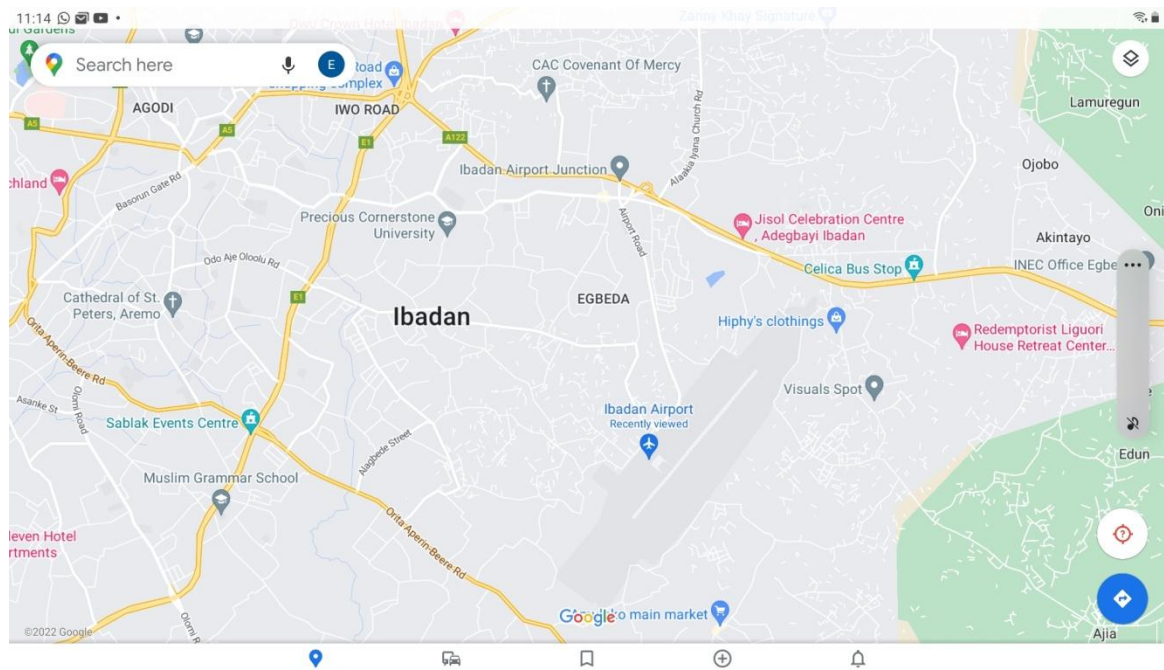


Figure 4.1: Ibadan Airport Site Location Map

Source; Google Map (2022)

#### 4.1.2 Site Selection Criteria

Ibadan Airport site at Egbeda Local Government Area, Oyo State existing facility and its site selection have met the following criteria:

- i. Availability of Land: The existing total land mass acquired for Ibadan Airport is about 557.1 hectares which can accommodate a standard international airport and has been reserved for this development.
- ii. Ideal location for airport noise level; Airports' primary activities generate noise and air pollution and thus require that airports be sited away from residence. Moreover, the site is surrounded by buffer zones internally to minimize noise impact in the neighboring communities.
- iii. Conformity with Development Plan of the Federal Government: This is in conformity with Urban Development goal of both state and federal government of Nigeria.

- iv. Availability of Land for Expansion: The site is on the extreme part of Alakia in a developing area and this provides opportunity for future expansion.
- v. Accessibility to ground transportation: Ibadan town have existing ground transportation system which reduces the high cost of construction of access to the airport. This provides different accesses to the airport from the major highway road reducing traffic congestion in town.

## **4.2 Project Analysis and Design Synthesis**

### **4.2.1 Brief Analysis**

Ibadan Airport is an existing facility basically for domestic flight from Ibadan to Abuja, Lagos to Ibadan and vice versa. This airport facility needs an upgrade from its current dilapidated state and obsolete outlook to international standard.

### **4.2.2 Brief Development**

Both State and Federal government of Nigeria have decided to expand Ibadan Airport facilities to international standard and to boost economy of the country.

### **4.2.3 Design Criteria**

The design criteria for this project are to achieve sustainable airport void of CO<sub>2</sub> or to be reduced to the minimal state.



#### 4.2.4 Conceptual Development

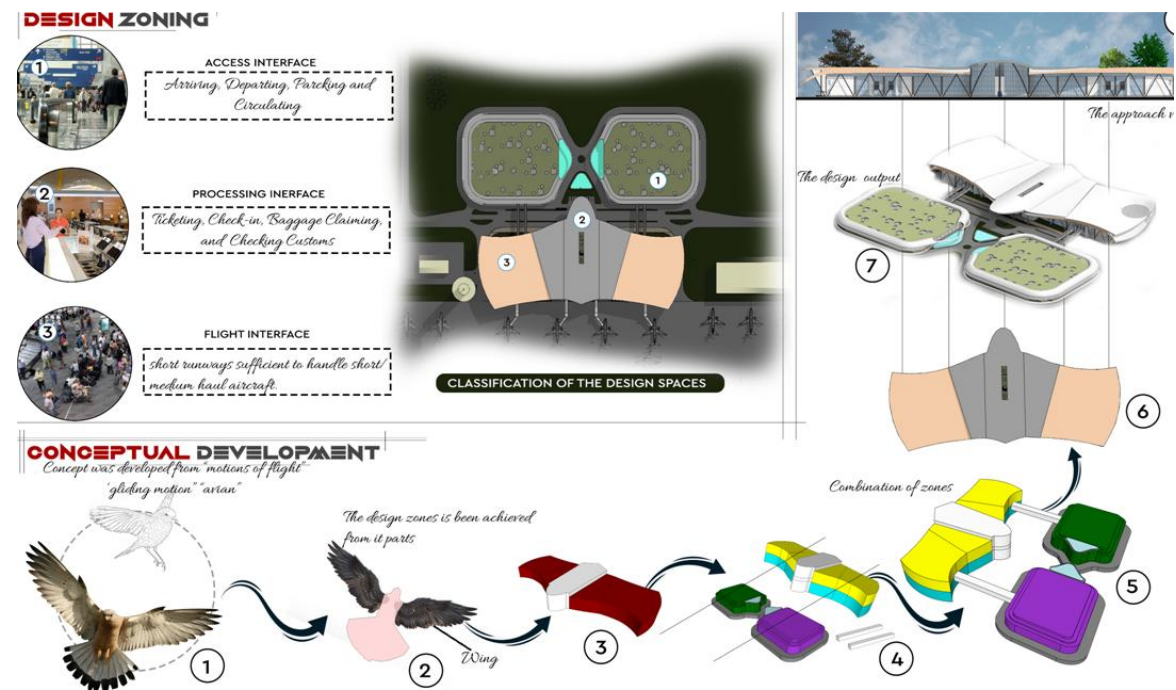


Figure 4.2: Conceptual Development

Source: Researcher field work (2022)

The inspiration of this design concept was drawn from the motion of flight of a bird by gliding. To glide means to move with a smooth and quiet motion. This is utilized to achieve ease of movement of passengers from the departure and arrivals without confusion.

#### 4.2.5 Functional Relationship

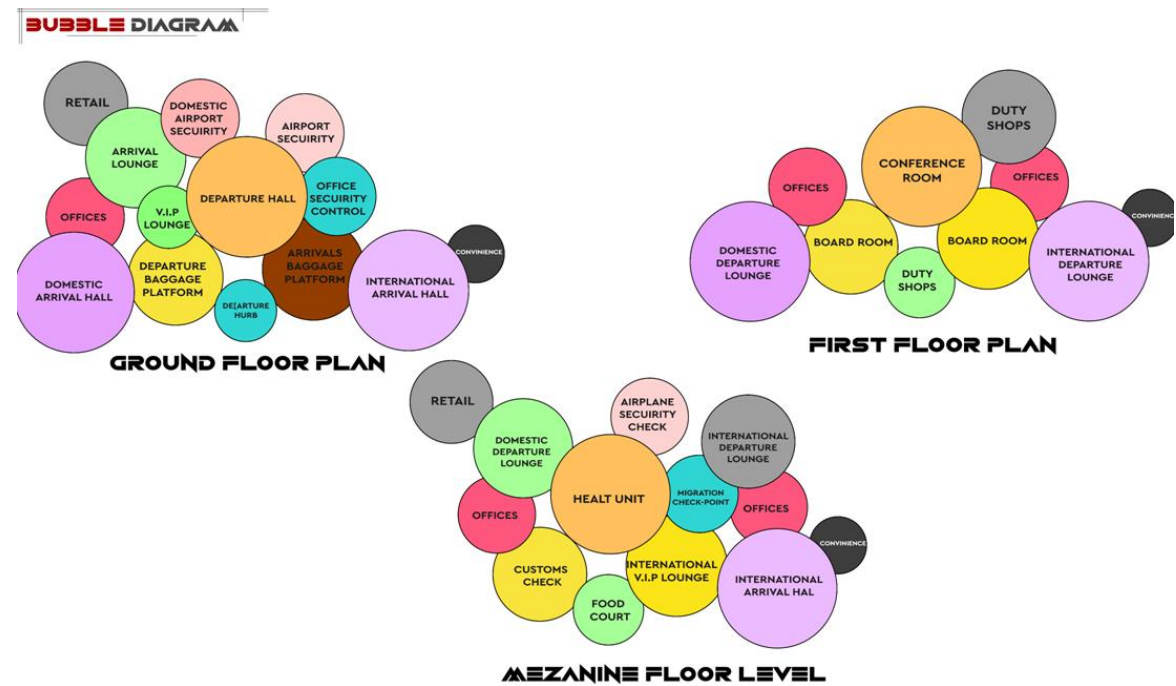


Figure 4.3: Bubble Diagram

Source: Researcher field work (2022)



Figure 4.4: Circulation flow chat

Source: Researcher field work (2022)



#### **4.2.6 Space Allocation/Schedule of Accommodation**

Departures Hall: Security checkpoint, waiting, eating, drinking, boarding airplanes, using restrooms.

Area—3240m<sup>2</sup>

Arriving Hall - greeting people, baggage claim, renting car, getting food and drinks, restrooms.

Area - 1162m<sup>2</sup>

Airline offices - record keeping, balancing receipts, scheduling flights and employees

Area - 260m<sup>2</sup>

Baggage Processing- x-ray baggage, load/unload baggage to/from planes, sorting of baggage, tractor and cart storage

Area - 1162m<sup>2</sup>

Baggage Claim- loading bags onto carousel, waiting for baggage, sorting through bags for your own.

Area - 1162m<sup>2</sup>

Restaurant/Lounge- food / drink preparation, ordering, waiting, eating/drinking, clean-up of dishes, glasses and utensils.

Area –339m<sup>2</sup>

Rental Car Counters- waiting, getting car rental, getting directions, returning rental

Area – 66m<sup>2</sup>

**Airport offices Activities** - coordinating with airlines, overseeing maintenance of facility, public relations

Area – 350m<sup>2</sup>

**Security offices Activities** - watching closed circuit monitors, making reports, temporary holding for troublemakers

Area–220m<sup>2</sup>

**Conference hall**–Meeting, seminar, lectures, conference

Area–948m<sup>2</sup>

Departure Lounge – waiting area.

Area - 4594

**Airport Board Room** - conference room, seating and conference table, presentation boards,

Area – 340m<sup>2</sup>

Duty free shop: selling and buying of gifts

Area: 612m<sup>2</sup>

#### **4.2.7 Construction Methods and materials**

##### **4.2.7.1 Methods of construction**

The construction industry itself is one of the largest consumers of minerals and natural resources. The necessity and importance of sustainability in construction has become a topic of debate because of growing concerns about global warming and the limited nature of resources.

The followings are necessary methods of constructing airport to be sustainable:

- i.** Control materials reduce waste.
- ii.** Management of waste such as waste sorting and recycling.
- iii.** Construction of eco-friendly buildings.
- iv.** Transforming old building to adapting reuse projects
- v.** Manage building sites to enhance conservation efforts.

- vi. Energy Conversation
- vii. Selecting eco-friendly and recycled materials.

#### 4.2.7.2 Material finishes

The primary consideration for the material finishes in this design are the durability, maintainability aesthetics, sustainability and durability.

### 4.2.8 Building Services

#### 4.2.8.1 Mechanical-Heating, Ventilation and cooling system

The design focuses on an integration of passive and active ventilation and cooling systems. Natural ventilation was fully allowed for in the management and airline offices. However, for the large passenger and cargo terminal halls, artificial heating, ventilation and cooling systems were installed to facilitate the quality of indoor environmental quality. Variant refrigerant flow (VRF) HVAC system was adopted in this building. The VRF is a ductless system which makes use of multiple units controlled from a central system.

#### 4.2.8.2 Electricity and Lighting services

The airport's primary power supply is PHCN from the national power grid. The entire lighting is concealed in duct pipes within the site and trunked underground. The facilities have dedicated transformers and stand by generators. With sustainability as the focus of this design, solar panels and photovoltaic cells are used to generate alternative power supply to reduce dependence on fossil fuels.

#### 4.2.8.3 Water supply

The site is serviced by water from the Benue state water board and on-site boreholes. To offset the water demands of the facilities, rain water harvesting is adopted to store water, treat and reuse it in the buildings. A water reservoir is introduced in the main terminal

building as well as several reservoirs on the site to collect water runoff from roofs, treat and use it in the building. Mechanized pressure pumps are used to facilitate the water supply and also for fire hydrants to ease firefighting.

#### 4.2.8.4 Fire safety

Fire detecting equipment's such as fire alarm and smoke detectors are used in the buildings. Also, fire extinguishers and hydrant pipes are located in strategic areas to ease firefighting issues. In addition to these strategies, a dedicated firefighting facility with all the necessary equipment's is designed.

#### 4.2.8.4 Building maintenance

Airports are very busy and energy intensive buildings hence it is imperative to have a proper maintenance plan. The maintenance plan drafted includes planned preventive maintenance that will be carried out daily, monthly and annually.

#### 4.2.8.5 Waste management system

For solid waste within the buildings and around the airport vicinity, cans and baskets are placed around the site and channeled through a chute to the central system. Liquid waste from airside activities is channeled through underground pipes to the central sewage treatment system.

#### 4.2.8.6 Security

Surveillance systems are installed in and outside the building to assist human security efforts.

#### 4.2.8.7 Signage, way-finding and advertisement

All signage's and advertisement boards are properly fastened, mounted on the surfaces at a reasonable height above ground level. Also, hardware not exposed and the patterns are repeated with in a symmetrical order, and have antiglare, matte finish screeds.

## **Chapter Five**

### **Conclusion**

#### **5.1 Project Proposal**

The proposed Ibadan Commercial International Airport consists of both Domestic and international wings accommodated in a single terminal building in a linear centralized concept which makes it economical, compact and allow passengers to maximally utilize all the facilities designed for them. It has short walking distance for ease of passengers' movement. It has 4 boarding bridges, 6 carousels, duty free shops, airline offices, conference halls, board rooms, food court/restaurants, and many other facilities.

#### **5.2 Conclusion**

In conclusion, this project will therefore make our environment healthy and thus reducing maximally carbon emissions and physiological wellbeing of man will be boosted.

#### **5.3 Recommendations**

1. Healthy positioning of landside and airside.
2. The walking distance between curbside and the gate should be minimum to ease traveler's movement. If the distance traveled exceeds 1000 feet, lift, escalator, and any other automatic means of moving people should be provided.
3. Passenger's feeling and Comfortable temperature
4. Pier or Linear terminal concept offers better configuration than transporter or transport terminal.
5. Performance standards of facilities must be analyzed and designed to enhance optimum performance.

6. Signage and zoning of facilities must be considered to ensure free flow of new passengers around the airport.
7. Green plants
8. Proper orientation of the building is relative to routes of sun which provides natural internal light while maximizing passive and active solar active improvement to obtain sustainability goals.
9. Functionality and practicality of design and financial activities
10. Maximum usage of current facilities.
11. Traffic peaking characteristics must be forecasted to ensure that facilities provided are adequate.
12. Future growth design must be flexible to accommodate future expansion.
13. Retail spaces should be designated to ensure passengers' comfort.
14. Flexibility of maintenance is required to meet future needs.

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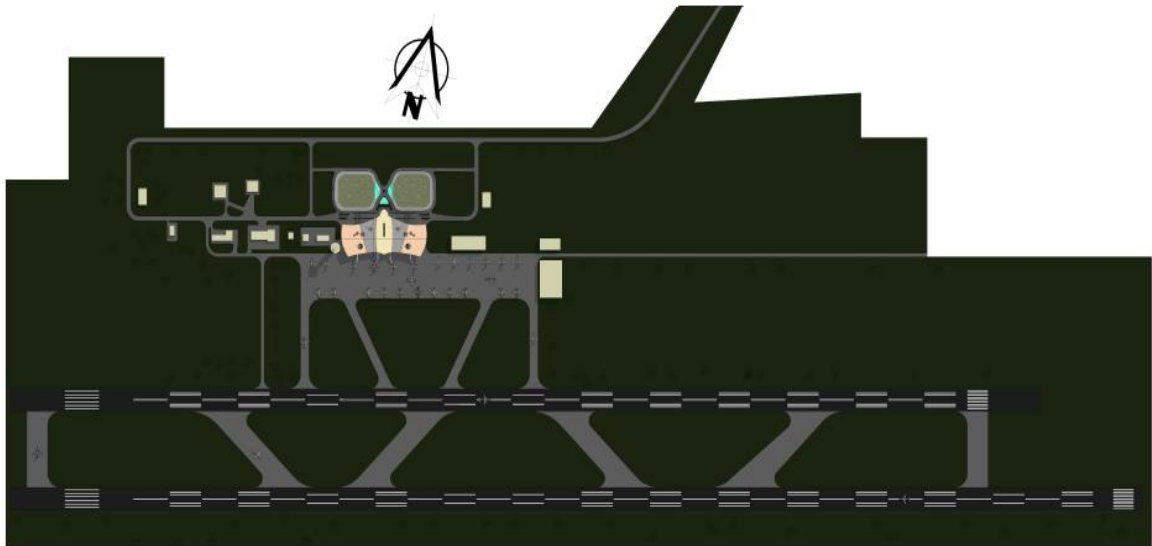
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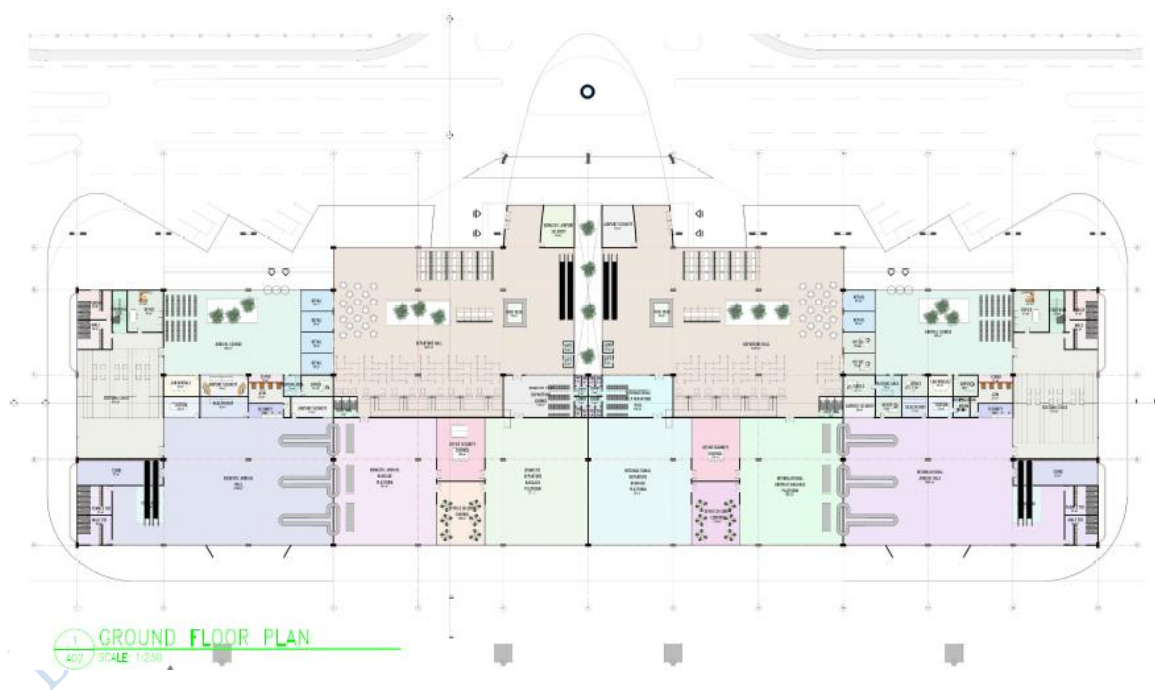
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## Appendixes

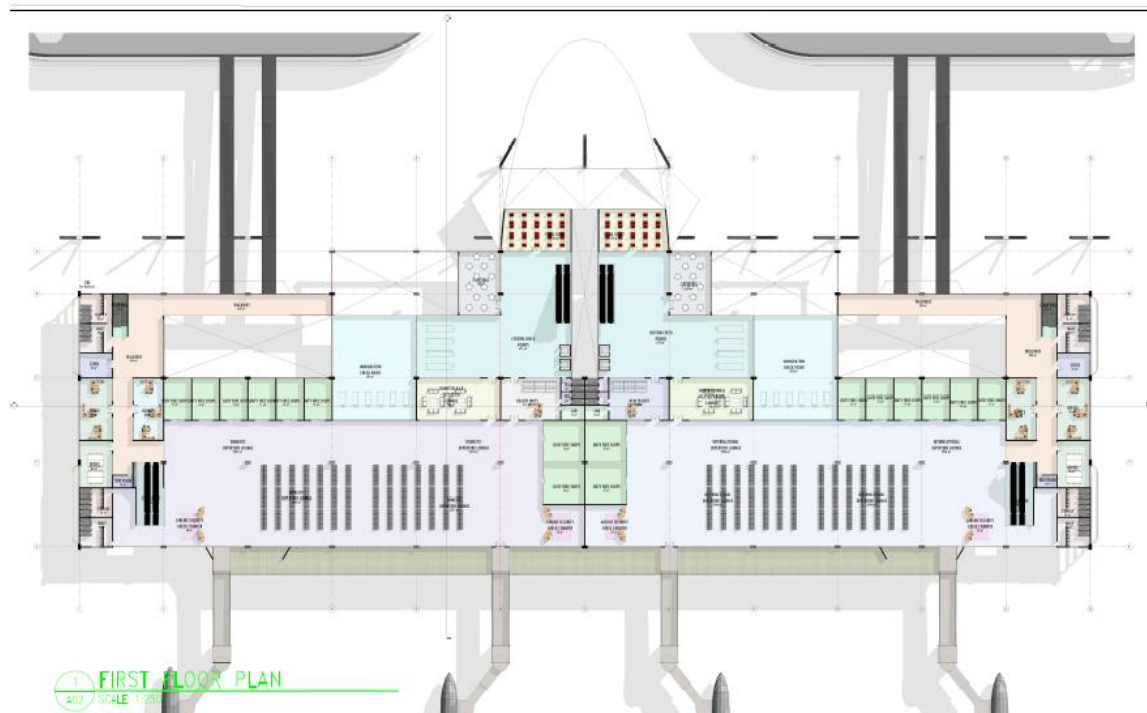


Site Plan

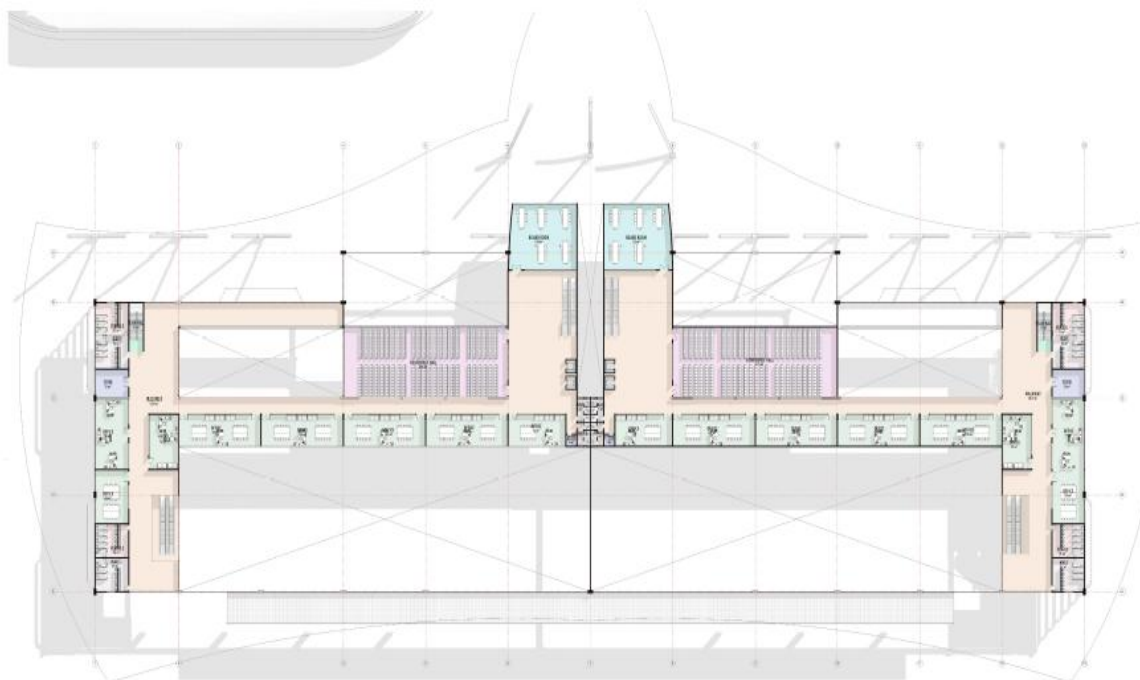


Ground Floor Plan

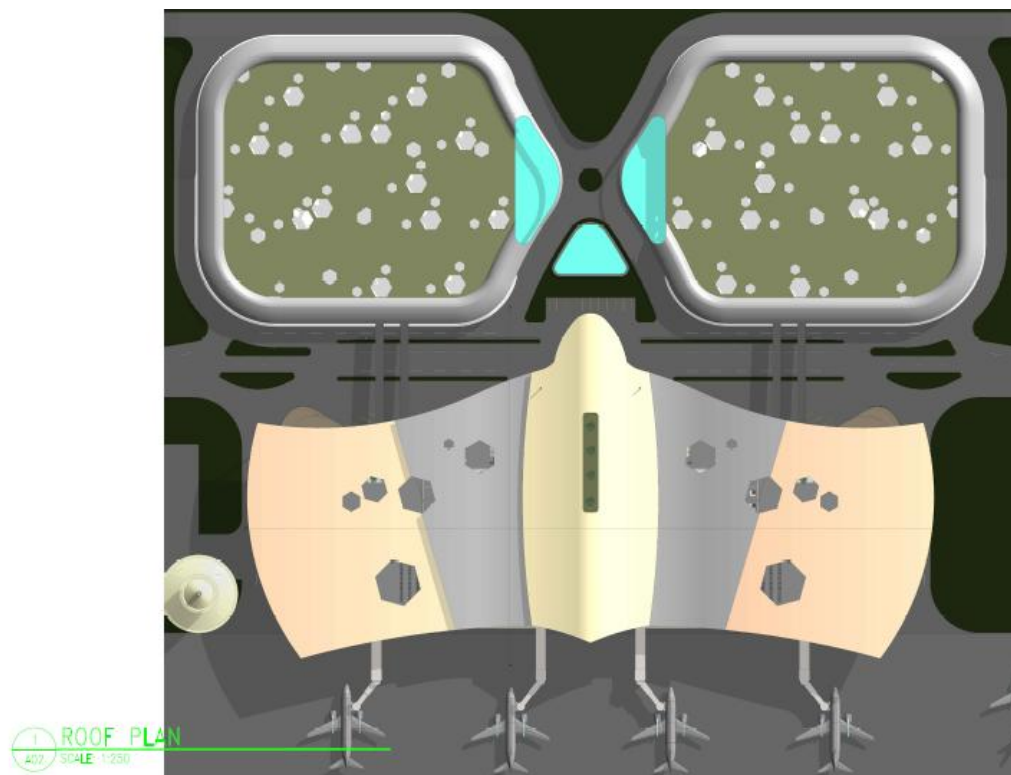




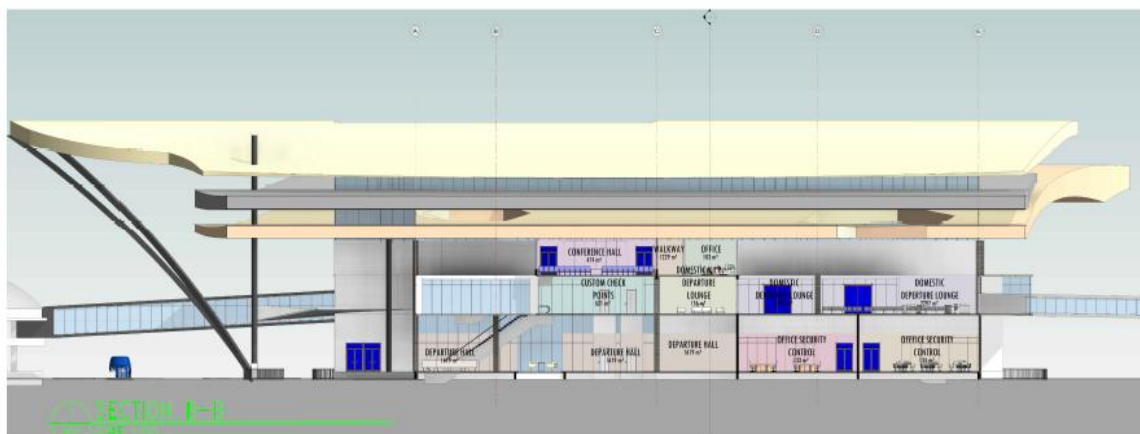
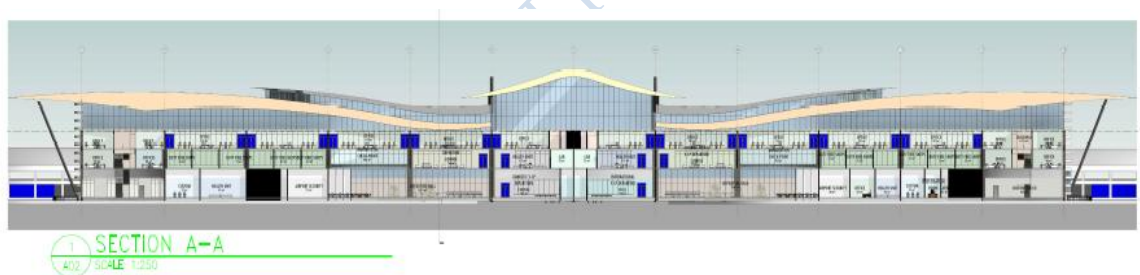
First Floor Plan



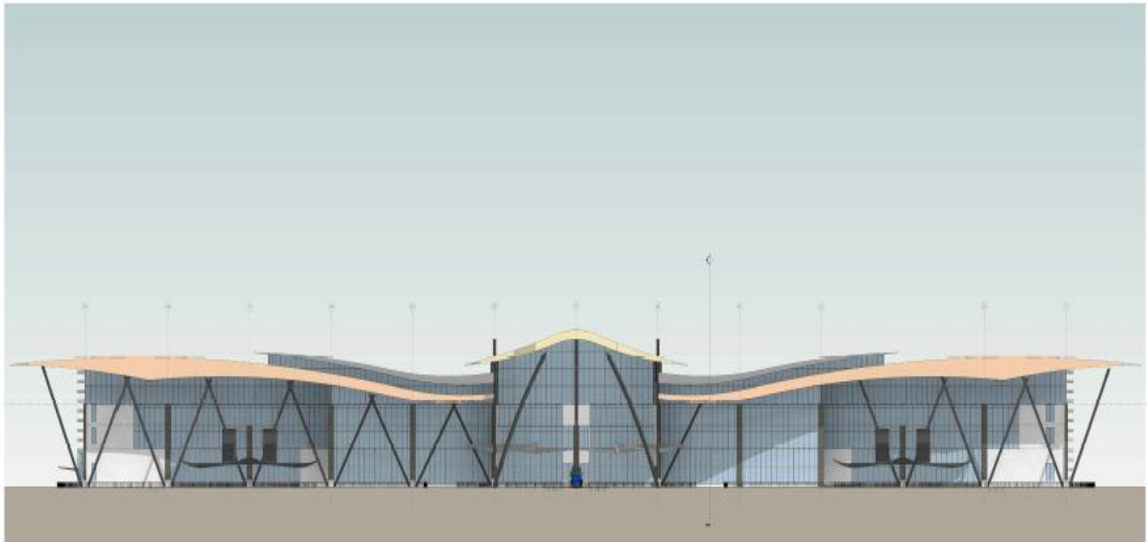
Second Floor Plan



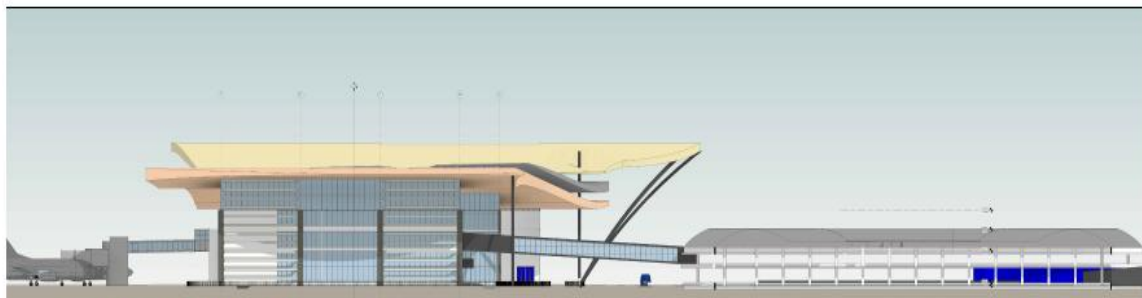
Roof Plan



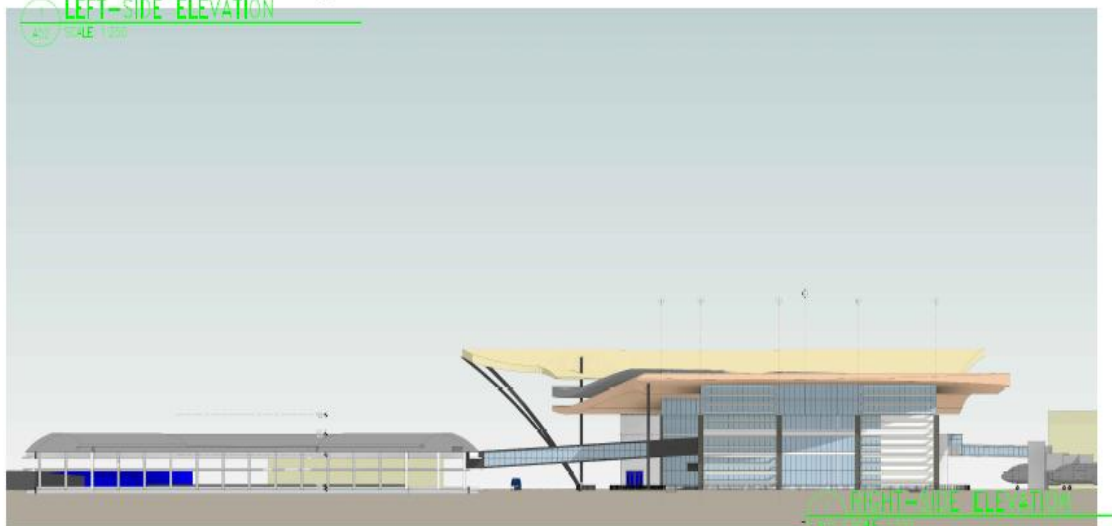
Sections



Front Elevation



LEFT-SIDE ELEVATION  
SCALE 1:200



RIGHT-SIDE ELEVATION

Elevations

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