SPATIAL ANALYSIS OF THE THREAT OF POTENTIAL AERODROME OBSTACLES ON FLIGHT SAFETY OPERATIONS, IN MALLAMAMINU KANO INTERNATIONAL AIRPORT, KANO-NIGERIA

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DEPARTMENT OF GEOGRAPHY
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MAY, 2016

DECLARATION

I declare that this dissertation entitled **"Spatial Analysis of the Threat of Potential Aerodrome Obstacles on Flight Safety Operations, in MallamAminu Kano International Airport, Kano-Nigeria"** has been carried out by me in the Department of Geography. The information derived from the literature was duly acknowledged in the text and referenced. No part of this dissertation was previously presented for the award of another degree or diploma in this university or at any other institution.

Audu IBRAHIM _____ _____

Signature **Date**

CERTIFICATION

This dissertation entitled **"SPATIAL ANALYSIS OF THE THREAT OF POTENTIAL AERODROME OBSTACLES ON FLIGHT SAFETY OPERATIONS, IN MALLAMAMINU KANO INTERNATIONAL AIRPORT, KANO-NIGERIA"** by Audu IBRAHIM meets the regulations governing the award of the degree of Masterof Science in Remote Sensing and GIS of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

Prof. I.J. Musa Chairman, Supervisory Committee	_____ (Signature)	_____ Date
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DEDICATION

This dissertation is dedicated to Almighty Allah (S.W.A).

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ABSTRACT

The study focuses on the spatial analysis of the threat of potential Aerodrome obstacles on flight safety operations, in the study area. The safety of travelling by air is an absolute pre-requisite for air transport, as it is recognized as a very safe and fastest mode of transportation worldwide. The safety of an aircraft around the vicinity of an aerodrome during approach, take-off and taxing around the maneuvering area is very critical and of tremendous significant in flight operations.Quick Bird satellite images, coordinates from field survey using Differential Global Positioning System (DGPS) and administrative map of the study area, were some of the materials/data used for the study. Average nearest neighbor statistics was utilized to analyze the spatial patterns of distribution of the identified aerodrome obstacles.Level of conformity of the location of the aerodrome obstacles with the International Civil Aviation Organization (ICAO) standards and recommended practices (SARPS) was determined by characterizing the obstacles into authorized and unauthorized obstacles. The research findings identified eight (8)types obstacles which include antennas, trees, buildings, instrument landing systems (ILS), communication mast, hill, pole and concrete pillar that penetrates into different obstacle limitation surfaces within the study area. The result further revealed that60.0% of the obstacles atMAKIA aerodrome were communication masts, 26.7% are made up of the instrument landing system (ILS).14.8% of the obstacle constitute of trees, 3.0% of the obstructions were buildings, while antenna, concrete pillar, hill and pole contributes 1.5%, 1.5%, 0.7% and 0.7% respectively.The result also indicated that the obstacles on the approach surface, runway, inner horizontal surface, conical surface and transition surface were clustered, while those obstacles on the take-off climb and the outer horizontal surface were dispersed. It was also observed that 147 obstacles lies within the study area, of which only 41 were authorized obstacles, and these obstacles were found on the runway and transitional surface, and are basically Lighting/ ILS for an aircraft approaching the runway. On the other hand, the study revealed 106 unauthorized obstacles, most of them found on the inner horizontal surface. The conical surface has 14 unauthorized obstacles, the runway and transitional surface have 12 unauthorized obstacles while the approach, take-off climb and the outer horizontal surface have 9, 2 and 2 respectively. In view of the threats / risk posed by the identified obstacles, efforts should be made by all the Aviation Stake Holders to keep the study area and of course all the airports free of obstacles that may have direct or indirect operational significance to the safety of an aircraft, so that flight safety operations can be adequately enhanced.Consequently, based on the findings of these studies. It is recommended that Nigeria being a member state of ICAO, should as a matter of urgency be ICAO e –TOD compliant (Electronic, Terrain and Obstacles data). As this will go a long way in checking the menace of Aircraft / Obstacles collision to the barest minimum, so as to ensure regularity, efficiency and above all safety in Aviation Industry.

TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Transportation is the movement of people, animals and goods from one location to another (Blanchard, 1996). Modes of transport worldwide include air, rail, road, water, cable, pipeline and space. Transportation as embedment can be divided into infrastructure, vehicles and operations. Transport is important because it enables trade between persons which is essential for the development of civilizations. Transport infrastructures consists of the fixed installations such as roads, railways, airways, waterways, canals, pipelines and terminals. such as airports, railway stations, bus stations, warehouses, trucking terminals, refueling depots and seaports (Blanchard, 1996). Terminals may be used both for interchange of passengers and cargo and for maintenance; Vehicles travelling on these networks may include automobiles, bicycles, buses, trains, trucks, people, helicopters, watercraft, spacecraft and aircraft. Operations deal with the way the vehicles are operated, and the procedures set for this purpose. In the transport industry, operations and ownership of infrastructure can be either public or private, depending on the country and mode of operations(Blanchard, 1996).

Aviation industry (Air transport system) is a critical component of our national economy providing for the movement of people and goods throughout the world, which is also critical for economic growth. It is a fast growing sector of the economy, providing a number of social and economic benefits (Whitelegg, 2000). According to International Civil Aviation Organization ICAO (2001). Aerodrome is a defined area on land or water (including any buildings, installations and equipment) intended to be used either wholly or in part for the arrival, departure and surface movement of aircraft. While, Aircraft is any machine that can derive support in atmosphere from the reactions of air other than reactions of air against the earth's surface.

The safety of travelling by air is an absolute pre-requisite for air transport. Air transport is recognised as a very safe and fastest mode of transportation, even of recent there some challenges (Euro-control: Challenges of Growth study, 2008). South Africa-Civil Aviation Regulation SA-CAR (1997:12) stated that, "No person shall, through any act or omission endangers the safety of an aircraft or person therein, or cause or permit an aircraft to endanger the safety of any person or property". As navigable airspace, where "heavier than air" craft can operate, it means that any obstacle, anywhere, need to be evaluated. The main reason of evaluating such obstacle according to ICAO is to control or prevent structures that could have a serious effect on aviation safety, especially in the vicinity of an aerodrome.

Sebastian, Sanjiv, Lyle and Mike (2008), observed that the threat on some of the aircrafts flying at low altitude such as aerial vehicles (UAVs) to operate at high altitude, have to be under a close human supervision at low altitude, this is because even a low-speed collision within the environment can be fatal.

Green, Sevcik and Oh, (2005) argued that, unmanned aerial vehicles (UAVs) performing reconnaissance survey for the police, news or the military must fly at low altitude. Sebastian *et. al.* (2008) pointed out that flying close to and among obstacles is difficult because of the challenges in sensing and observing small obstacles, also controlling a complex system to avoid obstacles in three (3) dimensions is usually difficult. Some aspects of collision avoidance are easier for air vehicles than ground vehicles. Any object close to the intended path of an air vehicle must be avoided as opposed to ground vehicles where deviations from the nominal ground plane indicate obstacles and are often not visible until they are close. The use of helicopters, rather than fixed wing aircraft also helps in case of any eventuality, because it is possible to come to a hover in front of an obstacle. The availability of appropriate sensors, logistical issues of mounting a vehicle

with sufficient sensing, computing and communication gear. This could be seen January, 2015 in France which led to the closure of two out of the four runways at the Charles de Gaulle international Airport. The two runways were shut down due to the fact that the police helicopters were operating at a very low level in an attempt to track the suspects of the Charlie Hebdo incidence in France (Jim, 2015).

The safety of an aircraft around the vicinity of an aerodrome during approach, take-off and taxing around the manoeuvring area is very critical and of tremendous significant in flight operations. A high-rise building, a series of wind turbines, electricity poles, communication mast, hills, mountains are fixed obstacles that affects the safety of aerodrome traffic and poses dangers to flight operations (Peter and Vander,2008).

South African Civil Aviation Regulation (SA-CAR), 2015 stated that any communications structure, buildings, whether temporary or permanent which has the potential to endanger the navigable airspace, or has the potential to interfere with the operation of navigation, surveillance systems, instrument landing systems and meteorological systems are referred to as Obstacle. Obstacles in the vicinity of an airport, whether they are natural or constructed, may seriously limit the scope of aviation operations into and out of the airport. It is essential that off-airport land use planning take full account of obstacles implications.An airport's obstacles limitation surface (OLS) is determined in accordance with ICAO (1987).

The most important role of aerodrome obstacles limitation surfaces (OLS) is to set and supervise the maximum height that an obstacle around an airport is allowed. This is usually referred to as Inner Horizontal Surfaces (IHS) or Conical Surface. The inner Horizontal Surfaces (IHS) is a circular surface, which has a height of 45m with a radius ranging from 2 to 4km, depending on the runway reference length. The conical surface slopes outward from the IHS with a slope angle of 5% up to a runway reference length.

Where, one of these surfaces is protruding, an aeronautical study should be carried out to ensure that the obstacles do not affect the safety and regularity of operations to/from the airport (Teuge, 2009).

Civil Aviation Act (2006) defined the airspace around the aerodromes to be maintained free from obstacles so as to permit the intended aeroplane operations at the aerodromes from becoming unusable by the growth of obstacles around the aerodromes. In Nigeria, Nigerian Civil Aviation Authority (NCAA) is empowered to prohibit and regulate installation of any structure which by virtue of its height or position is considered to be an obstacle to safe operations.

It is imminent to mention that MallamAminu Kano International Airport (MAKIA) has been witnessing a lot of construction activities in and around the vicinity of the airport which may become obstacles to flight operation.

1.2 STATEMENT OF THE RESEARCH PROBLEM

In most developing countries particularly Nigeria, several plane crashes were recorded resulting from collision with obstacles within the vicinity of an aerodrome. For example in June 1996, a plane crash occurred at Jos airport resulting from collision of an aircraft with acommunication mast which led to loss of lives and property (Kurawa, 2009). Also, Sky Executive Aviation Services crash on the approach to Calabar Airport on 21st May, 2002 (Federal Ministry of Aviation, 2015). Another serious incident involving a Baggage tractor (DOUGLAS) Towing tug on the ramp collides with the aircraft while taxing at MurtalaMuhammed International Airport, Ikeja-Lagos, in January, 2008 (Accident Investigation Bureau, 2015).

From the field survey, it was observed that a lot of infringement and new construction has be done around the vicinity of airport, which may be an obstacles and menace to low flying aircraft in and around the vicinity of MAKIA. This may not be unconnected with

increase in the rate of urbanization and human activities taking place in Kano and its environs.

Thomson (2007) carried out a research on cost effective Grassland Management strategy to reduce the number of Bird strikes at the Brisbane Airport, Australia. The Data used for the study are mainly, Maps of Brisbane Airport showing each habitat type which is divided into 250mx250m to allow reference points to be located at least 250m apart in close habitat and 500m apart in open habitat. The result of the study showed that, the habitat compared within Brisbane airport boundaries, grasslands surrounding runways, taxiways and aprons possesses the greatest richness and abundance of bird species that pose the potential hazard to aircraft operations. Also, Ibis and Australian Kestrel were identified as the bird species that poses risk to aircraft at Brisbane airport.

Peter and Vander (2009) also carried out a research on the spatial variation on flight safety between the existing pylons and two optional routes for the new transmission line around Schiphol in Geval Van, Germany. The result of the research opined that the two routes plays same role in the movement of aircraft in and around and the chance of collision with birds are deem to be insignificance.

Jinfeng and Herricks (2010) conducted a research on bird aircraft strike threat assessment using Avian Radar Information at New Jersey airport, USA. The study made use of Accipiter Avian Radar Technologies, Inc., 25 kW, X-band marine radar operating at 9.4 GHz with a wavelength of 3cm. The result of the study revealed that, the changing pattern of both bird activity and threat density in four target areas (A,B,C and D) in 24hr period were similar. However, daily variation may be influenced by factors other than bird activity at day time and at night, like weather and wave action.

Anastasiosis (2002) worked on Bird strikes risk assessment using GIS, at Athens International Airport, South Africa. The research made use of the study includes: the

observation of the Airside Monitoring and Inspection team (AMI) that performs routine and non-routine inspections on air fields concerning the status of the runways and taxiways. The findings of the study found a temporal variation of the bird strikes for example, during the first Month of the year the majority of the birds contributed to bird strike risk were water fowl, with a significant contribution from starlings and a minor one of gulls. In spring and the beginning of summer, gulls bird species participated in the bird strike risk. From mid-Summer to mid-Autumn, it was raptors bird species that posed the highest risk. During the two last months of the year the contribution of starlings to the bird strike risk was the most significant.

Dukiya and Gahlot (2012) carried out a research on the evaluation of the effect of bird strikes on flight safety operations at MallamAminu Kano International Airport, Kano. The study made use of aviation safety ranking value (ASRV) to evaluate and rank the risk of bird strikes species. Their result concluded that a significant number of varieties of bird species were observed in the vicinity of Kano airport and the propensity of these birds to collide with aircraft is real and this is a menace to the aviation industry.

Ahmed (2011) conducted a study on the assessment of the effect of birds strike on flight safety operations in MallamAminu Kano international airport Kano, Nigeria. The result of the study came to conclusion that twelve of the bird species were involved in forty four (44) strikes at the airport during the period 2001-2010. The study also revealed that most of the strikes occurred during the rainy seasons from May- October. Distribution of the bird strikes by phase indicates that 32% occurred on approach, 25% on landing roll, 20% on take-off, 4.5% on descend, 4.5% during climb, while 14% of these strikes the phase is unknown.

However, it is of interest to note that, to the best of the researchers knowledge despite the potential risk pose by the Aerodrome obstaclesnone of the previous studies have

focusedon the spatial analysis of the threats of potential fixed aerodrome obstacles on flight safety operatioDn in the study area. This became necessary because of the increase in the rate of urbanization that Kano is experiencing in recent years, led to construction of more buildings and other human activities taking place within the vicinity of the airport. This is the gap in knowledge that the present research intends to fill. The following form the basic research questions for this study:

1) Where are the potential aerodrome obstacles located in the study area?
2) What is the spatial pattern of distribution of the potential aerodrome obstacles in the study area?
3) What are the characteristics of the potential aerodrome obstacles as relates to ICAO standards and recommended practices?

1.3 AIM AND OBJECTIVES

The aim of the study is to analyse the spatial threat of potential aerodrome obstacles on flight operations in the study area. The aim will be achieved through the following specific objectives:-

i. define, identify and map out the potential aerodrome obstacles on flight safety operations in the study area.
ii. determine the spatial distributionpattern of the potential aerodrome obstacles on flight operations in the study area.
iii. characterize the potential aerodrome obstacles as relates to ICAO Standards and Recommended Practices (SARPS)

1.4 SCOPE OF THE STUDY

The study area is in Kano state. It is designed to cover MallamAminu Kano International Airport (MAKIA) Kano and its immediate environment (i.e. 10 nautical miles from the aerodrome reference point). The study was carried out to map and determine the pattern of the obstacles within the aerodrome based on the field survey data collected in 2015. Also, the study is limited to aerodrome traffic control zone which comprise the approach, take-off and taxing aircraft within the manoeuvring area of the aerodrome.

1.5 JUSTIFICATION FOR THE STUDY

This study is borne out of the contention that safe flight is essential for wide spread acceptance of aircraft that must fly at low level. In a report issued in 2001 by the Advisory Council for Aeronautic Research in Europe (ACARA). It was predicted by 2020, air traffic will triple with respect to 2000. This implies that airport will continue to get bigger and busier and that the number of aircraft movement will increase. This will make it harder to ensure safe separation between aircraft and surrounding objects/features at low level. ACARA (2001).

The most congested and critical stage in flying are those flights in the approach (landing aircraft), take off (departing aircraft) and taxing aircraft within the manoeuvring area of the aerodrome. This is a very dynamic situation with several aircraft approaching, departing and taxing in and out of its stands, as parked aircraft being refuelled, loaded/unloaded and boarded simultaneously. Aircraft are situated very close to each other, making it demanding to manoeuvre in such confined spaces. Taxiways are also very busy, with multiple aircraft moving between the runway and the ramp and queuing to enter the runway. Different types of obstacles can be found on the vicinity of an aerodrome, these may include fixed structures such as, electric poles, trees, hills,

mountains, hangers, construction equipment and terminal buildings, etc.Prinzel and Parish (2000)

In such a crowded environment, aircraft/fixed aerodrome obstacles collision are minimised by designing airports, operating procedures and avionics systems in such a way to ensure appropriate separation between an aircraft and fixed aerodrome obstacles. Hence, the need for this study becomes imperative. Kano is selected as the study area because Kano being commercial nerve centre in the northern part of the country and the role MallamAminu Kano International Airport plays in both domestic and international flight operation in the region.

CHAPTER TWO:CONCEPTUAL ISSUES AND LITERATURE REVIEW

2.1 INTRODUCTION

This chapter discusses the conceptual issues related to aerodrome obstacles, application of Geographic Information Systems (GIS) in aerodrome obstacle mapping. Related literature were reviewed concerning ICAO standard on aerodrome obstacles limitation surfaces (OLS) and bird strikes

2.2 CONCEPTUAL ISSUES

2.2.1 Aerodrome Mapping

Aerodrome is defined as area on land or water (including any buildings, installations and equipment) intended to be used either wholly or in part for the arrival, departure and surface movement of aircraft. The term aerodrome is used in this sub-section include: aerodromes, heliports, vertiports, and sea-plane aerodromes. As future applications are developed, more stringent data numerical requirements may be required. Aerodrome mapping data originators and integrators are urged to use this information when providing those data to system designers and users Civil Aviation Act (CAA, 2008).

Based on the availability of one standardized aerodrome mapping database (AMDB), a wide variety of applications can be envisioned. It is important to note that multiple user classes can benefit from using these databases, including: pilots, controllers, aerodrome managers, and aerodrome emergency/security personnel. The following is the application of standardized aerodrome mapping database (AMDB):

a) Runway operations

b) Emergency and security service management

c) Surveillance and runway incursion detection and alerting

d) Aerodrome surface guidance and navigation

e) Aerodrome facility and asset management

f) Route and hold-short display and deviation detection and alerting

g) Chart information

h) Display of digital ATIS information

i) Aerodrome and airline resource management

j) Training (flight simulation)

2.2.1.1 Characterization of Aerodrome Mapping

Unlike terrain databases, which are typically represented as grid points with associated elevation data, aerodrome databases are typically constructed from a photogrammetric image that is converted to vectors and assigned themes and attributes using GIS techniques. This is because many important data elements are features and not just elevations. These features are more easily characterized by points, lines, and polygons. Examples include runway edges, hold points, and stand locations. In other words, in AMDBs, not only should the aerodrome surface be properly represented (as is done in terrain databases), but also all existing natural or man-made objects (features) should be properly characterized (CAA, 2008). The use of vector-based data has several advantages:

- Small data storage requirement
- Easy use of a relational database structure
- Easier updating
- No need of feature recognition software
- Easy attachment of attributes

Consequently, it is recommended that vector-based data (points, lines, and polygons) be used for the characterization of aerodrome features in AMDBs. An alternate approach is to use raster data or imagery. Using this approach, features are portrayed via contiguous

pixels of equal or similar density number. This less precise method may be acceptable for some applications.

Aerodrome surface data, unlike terrain data, represents regular geometric objects that can be grouped or classified. Examples of classifications are: runways, taxiways, service roads, localizer antennas, glide slope antennas, buildings, radar sites, radio navigation facility sites, etc. All of these can be described with their own set of attributes, most of which are related to horizontal positioning. These attributes combine to provide a set of aerodrome data requirements that are distinguished from those of terrain data. This distinction must be recognized and preserved, since more attributes will be required to appropriately create the aerodrome images for use by different users including flight crews.

The array of attributes used to describe aerodrome features is not complete. It is imperative, to reduce the cost of systems that use the aerodrome data, to use standard representation classes and attributes. It is the intent of this document to define these requirements.

2.2.1.2 Aerodrome obstacle data

Aerodrome obstacles penetrate a defined obstacle identification surface. In determining obstacle data requirements, certain accuracy parameters are applied to construct buffers around obstacles and estimate whether they penetrate the defined surface. Depending on the area specified, unrealistically large, converging or overlapping buffers may be generated, resulting in high false alarm conditions. Internationally recognized survey standards should be used.

2.2.1.3 Aerodrome area terrain data

Consideration of terrain on and around the aerodrome is essential to terminal area airspace operations such as approach, departure, and contingency procedure planning.

Hazards related to terminal area terrain awareness and avoidance have been cited as a major contributing factor in controlled flight into terrain (CFIT) accidents. Terrain is also important to aerodrome surface operations. It defines the surface topography of the ground in and around the surface movement areas. Since terrain data shares a physical boundary with many surface geometric objects on the aerodrome (runways, taxiways, buildings, etc.), it is important that the terrain data be correlated with these other data types.

2.2.2 Data Element Extent and Boundary Definition

A complete AMDB is composed of a variety of thematic data elements including, but not limited to, vertical objects, runways, taxiways, and building geometry. The methods employed to collect and handle each data type may differ widely. For example, vertical object data may be obtained using traditional ground-based aerodrome surveys. In addition to collection methods, the data types pose different hazards, risks, and informational opportunities to surface and terminal-area navigation applications. Therefore, the spatial or surveyed extent of the AMDB is defined on an element-by-element basis. Practical methods of data collection employed by industry (vis-à-vis aerodrome surveyors and GIS specialists) are also considered when defining the AMDB extent.

a) **Vertical Objects**

Requirements regarding the collection of vertical objects are given in Annex 15 through terrain/obstacle data collection surfaces. Applications requiring *Fine* quality data require many elements in the movement area to be surveyed to sub-meter accuracy. Initially, these high-accuracy survey requirements will be imposed upon area in and around the movement areas. Rationale for the vertical extent boundary is driven by three considerations:

i. wing-tip and airframe clearance requirements,

ii. air-ground (landing) and ground-air (take-off) proximity operations, and

iii. Helicopter maneuvering operations.

Criteria for surveying and collection of obstacles are provided in Chapter 3 of this document. Control towers must always be captured regardless of its location on the aerodrome.

b) **Aerodrome Structure**

Aerodrome structure is a general term used to describe the aerodrome terminal, tower, hangars, and other miscellaneous buildings on the aerodrome area. Based on the geometric complexity of these objects and their location in respect of the aerodrome operations, they are not traditionally surveyed, or in some cases, only the corners are surveyed. Future applications, particularly those with regard to efficiency and routing applications, will require detailed models of these geometric elements. Therefore, the following requirement is asserted:

Aerodrome structures must be modeled with a two-dimensional bounding polygon and a maximum height field, indicating the highest point on the building extent (bounding box). Towers and antennas protruding from the top of the building must be captured separately as vertical objects (obstacles) (Odkhuu and Chinsorig, 2012).

2.2.3 Aerodrome Obstacle Limitation Surfaces

Civil Aviation Authority Singapore CAAS (2014) states that an effective utilization of an aerodrome may be influenced by natural features and man-made objects inside and outside the aerodrome boundary. These may result in –

a) Limitations on the distance available for aircraft take-off and landings;

b) The range of meteorological conditions in which take-off and landings can be undertaken; or

c) A reduction in the payload of some aircraft types, or all the above.

2.2.3.1 Elements of Obstacle Limitation Surfaces

The requirements for obstacle limitation surfaces are specified on the basis of the intended use of the runway with respect to take-off or landing and type of approach, and are intended to be applied when such use is made of the runway. In cases where operations are conducted to or from both directions of a runway, then the function of certain obstacle limitation surfaces may be nullified because of more stringent requirements of another lower surface. The following are essential elements of the aerodrome design obstacle limitation surfaces:

The aerodrome design specifications state that all existing objects penetrating the obstacle limitation surfaces should, as far as practical, be removed unless they are shielded by existing immovable objects. Detailed specifications about the marking and lighting of obstacles are contained in the Annex 14 (ICAO, 2013).

a) The Take-off Climb Surface

i. A take-off climb surface is an inclined plane located beyond the end of the take-off run available or at the end of the clearway where one is provided.
ii. A take-off climb surface is established for each runway direction intended to be used for take-off.

b) Approach Surface

i. An approach surface is an inclined plane or combination of planes preceding the threshold.
ii. An approach surface is established for each runway direction intended to be used for the landing of aircraft.

c) Transitional Surface

i. The transitional surface is a complex surface along the side of the runway strip and from part of the side of the approach surface that slopes upwards and outwards to the inner horizontal surface.

ii. Transitional surfaces are established for every runway intended to be used for landing.

iii. The transitional surface along the strip will be curved if the runway profile is curved, or a plane if the runway profile is a straight line. The intersection of the transitional surface with the inner horizontal surface will also be curved or a straight line, depending on the runway profile.

d) Inner Horizontal Surface

i. An inner horizontal surface is a horizontal plane located above an aerodrome and its environs. It represents the level above which consideration needs to be given to the control of new obstacles and the removal or marking of existing obstacles to ensure safe visual manoeuvring of airplanes in the vicinity of the aerodrome.

ii. An inner horizontal surface is established for every aerodrome.

e) Conical Surface

i. A conical surface is a surface sloping upward and outward from the periphery of the inner horizontal surface. It represents the level above which consideration needs to be given to the control of new obstructions and the removal or marking of existing obstructions so as to ensure safe visual manoeuvring in the vicinity of an aerodrome.

ii. A conical surface is established for every aerodrome.

f) Outer Horizontal Surface

i. An outer horizontal surface is a specified portion of a horizontal plane around an aerodrome beyond the limits of the conical surface. It represents the level above which consideration needs to be given to the control of new obstacles in order to facilitate practicable and efficient instrument approach procedures, and together with the conical and inner horizontal surfaces to ensure safe visual manoeuvring in the vicinity of an aerodrome.

ii. An outer horizontal surface is established for every aerodrome where the main runway is 1100 metres or more in length.

2.2.3.2 Characteristics of Aerodrome Obstacle Limitation Surfaces

a) Aerodrome Obstacle Chart - Type "A"

Significant obstacles in the take-off flight path area of runways regularly used by international aviation must be published in the AIP. The aerodrome operator is responsible for providing or arranging for the provision of necessary surveyed aerodrome obstacle data to the AIS. The aerodrome operator must notify the AIS of any significant obstacles in the take-off flight path area of the runway.

The aerodrome obstacle chart Type "A" represents a profile of the take-off obstruction environment on departure from a specific runway. The basic slope shown on the chart is 1.2 percent which is below the slope of the protected take-off climb surface established for a runway intended for use by Group A aircraft (ICAO, 2013)..

Although objects may penetrate the 1.2 percent slope, there is no need to remove any which are beneath the aerodrome design take-off climb surface. However, all objects shown are accountable in the calculation of the aircraft take-off performance and in some instances may affect the payload of a particular aircraft type. The extent of this limitation depends on individual circumstances, but it is possible to significantly reduce the payload

penalty by judicious obstacle removal close to the aerodrome. Conversely, it may be that an obstacle several kilometers from the aerodrome is the limiting factor (ICAO, 2013).

2.2.4 Obstacle Control

i. Ultimate responsibility for limitation and control of obstacles, must in practice, rest with the aerodrome operator. This includes the responsibility for controlling obstacles on aerodrome property and for arranging the removal or lowering of existing obstacles outside the aerodrome boundaries.

ii. Each aerodrome operator should designate a member of his staff to be responsible for the continuing process of ensuring that aerodrome approach, departure and manoeuvring areas remain clear of obstacles which may jeopardize safety. The aerodrome operator must maintain constant vigilance to prevent erection of obstacles around his aerodrome. The aerodrome operator should establish a programme of regular and frequent visual inspections of all areas around the aerodrome in order to be sure that construction activity or natural growth likely to infringe any of the obstacle limitation surfaces is discovered before it becomes a problem. This inspection programme should also include a daily observation of all obstacle lights, both on and off the aerodrome, and corrective action taken in event of light failure.

iii. When considering obstacle control the following should not be overlooked:

iv. Objects which penetrate the approach surface are critical since they represent an erosion of the clearance between the final approach path, usually 3 degrees, and fixed or mobile obstacles on the ground. On an approach where the approach surface is significantly obstructed, the safe operation of aircraft is ensured by raising the aerodrome approach meteorological minima. If the object penetrates into the approach surface, the landing threshold is displaced, effectively reducing

the available landing distance. This can have an adverse effect on the regularity of aircraft operations and could impose payload penalties on landing aircraft;

v. The transitional surfaces are adjacent to the runway strip and approach surface. Penetration of them by an obstacle results in the reduction in the clearance available whilst carrying out an approach to land or during a missed approach procedure. Such obstacles may have an adverse effect on the aerodrome meteorological minima and may need marking and lighting;

vi. Aircraft performance requirements, applicable to take-off and climb, require all aircraft to clear all obstacles by a minimum specified margin. For a multi-engine aircraft, that requirement includes the climb following failure of the critical engine. Objects which penetrate approach and take-off climb surfaces do not represent a degradation of safety standards but they may impose significant payload penalties on aircraft taking off;

vii. The inner horizontal surface is more significant for VFR operations. It also provides protection for circuiting aircraft following an instrument approach. It does not usually represent a critically limiting surface around a large aerodrome handling IFR traffic, except in so far that it extends beneath the approach surface;

viii. The conical surface represents the obstacle limiting surface some distance from the aerodrome. It is often not practical to control obstacles which penetrate this surface, although it does usually provide a limit to new construction;

ix. Obstacle control, to maintain or improve the Aerodrome Obstacle Chart - Type "A" obstacle profile, should be based on the clear understanding of the performance requirements of the aircraft regularly using the aerodrome or those proposed to be brought into regular use;

x. Any obstacles which are allowed to penetrate the established PANS-OPS surfaces could raise the minimum safe altitudes of the aerodrome instrument flight procedures. This could have an adverse effect on the regularity of aircraft operations (BCAD, 2007).

2.2.5 Identifying obstacles

i. Identification of obstacles requires a complete engineering survey of all areas beneath the aerodrome obstacle limitation surfaces.

ii. The initial survey should produce a chart presenting a plan view of the entire aerodrome and its environs. The scope of the chart should be to the outer limit of the conical, approach and take-off climb surfaces. It will need to include profile views of all obstacle limitation surfaces. Each obstacle should be identified in both plan and profile with its description and height above the datum, which should be specified on the chart. Engineering field surveys can be supplemented by aerial photographs and photogrammetry to identify possible obstacles not readily visible from the aerodrome.

iii. Constant vigilance is required to ensure the control of obstacles. Periodic surveys should be conducted to ensure the validity of the information in the initial survey. The aerodrome operator should make frequent visual observations of surrounding areas to determine the presence of new obstacles. Follow-up surveys should be conducted whenever significant changes occur. A detailed survey of a specific area may be necessary when the initial survey indicates the presence of obstacles for which a control programme is contemplated. Following completion of an obstacle control programme, the area should be resurveyed to provide corrected data on the presence or absence of obstacles. Similarly, revision surveys should be conducted if changes are made, or planned, to the aerodrome characteristics such

as runway length, elevation or orientation. Changes in obstacle data arising from surveys are to be notified to the Aeronautical Information Service (AIS) as soon as practicable for promulgation to aircraft operators (BCAD, 2007). .

2.2.6 Methods of Obstacle Control

The viability and safety of aerodrome use by aircraft operators can be assured by establishing effective obstacle control to maintain the obstacle limitation surfaces. Control can be achieved in a number of ways, by:

a) Enactment of height zoning protection by the local government authority;

b) Establishing an effective obstacle removal programme; or

c) Purchasing of easement or property rights, or all of these.

I. *Height Zoning*

The objective of height zoning is to protect the aerodrome obstacle limitation surfaces from intrusion by manmade objects and natural growth such as trees. This is done by the enactment of ordinances identifying height limits underneath the aerodrome obstacle limitation surfaces. The responsibility for the enactment of such an ordinance is a matter between the aerodrome operator and the local government authority (BCAD, 2007). .

II. *Obstacle Removal*

When obstacles have been identified, the aerodrome operator should make every effort to have them removed, or reduced in height so that they are no longer an obstacle. If the obstacle is a single object it may be possible to reach agreement with the owner of the property to reduce the height to acceptable limits without adverse effect. Examples of such objects are a tree, a television aerial or a cell phone tower.

In the case of trees, which are trimmed, agreement should be reached in writing with the property owner to ensure that future growth will not create new obstacles. Property owners can give such assurance by agreeing to trim the trees when necessary, or by

permitting access to the premises to have the trimming done by the aerodrome operator's representative. It is important to assess the growth rate of trees and trim them low enough so that the ensuing growth will be below the obstacle surface until the surface is next due for survey.

Some aids to navigation both electronic, such as ILS components, and visual, such as approach and runway lights, constitute obstacles which cannot be removed. Such objects should be frangibly designed and constructed, and mounted on frangible couplings so that they will fail on impact without significant damage to an aircraft (BCAD, 2007). .

2.2.7 Easements or Property Rights

In those areas where zoning is inadequate the aerodrome operator may take steps to protect the obstacle limitation surfaces by other means. Examples of zoning inadequacies might be locations close to runway ends or where obstacles exist. Examples of other means might be such as gaining easements or property rights. They should include removal or reduction in height of existing obstacles and measures to ensure that no new obstacles are allowed to be erected in the future.

Where agreement can be reached for the reduction in height of an obstacle, the agreement should include a written aviation easement limiting heights over the property to specific levels unless effective height zoning has been established (BCAD, 2007). .

III.*Marking and Lighting of Obstacles*

Where it is impractical to eliminate an obstacle it should be appropriately marked or lighted, or both, to be clearly visible to pilots in all weather and visibility conditions.

Note that the marking and lighting of obstacles is intended to reduce hazards to aircraft by indicating the presence of obstacles. It does not necessarily reduce operating limitations which may be caused by the obstacle. Obstacles shall be marked and, if the aerodrome is used at night, lighted, except that:

i. Lighting and marking may be omitted when the obstacle is shielded by another obstacle; and

ii. The marking may be omitted when the obstacle is lighted by high intensity obstacle lights by day.

iii. Vehicles and other mobile objects, excluding aircraft, on movement areas of aerodromes should be marked and lighted, unless they are used on apron areas only.

iv. The aerodrome operator should make a daily visual inspection of all obstacle lights on and around the aerodrome, and take steps to have inoperative lights repaired.

IV. *Obstacle Shielding*

The principle of obstacle shielding is employed to permit a more logical approach to restricting new construction and to the requirements for marking and lighting of obstacles. Shielding principles are employed when some object, an existing building or natural terrain, already penetrates above one of the aerodrome design obstacle surfaces. If the obstacle is permanent, then additional objects within a specified area around it can penetrate the surface without being obstacles. The original obstacle dominates or shields the surrounding area (BCAD, 2007).

2.2.8 ICAO Standards and Recommended Practices (SARPS) for Aerodrome Obstacles Limitation Surface

2.2.8.1 Obstacle Limitation Surfaces

Obstacle limitation surface has to do with defining the airspace around aerodromes to be maintained free from obstacles in order to minimize the dangers presented by obstacle to an aircraft, either during an entirely visual approach or during the visual segment of an instrument approach; and to prevent the aerodrome from becoming unusable by the

growth of obstacles around the aerodrome. These objectives are achieved by establishing a series of obstacle limitation surfaces that define the limits to which objects may project into the airspace.

- Obstacle limitation surfaces normally extend beyond the boundary of the aerodrome such surfaces can be protected by the enactment of Registered Zoning Regulations in accordance with the Aeronautics Act. Enactment of such a regulation will prohibit the erection of any new structure which would violate any of the defined surfaces.
- Objects which project into the obstacle limitation surfaces may in certain circumstances cause an increase in the obstacle clearance altitude/height for an instrument approach procedure or any associated visual circling procedure. Criteria for evaluating obstacles are contained in, Criteria for the Development of Instrument Procedures, TP 308. TP 308 also provides further information on the distinction between obstacle limitation surfaces and obstacle clearance surfaces.
- The establishment of, and requirements for, an obstacle protection surface for visual approach slope indicator systems are

2.2.8.2Outer Surface

Characteristics

Standard. - The limits of an Outer Surface shall comprise a common plane established at a constant elevation above the assigned elevation of the aerodrome reference point and extending over a horizontal distance:

- of at least 4000 m where the code number is 1, 2 or 3;
- to be determined by an aeronautical study where the code number is 4, but never less than 4000 m;
- measured from the designated aerodrome

- reference point or points and extending over an
- area not less than 180° sector along the runway centre line

Recommendation. — An outer surface should extend horizontally 360° about the aerodrome.

Standard. — An outer surface shall be established at 45 m above the assigned elevation of the aerodrome reference point except, when the common plane is less than 9 m above the ground, an imaginary surface shall be established 9 m above the surface of the ground. (See Figure 2.1)

>The imaginary surface at 9 m is intended to allow for an isolated topographical obstruction.

2.2.8.3 Take–Off/Approach Surface

Characteristics

I. *Standard.* — The limits of the take–off/approach surface shall comprise:

a) an inner edge of specified length perpendicular to and evenly divided on each side of the extended centre line of the runway beginning at the end of the runway strip;
b) two sides originating at the ends of the inner edge, diverging uniformly at a specified rate in the direction of take–off, terminating at the outer edge; and
c) An outer edge parallel to the inner edge at a specified length from the inner edge.

- The width of the take–off/approach surface at any point can be found by summing the products of the length (i.e. distance from inner edge) and the divergence (either side) with the length of the inner edge.

II. *Standard.* — Where a threshold has been displaced, the inner edge shall be located at the point of displacement. In this event the landing distance available will be reduced by an amount equal to the displacement and it will

be necessary to recalculate the declared distance information for the aerodrome.

III. *Standard.* — The elevation of the inner edge shall be equal to the elevation of the threshold.

- Because of transverse slopes on a strip, in certain cases portions of the inner edge of the take–off/approach surface may be below the corresponding elevation of the strip. It is no intended that the strip be graded to conform to the inner edge.

IV. *Recommendation*. — Where practicable, the inner edge should be located at a position that will allow the take–off/approach surface to clear the airport boundary by at least 9 m vertically.

V. *Standard.* — The slope(s) of the take–off/approach surface shall be measured in the vertical plane containing the centre line of the runway, and shall be of a constant gradient.

VI. *Standard.* — The widths and lengths of the take–off/approach surfaces shall be measured in the horizontal plane.

2.2.8.4Transitional Surface

Characteristics

VII. *Standard*. — The limits of the transitional surface shall comprise:

a) a lower edge beginning at the intersection of the side of the approach surface with the outer surface and extending down the side of the approach surface to the inner edge of the approach surface and from there along the edge of the strip; and

b) An upper edge located in the plane of the outer surface or 45 m above airport assigned elevation if no outer surface has been established.

- A transitional surface is a combination of three planar surfaces. The first is a trapezoidal surface that rises from the edge of the runway strip at the specified slope

till reaches the upper edge. Joining this surface on either end are triangular surfaces that are completed by the lower edge along the take–off/approach surface and the upper edge (see Figure 2.1).

VIII. *Standard.* — The elevation of a point on the lower edge shall be:

a) along the side of the take–off/approach surface prescribed in this chapter; equal to the elevation of the take–off/approach surface at that point; and,

b) along the runway strip; equal to the elevation of the nearest point on the centre line of the runway or its extension, to the edge of the graded area.

IX. *Recommendation.* — The slopes of any portion of the strip beyond the graded area should not exceed an upward slope of 5% as measured from the edge of the graded area perpendicular to the runway. This upward slope will extend to intersect with the transitional surface.

X. *Standard.* — The slope of a transitional surface shall be measured in a vertical plane perpendicular to the extended centre line of each runway.

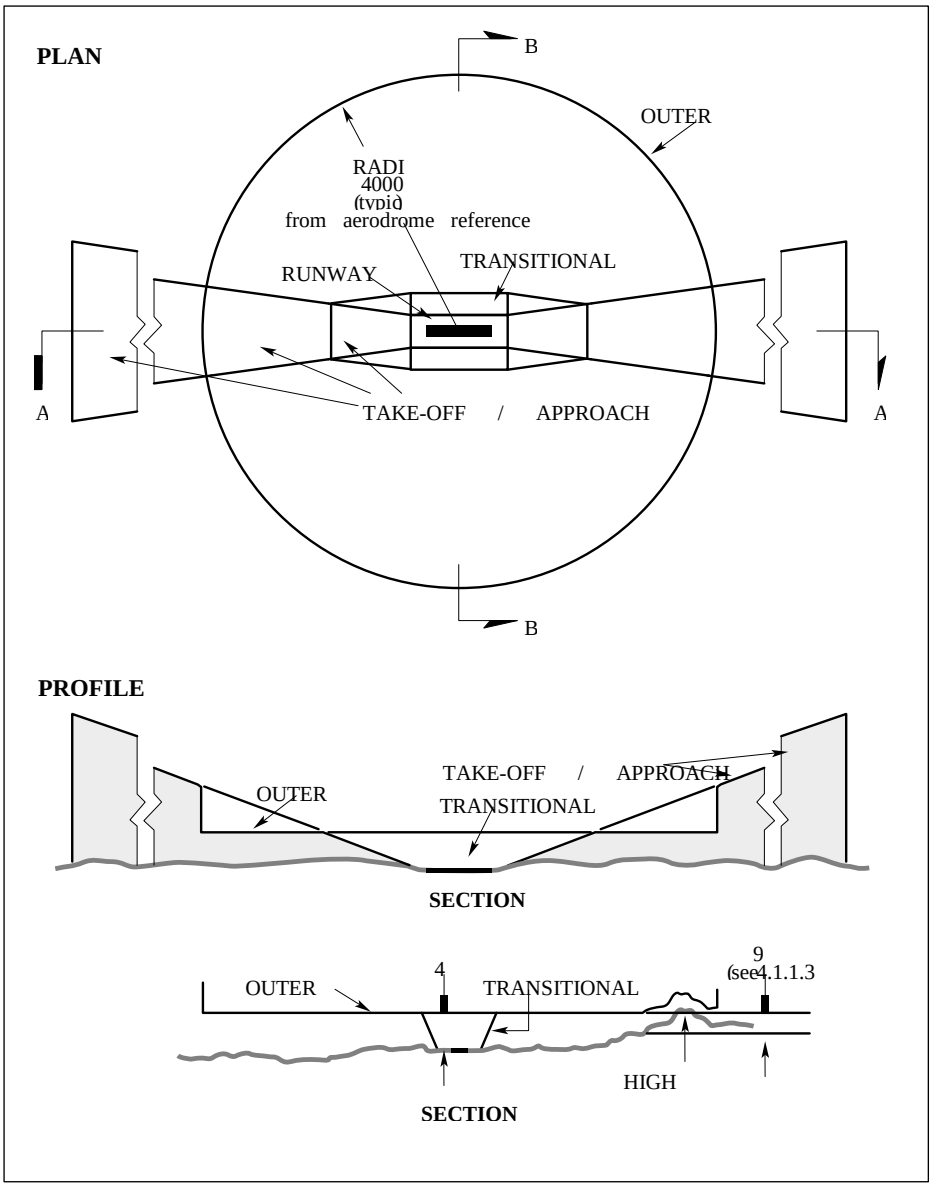

Figure 2.1: Obstacle Limitation Surfaces

2.2.8.5 Obstacle Limitation Requirements

>The requirements for obstacle limitation surfaces are specified on the basis of the intended use of a runway, i.e. type of approach and take–off or landing, and are intended to be applied when such use is made of the runway.

>A runway is categorized by the following types of approach:

i. Non–instrument,

ii. Non–precision,

iii. Precision.

General

Standard. — An outer surface shall be established where required for the protection of airspace for aircraft conducting a circling procedure or manoeuvring in the vicinity of an aerodrome.

2.2.8.6 Non–Instrument Runways

Standard. — The following obstacle limitation surfaces shall be established for all non–instrument runways:

i. Take–off/approach surfaces; and

ii. Transitional surfaces, except as specified in 4.2.2.4 (c).

Standard. — An outer surface shall be established for a runway which does not have an straight–in instrument approach but where there is a published circling approach procedure to that runway or where it is necessary, in the view of the certifying authority, to protect airspace for aircraft manoeuvring in the vicinity of the airport.

Standard. — The heights of these surfaces shall not be greater than, and their other dimensions not less than, those specified in Table 4–1, except in the case of the outer surface.

- It may not be necessary to protect the airspace from obstacles in all sectors of the outer surface at certain airports. In these cases, it is possible to establish an outer surface with non–uniform dimensions, provided procedures are established to ensure that aircraft do not fly in these sectors.

Standard. — The slope of the transitional surface where the code number is 1 or 2 shall not exceed the appropriate value shown in Table 4-1 except where:

a) the slope cannot be established due to topographic or unavoidable natural obstructions;

b) The aerodrome is used only in VMC; and

c) One of the following measures is undertaken and approved by the certifying authority:

i. the width of the runway strip is increased to at least 45 m from the centre line of the runway and a transitional surface is established with a slope not exceeding 33 % (1:3); or

ii. the width of the runway strip is increased to at least 60 m from the centre line of the runway where the code number is 2 and a transitional surface is established with a slope not exceeding 50% (1:2); or

iii. the width of the runway strip is increased to at least:

- 60 m from the centre line of the runway where the code number is 1;
- 75 m from the centre line of the runway where the code number is 2.

Standard. — The slope of the transitional surface where the code number is 3 or 4 shall not exceed the appropriate value shown in Table 2.2.

Standard. — New objects or extensions of existing objects shall not be permitted above a take–off/approach or transitional surface except when, in the opinion of the certifying authority, the new object or extension would be shielded by an existing immovable object.

- Circumstances in which the shielding principle may reasonably be applied are described in the ICAO Airport Services Manual, Part 6.

Recommendation. — New objects or extensions of existing objects should not be permitted above the outer surface except when, in the opinion of the certifying authority, the object would be shielded by an existing immovable object, or after aeronautical study it is determined that the object would not adversely affect the safety or significantly affect the regularity of operations of aircraft.

Recommendation.— In considering proposed construction, account should be taken of the possible future development of an instrument runway and consequent requirement for more stringent obstacle limitation surfaces.

2.2.8.7Non–Precision Approach Runways

Standard.— The followingobstacle limitation surfaces shall be established for a non–precision approach runway:

i. Outer surface;

ii. take–off/approach surface; and

iii. Transitional surfaces.

Standard. — The heights and slopes of the surfaces shall not be greater than, and their other dimensions not less than, those specified in Table 2.1.

Table 2.1: Dimensions and Slopes of Obstacle Limitation Surfaces

SURFACE and DIMENSIONS	RUNWAY TYPE / CODE NUMBER									
	Non-instrument				Non-precision approach			Precision approach Cat I		
	(1)				(2)			(3)		
	Code number				Code number			Code number		
	1	2	3	4	1&2	3	4	1&2	3 & 4	
OUTER SURFACE										
- Height	45m	45m	4000m	45m	45m	45m	45m	45m	45m	45 m
- Radius	4000m			4000 m	4000 m	4000 m	4000 m	4000 m	4000 m	4000 m
TAKE-OFF/APPROACH SURFACE										
- Length of Inner Edge	30 m	30 m		45 m	75 m	45 m	75 m	150 m	75 m	150 m
- Distance from threshold	30 m	60 m		60 m	60 m	60 m	60 m	60 m	60 m	60 m
- Divergence (minimum each side)	10%	10%		10%	10%	10%	15%	15%	15%	15 %
- Length (minimum)	2500 m	2500m		2500m	2500m	2500 m	3000 m	3000 m	15000m	15000 m
- Slope (maximum)	5% (1:20)	4% (1:25)		2.5% (1:40)	2.5% (1:40)	3.33% (1:30)	2.5% (1:40)	2.5% (1:40)	2.5% (1:40)	2.0 % (1:50)
TRANSITION SURFACE										
- Slope (maximum)	20.0% (1:5)	20.0% (1:5)		14.3% (1:7)	14.3% (1:7)	14.3% (1:7)	14.3% (1:7)	14.3% (1:7)	14.3% (1:7)	14.3 % (1:7)

Source: ICAO, 2013

Recommendation. — Where practicable, the slope of the take–off/approach surface should be 2.0%.

Standard. — New objects or extensions of existing objects shall not be permitted above a take–off/approach surface within 3000 m of the inner edge or above a transitional surface except when, in the opinion of the certifying authority, the new object or extension would be shielded by an existing immovable object.

- Circumstances in which the shielding principle may reasonably be applied are described in the ICAO Airport Services Manual, Part 6.

Recommendation. — New objects or extensions of existing objects should not be permitted above the take–off/approach surface beyond 3000 m from the inner edge or above the outer surface except when, in the opinion of the certifying authority, the object would be shielded by an existing immovable object, or after aeronautical study it is determined that the object would not adversely affect the safety or significantly affect the regularity of operations of aircraft.

Recommendation. — Existing objects above any of the surfaces required by 4.2.3.1 should as far as practicable be removed except when, in the opinion of the certifying authority, the object is shielded by an existing immovable object, or after aeronautical study it is determined that the object would not adversely affect the safety or significantly affect the regularity of operations of aircraft.

>Because of transverse or longitudinal slopes on a strip, in certain cases the inner edge or portions of the inner edge of the take–off/approach surface may be below the corresponding elevation of the strip. It is not intended that the strip be graded to conform with the inner edge of the take–off/approach surface, nor is it intended that terrain or objects which are above the take–off/approach surface beyond the end of the strip, but below the level of the strip, be removed unless it is considered they may endanger aeroplanes.

2.2.8.8 Precision Approach Runways

>Guidance on obstacle limitation surfaces for precision approach runways is given in the ICAO Airport Services Manual, Part 6.

Standard. — The following obstacle limitation surfaces shall be established for a precision approach runway category I:

i. Outer surface;

ii. Take–off/approach surface; and

iii. Transitional surfaces.

- Obstacle limitation surfaces for precision approach runways categories II & III are established in accordance with specifications contained in TP 1490, Manual of All Weather Operations.

Standard. — The heights and slopes of the surfaces shall not be greater than, and their other dimensions not less than, those specified in Table 2.1

Recommendation. — Where practicable, for new runways where the code number is 3 or 4, the slope of the take–off/approach surface should be 1.66% for the first 3000 m and 2.0% thereafter for a total length of 15000 m.

Standard. — Fixed objects shall not be permitted above the take–off/approach surface, or the transitional surface, except for frangibly mounted objects which because of their function must be located on the strip. Mobile objects shall not be permitted above these surfaces during the use of the runway for landing.

Standard. — New objects or extensions of existing objects shall not be permitted above a take–off/approach surface or a transitional surface except when, in the opinion of the certifying authority, the new object or extension would be shielded by an existing immovable object**.**

- Circumstances in which the shielding principle may reasonably be applied are described in the ICAO Airport Services Manual, Part 6.

Recommendation. — New objects or extensions of existing objects should not be permitted above the outer surface except when, in the opinion of the certifying authority, an object would be shielded by an existing immovable object, or after aeronautical study

it is determined that the object would not adversely affect the safety or significantly affect the regularity of operations of aircraft.

Recommendation. — Existing objects above a take–off/approach surface, a transitional surface, and the outer surface should as far as practicable be removed except when, in the opinion of the certifying authority, an object is shielded by an existing immovable object, or after aeronautical study it is determined that the object would not adversely affect the safety or significantly affect the regularity of operations of aircraft.

Note. — Because of transverse or longitudinal

2.2.8.9 Other Objects

General

Recommendation. — Objects which do not project through the take–off/approach surface but which would nevertheless adversely affect the optimum siting or performance of visual or non–visual aids should, as far as practicable, be removed.

Recommendation.— Anything which in the opinion of the certifying authority after aeronautical study, endanger aircraft on the movement area or in the air within the limits of the outer surface should be regarded as an obstacle and should be removed in so far as practicable.

- In certain circumstances, objects that do not project above any of the surfaces enumerated in 4.1 may constitute a hazard to aircraft as, for example, where there are one or more isolated objects in the vicinity of aerodrome.

Standard. — Any transportation corridor underlying an Obstacle Limitation Surface shall be considered as an object. As a minimum, 4.3 m shall be allowed above the crown of a road and for a railway, 6 m above the top of the rails. The height to be allowed above a waterway, river, canal, etc. shall be established by Aeronautical Study. Slopes on a strip, in certain cases the inner edge or portions of the inner edge of the take–off/approach

surface may be below the corresponding elevation of the strip. It is not intended that the strip be graded to conform with the inner edge of the approach surface, nor is it intended that terrain or objects which are above the approach surface beyond the end of the strip, but below the level of the strip, be removed unless it is considered they may endanger aircraft.

2.2.9 Electronic Terrain and Obstacle Database (e-TOD)

E-TOD suite of software tools is designed to manage airport, terrain and obstacle data ensuring compliance with international data quality requirements (ICAO Annex 15, Amendments 33, 34 and 36). Its main functionalities include data administration, reporting and processing, making all elements available for modelling airport areas and ICAO obstacle chart construction and delivery Odkhuu and Chinzorig (2012).

The Terrain and Obstacle Database (TOD) and the Airport Mapping Data Base (AMDB) are able to support all activities and provide a common basis either to perform aeronautical charting or to design airspace and flight procedures within the IDS FPDAM interactive environment. e-TOD is composed of four products:

i. e-TOD Data Manager

ii. e-TOD Airport Data Analyzer

iii. e-TOD Obstacle Chart Builder

iv. e-TOD Obstacle Permission Manager

These can be used with IDS's Aeronautical Information Services system either individually or in combination.

2.2.9.1 e-TOD Data Manager

E-TOD Data Manager provides all the necessary tools to import, integrate, manage and deliver aerodrome mapping information, obstacle data and terrain data in accordance with ICAO Doc 9881 and ICAO Annex 15 up to Amendment 36.

The system is able to assist the user in managing the lifecycle of data, validating and detecting ambiguous and conflicting data as well as supporting data export and reporting. The e-TOD Data Manager is able to import several different types of data:

Digital terrain models (DTM, DSM)

i. Ortho-photos

ii. Raster files

iii. Three-dimensional vector maps

iv. Raw data lists

Data originating from raw data lists will be mapped into the AIXM data model. The system has the capability to add default values to the file for any missing AIXM/ICAO attributes.

All data undergo several validation checks during importation, a Cyclic Redundancy Check (CRC) code is computed to ensure data integrity, data are provided with metadata as required by ICAO Annex 15 and are then presented to the user via a graphical front end. All data and metadata are editable and the system maintains data consistency in the case of concurrent revisioning. Data can be displayed in a 2D or 3D GIS environment or in Google Earth.

2.2.9.2 e-TOD Airport Data Analyzer

e-TOD Airport Data Analyzer (ADA) provides all the tools necessary to import the airport, obstacle and terrain data needed to reproduce the airport environment and perform natural or human made obstacle assessment. Based on a GIS/CAD platform, ADA allows the user to load airport data including runways, helipads, taxiways, aprons, vertical structures, construction areas, survey control points, navaids, obstacles and terrain data in order to support activities such as impact analysis of airport infrastructures changes, obstacle limiting surface design or natural & artificial obstacle assessment. ADA

supports the design of Annex 4 &14 surfaces and the newest set of surfaces detailed in ICAO Annex 15, dedicated to obstacle collection.

2.2.9.3 e-TOD Obstacle Permission Manager

Obstacle Permission Manager is e-TOD's dedicated sub system for managing the process by which obstacles are planned, notified, surveyed and published. Obstacle owners who want to build a new obstacle, to change the size of an existing obstacle or to remove an existing one, can send their request using a dedicated web interface form.

This web application lets the user know if their request has an impact on aviation and Aeronautical Regulator approval is needed. The system also allows the user know to check the status of their request at any time. When the obstacle owner has sent his request, the system is able to perform the assessment to determine if the planned operation will impact aviation.

2.2.9.4 e-TOD Obstacle Chart Builder

e-TOD Obstacle Chart Builder provides all the necessary tools to extract obstacle and terrain information needed to create obstacle and terrain charts (ICAO type

A, B and PATC). It allows the user to manage and defied chart templates within a graphical environment and to modify the following parameters:

i. Header, profile view and plan view size and position

ii. Size and position of boxes

iii. Text size, colour and font for each box element

iv. Elements to be represented

Once created, charts can then be inserted into the central database from where any system user can later retrieve them using a number of different search criteria (e.g. date of issue, classification, ICAO code, etc.) and then display them with a single click. e-TOD Obstacle Chart Builder

2.2.10 Geographic Information Systems

The provision of terrain and obstacle data in accordance with the ISO 19100 series of standards allows the data sets delivered to be utilised by GIS. The following provides a high-level description of GIS.

A GIS is the group of Information Technology (IT) components which is used to describe, in a structured form, real-world phenomena. Contrary to other information systems, a GIS emphasises the spatial property of a phenomenon. Therefore, a GIS is used to capture, maintain, store, analyse, manage and present data that is linked to a location. In a more generic sense, GIS applications are tools that allow users to create interactive queries (user created searches), analyse spatial information, edit data, and present the results of all these operations (on screen or as maps). The following figure shows, at a high level, a typical GIS architecture (Eurocontrol, 2011).

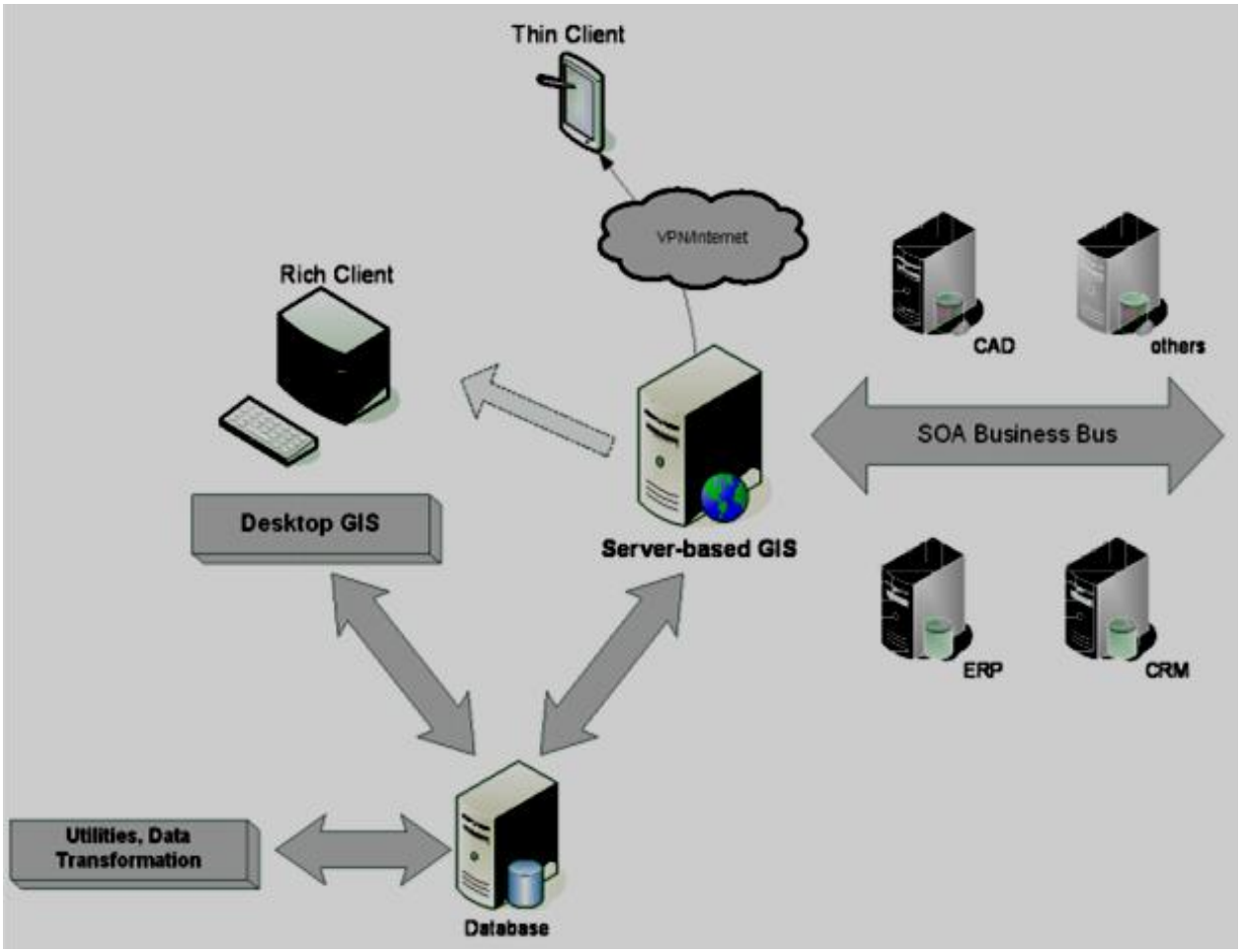

Figure 2.2: Typical Architecture of a GIS Environment

GIS and appropriate data sets offer vast opportunities for:

i. Fast and easy access to spatial data and system resources;

ii. Data sharing with external organisations;

iii. Integrating with other information systems;

iv. Faster and more accurate decision making;

v. Simpler data maintenance through elimination of redundancies;

vi. Provision of a wider range of spatial-based products.

2.3 LITERATURE REVIEW

This section focuses on the review of related literatures on obstacles in the study area.

Anastasiosis (2002) worked on Bird strikes risk assessment using GIS, at Athens International Airport, South Africa. The research made use of the study includes: the observation of the Airside Monitoring and Inspection team (AMI) that performs routine and non-routine inspections on air fields concerning the status of the runways and taxiways. The findings of the study revealed a temporal variation of the bird strikes for example, during the first Month of the year the majority of the birds contributed to birth strike risk were water fowl, with a significant contribution from starlings and a minor one of gulls. In spring and the beginning of summer, gulls bird species participated in the bird strike risk. From mid-Summer to mid-Autumn, it was raptors bird species that posed the highest risk. During the two last months of the year the contribution of starlings to the bird strike risk was the most significant.

Thomson (2007) carried out a research on cost effective Grassland Management strategy to reduce the number of Bird strikes at the Brisbane airport, Australia. The Data used for the study are mainly, Maps of Brisbane airport showing each habitat type which is divided into 250mx250m to allow reference points to be located at least 250m apart in close habitat and 500m apart in open habitat The method of data analysis used in the research was 2 way ANOVA (Analysis of variance) on all data in order to determine the significance of bird population parameters. The result of the study revealed that, the habitat compared within Brisbane airport boundaries, grasslands surrounding runways, taxiways and aprons possesses the greatest richness and abundance of bird species that pose the potential hazard to aircraft operations. Also, Ibis and Australian Kestrel were identified as the bird species that poses risk to aircraft at Brisbane airport. From the

research findings it is recommended that, an improve reporting process that allow correct identification of all individual bird species involved in bird strike will not only increase the accuracy of risk assessment, but will also allow the implementation of more effective control strategies at Brisbane airport. It was also established that, compared with the current grassland practices, a vegetation management option of maintaining grass height at 30-50cm reduced the total bird utilization by 89%,while utilization of grassland by potentially hazardous bird was also reduced by 85%.

Peter and Vander (2009) also carried out a research on the spatial variation on flight safety between the existing pylons and two optional routes for the new transmission line around Schiphol in Geval Van, Germany. The result of the research revealed that the two routes plays same role in the movement of aircraft in and around and the chance of collision with birds are deem to be insignificance.

Jinfeng and Herricks (2010) conducted a research on bird aircraft strike threat assessment using Avian Radar Information at New Jersey airport, USA. The method adopted made use of Accipiter Avian Radar Technologies, Inc., 25 kW, X-band marine radar operating at 9.4 GHz with a wavelength of 3 cm. The radar sensor was equipped with a slotted array antenna providing a nominal 20 degree high by 2 degree wide beam. The radar is provided with a processor which provides detection time; track ID, ground speed, heading direction, latitude and longitude. The result of the study revealed that, the changing pattern of both bird activity and threat density in four target areas (A,B,C and D) in 24hr period were similar. However, daily variation may be influenced by factors other than bird activity at day time and at night, like weather and wave action.

Ahmed (2011), Conducted a study on assessment of the effect of birds strike on flight safety operations in MallamAminu Kano international airport Kano, Nigeria. The data

were collected through oral interview and questionnaire survey. The method of data analysis used in bird strike record was descriptive statistic which reveals that, twelve of these bird species were involved in forty four (44) strikes at the airport during the period 2001-2010. The finding of this study is that most of these strikes occurred during the rainy seasons from May- October. Distribution of these strikes by phase indicates that 32% occurred on approach, 25% on landing roll,20% on takeoff,4.5% on descend,4.5% during climb, while 14% of these strikes the phase is unknown.

Dukiya and Gahlot (2012) carried out a research on the Evaluation of the effect of bird strikes on flight safety operations at MallamAminu Kano International Airport, Kano.Questionnaire survey and field observation were used as the main instrument to source for data in this study. The aviation safety ranking value (ASRV) was the method adopted for data analysis to evaluate and rank the risk of bird strikes specie. Their study revealed that a significant number of varieties of bird species were observed in the vicinity of Kano airport. The propensity of these birds to collide with aircraft is real and this is a menace to the aviation industry. From the findings of Dukiya and Gahlot it is recommended that Nigeria as a signatory to the convention on international civil aviation organisation (ICAO), Chicago 1944, is obligated to implement the provision specified in annex 14 of the convention. It behoved the federal ministry of aviation (FMA) to collaborate with parastatals under its supervision to create the much needed synergy to promote safety through technological adoption and rigorous awareness campaign in order to reduce or effectively manage the menace of bird strike at the airport.

CHAPTER THREE:STUDY AREA AND METHODOLOGY

3.1 INTRODUCTION

This is chapter discussed the study area, the materials and methods use for the research work.

3.2 THE STUDY AREA

3.2.1 Size and Location

The area investigated covers a radius of 10 nautical miles from the aerodrone reference point and is located between Latitudes 11^{o} $52^{'}$ 30″ N and 12^{o} $07^{'}$ 30″ N of the Equator and between Longitudes 8^{o} $27^{'}$ 00″ E and 8^{o} $42^{'}$ 30″ E of the Greenwich meridian (KNSG, 2004). It is bordered by DawakinTofaL.G.A., to the northwest, Minjibir and GezawaL.G.A to the northeast, Warawa and Dawakin Kudu LGAs to the southeast and Madobi andTofaL.G.As. to the southwest. The Metropolitan area of the state covers 499km^{2}. Kano state is characterized by low rainfall (850-870mm) and high rainfall of about 4200mm in a wet year, thus it has a distinct wet and dry season. The temperature is slightly above 30^{o}C (Sarah and Charles, 1988) (Figure 3.1)

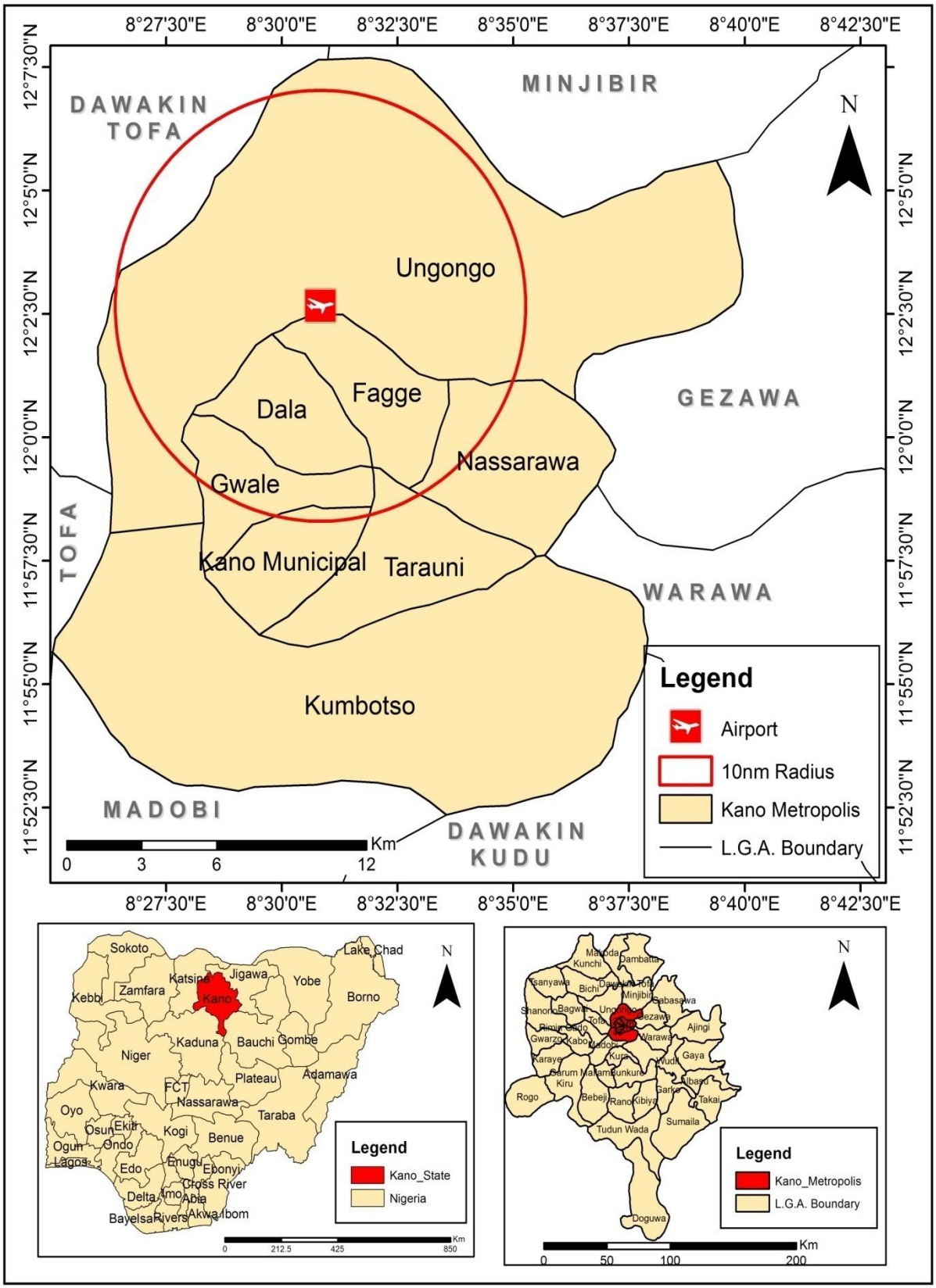

Figure 3.1: Kano Metropolis showing Location of MallamAminu Kano Int'l Airport
Source: Modified from the administrative map of Kano State

3.2.2 Weather and Climate

Kano State is located in the tropics, a region characterised by alternating wet and dry conditions, with annual rainfall of 850mm occurring between April/May and September/October with peak in July and August. The climate of Kano is also described as seasonally arid and in southern Kano rainy season average is about 150 days May to October. Mean annual rainfall in the southern parts is about 1000mm and in the north it is 635mm (Sarah and Charles, 1988).

The climate of Kano is described as Aw by Koppen, with both annual and seasonal variabilities wet years and dry years may record between 850 and 750mm (Olofin, 1987). The temperatures are characterised by warm to hot seasons with the occurrence of the Harmattan between November and February. The climate of Kano state is characterised by four seasons which are dictated by the movement of ITD that control north easterlies and south west easterlies. The four seasons are:-Hot and dry season (*Rani*) it is between February, March and early May, warm and wet season (*Damina*) it is between May to September and it is characterised by surface runoff available for steam flow, warm and dry season (*Kaka*) it is normally around October to November it is referred to as harvesting season. And lastly there is cool and dry season (*Bazara*) it is around December to February and it is dominated by the action of north easterlies that brings hamattan (Sarah and Charles, 1988).

3.2.3 Soil, Vegetation and Drainage Pattern

The study area is underlain by the Basement Complex rocks which are hard and impervious in nature with rivers that flow in north-south direction. Ahmed (2003) reported that there is a considerable relationship between groundwater and drainage pattern with the highest network of rivers in the Basement Complex areas. However the

small areas of Chad sediments in Dambatta and Gaya Local Government Areas are expected to have more groundwater and limited Channel development.

In the basement complex areas of Kano state two hydrological areas can be identified by USDA (1968) as reported by Ahmed (2003) that hydrological areas of Kano state are upland areas such areas include rivers like River Kano, River Challawa, River Iggi and Gaya. The second hydrological areas include the Gari area which comprises of River Gari, Thomas and Jakara. The upland areas receive rainfall of over 800mm annually while the Gari area receives annual rainfall of less than 800mm.

Several dams have been constructed to meet the rural water supply demands. About 25 small to large including those at: Gari dam, Wasai dam, Kafin-Ciri dam, ChalawaGorg dams, Ruwan-Kanya dam, Watari dam, Kanye dam, Gude dam and the Bagauda Lake dam. (Ahmed, 2003).

Together with such rivers as R. Kano, R. Watari, R. Chalawa, R. Wudil, R. Dudduru Gaya. They form the major hydrological systems that have the potential for rural water supply development. The stream flow in Kano state is characterised by seasonality, flash flours with flow rising in response to rainfall occurrences. The high flash flows exceeded 10% of the times are recorded mainly in July and August in response to rainfall events 30mm or more (Ahmed, 2003).

In Kano region groundwater regime was more favourable in both urban and rural areas in those days according to history. It is reported by Ahmed (2003) that groundwater regime was more favourable before the decades 1960s to 1980s. Level of well is between 10-12m deep in uplands mostly southern parts of Kano and about 2m in the lowland fadama areas but now 20-25m in uplands and 8m in low land fadama areas mostly northern parts of Kano state.

3.2.4 Socio-Economic Activities

Prior to this date, Kano also recorded the first ever aviation activity in Nigeria when a Royal Air Force aircraft operated by the British colonialist landed at a polo ground in the city in 1925. This historic reconnaissance flight during the WWI later developed into regular military flights. The infrastructural development of the airport actually started in 1930_s thus making the city of Kano into a veritable hub rivaled only by Khartoum in the African continent. Owing to the historical status of Kano Airport, the Nigerian airspace which comprises both the continental and oceanic territorial airspace is named the Kano Flight Information Region (FIR). Kano hosts KLM the longest-serving foreign airline in Nigeria which started operations since 1947. In January 1957, the airport was opened for 24 hours operations with Comet 15, DC-6 and Argon flights becoming the first to use the main runway. Currently the bulk of international flights cater for the large Lebanese community in Kano and Muslim pilgrimages to Mecca.

3.3 METHODOLOGY

This section focuses on the materials and method that was used to achieve the set objectives.

3.3.1 Reconnaissance Survey

Reconnaissance survey was carried out in order to get acquainted with the study area. During the reconnaissance survey observation on the ground scene of the study area was made.

3.3.2 Type and Sources of Data

The materials required for the study include the following:

Table 3.1: Types and sources of data

S/NO	Type of Data	Source	Characteristics
1	DGPS Coordinates	Field Survey	X, Y and Z in both geographic and projected coordinate system using WGS 1984 datum
2	QuickBird Imagery (2012)	NASRDA	High resolution (1m spatial resolution)
3	Administrative map	Ministry of Land and Survey Kano state	Scale: 1:50,000
4	Annex 14 (Aerodromes) ICAO Document	AIS Department NAMA	Standards and Recommended practices on Obstacles and Limitation Surfaces.

3.3.3 Materials and software

a. Differential Global Positioning Systems

b. Electronic Theodolite

c. Erdas Imagine version 9.2

d. ArcGIS Version 10.1

3.3.3 Data Collection Procedure

Differential Global Positioning System (DGPS) was acquired from the ministry of Land and Survey Kano state. Electronic Theodolites was sourced from survey units Federal Airport Authority Kano Airport. QuickBird imagery (2012) of spatial resolution of 1m was obtained from National Space Research and Development Agency (NASRDA). Administrative Map of the study Area was acquired from ministry of Local Government Kano State. While documents on obstacles and limitation surface based on ICAO Standards and Recommended Practices (SARPS) were sourced from Annex 14(Aerodromes).

A baseline of known length was established with the feature normal to themidpoint of the baseline. Two differential GPS points was formed at the ends of the baseline. Two theodolitereadings was taken to the top of the feature from each end of the baseline plus adistance.

Differential Global Positioning System (DGPS) was used to get the coordinates xyz of the Aerodrome obstacles. Electronic Theodolites was used to get the direction of bearing of the identified obstacles (i.e. obstacles on the runway and take-off climb). Administrative map was used to identify the location of the study area and feature such as roads and L.G.A. boundary. Quick Bird imagery was used to extract the fixed physical features (both manmade and natural) within the vicinity of the Kano Aerodrome and its environs in ArcGIS 10.1 using the editor tool. This served as the base map for the study. While the obstacle limitation surfaces (OLS) are set of standards used to check the level of conformity in terms of obstacles penetration with ICAO Standards. Secondary data was also obtained from published and unpublished thesis; information from journals, text books, internets materials, research thesis was also used.

3.3.4 Data Processing

3.3.4.1 Image Geo-referencing

The images were imported into Erdas Imagine 9.2 environment where they were rectified to a common projection (Universal Traverse Mercator). According to Wilford (1977), the UTM projection unlike the Geographic Coordinate System (latitude/longitude) is more reliable since its measurements are cited in linear, decimal units, rather than in angular, non-decimal units. This was done to translate the images real world coordinate to digital format so that it can be matched with other relevant and related maps that were used in this study.Georeferencing which involves registering data to the real world was carried out by assigning geographic information like location and position, to the data sets

(images). This helpedindefining the existence of those data sets in physical space as well as establishes their location in the real world.

3.3.4.3 Digitizing

The imagery was used to digitize the fixed physical features (both manmade and natural) within the vicinity of the Kano Aerodrome and its environs in ArcGIS 10.1 using the editor tool. This was done by creating layers of interest (shapefiles) such road, runway and L.G.A. boundaries. This served as the base map for the study.

3.3.4 Method of Data Analysis

3.3.4.1 Defining, identification and mapping of potential aerodrome obstacles on flight safety operations

The coordinates extracted from the differential GPS was converted to degree decimal and entered into the Microsoft Excel and save as comma separated value (.csv) file format and then imported into the ArcGIS environment where the points was overlaid on the base map.

3.3.4.2 Pattern of the Potential Aerodrome Obstacle on Flight Operations

This was achieved using average nearest neighbour analysis to determine if the distribution pattern of the obstacles within the approach, take off and taxing is random, clustered or dispersed. The average neighbour in ArcGIS calculates the z-score and the nearest neighbour index. The pattern was determine base on this two parameters. The nearest neighbour index is given by:

$$\text{Nearest neighbour index} = \frac{observed\ distance}{expected\ distance}$$

The Average Nearest Neighbor tool measures the distance between each feature centroid and its nearest neighbor's centroid location. It then averages all these nearest neighbor distances. If the average distance is less than the average for a hypothetical random distribution, the distribution of the features being analyzed is considered clustered. If the

average distance is greater than a hypothetical random distribution, the features are considered dispersed. The average nearest neighbor ratio is calculated as the observed average distance divided by the expected average distance (with expected average distance being based on a hypothetical random distribution with the same number of features covering the same total area).

3.3.4.3 Characterization of the potential aerodrome obstacles as relates to ICAO Standards and Recommended Practices (SARPS)

Having identified and mapped out the aerodrome obstacles with the pattern of spatial distribution and their threat to flight operations, this was achieved by characterizing the obstacles into authorized and unauthorized obstacles as specified by International Civil Aviation Organisation (ICAO) standards and recommended practices (SARPs) on obstacles limitations surfaces with the identified aerodrome obstacles in MallamAminu Kano International Airport.

Authorized obstacles are those structural facilities and equipment situated within the vicinity of the aerodrome which has direct operational significance to flight operations as such, they can be controlled by the aerodrome operators either by obstacles shielding, obstacle marking, or lighting. Unauthorized obstacles are structural features (natural or man-made) found within the vicinity of the aerodrome that has no direct or indirect significance to flight operations but considered to endanger the safety of an aircraft after an aeronautical study. They can be controlled by height zoning, complete obstacle removal programme, easement or property right as provided by ICAO provisions.

CHAPTER FOUR :RESULTS AND DISCUSSIONS

4.1 INTRODUCTION

This chapter is concern with the analysis of the data collected during field work. The analysis include: identifying and mapping of the aerodrome obstacle, the pattern of distribution of the obstacles. Finally the distribution of the obstacles were compared with ICAO standards and recommended practices.

4.2 DEFINING, IDENTIFICATION AND MAPPING OF AERODROME OBSTACLES ON FLIGHT SAFETY OPERATIONS

In an attempt to define, identify and map aerodrome obstacles at MallamAminu Kano International Airport (MAKIA), Kano State, Nigeria, a Differential Global Position System (DGPS) surveys was carried at the Airport and its immediate environment (i.e. 10nm from the aerodrome reference point) using the World Geodetic System 1984 (WGS-84) reference system in accordance with existing ICAO Standards and Recommended Practices and accepted industry best practices. The identification and mapping of the obstacles was carried out for different obstacle limitation surfaces (OLS). The objectives of the OLS is to define the airspace around the aerodrome to be maintained free of obstacles so as to permit the intended airplane operations at the aerodromes to be conducted safely and to prevent the aerodrome from becoming unusable by the growth of obstacles around the aerodrome. The distribution of obstacles for the different OLS is presented in the following sub-sections:

4.2.1 Pattern of Spatial Distribution of Aerodrome Obstacles

The spatial distribution of obstacles were identified and mapped for seven different obstacle limitation surface (OLS). The surfaces include: the approach surface, the take-off climb, the conical surface, runway, the inner horizontal surface, outer horizontal surfaces and transitional surface. Figure 4.8 represents the distribution of the aerodrome obstacles on the different surface while the types of obstacles where characterized in Table 4.1.

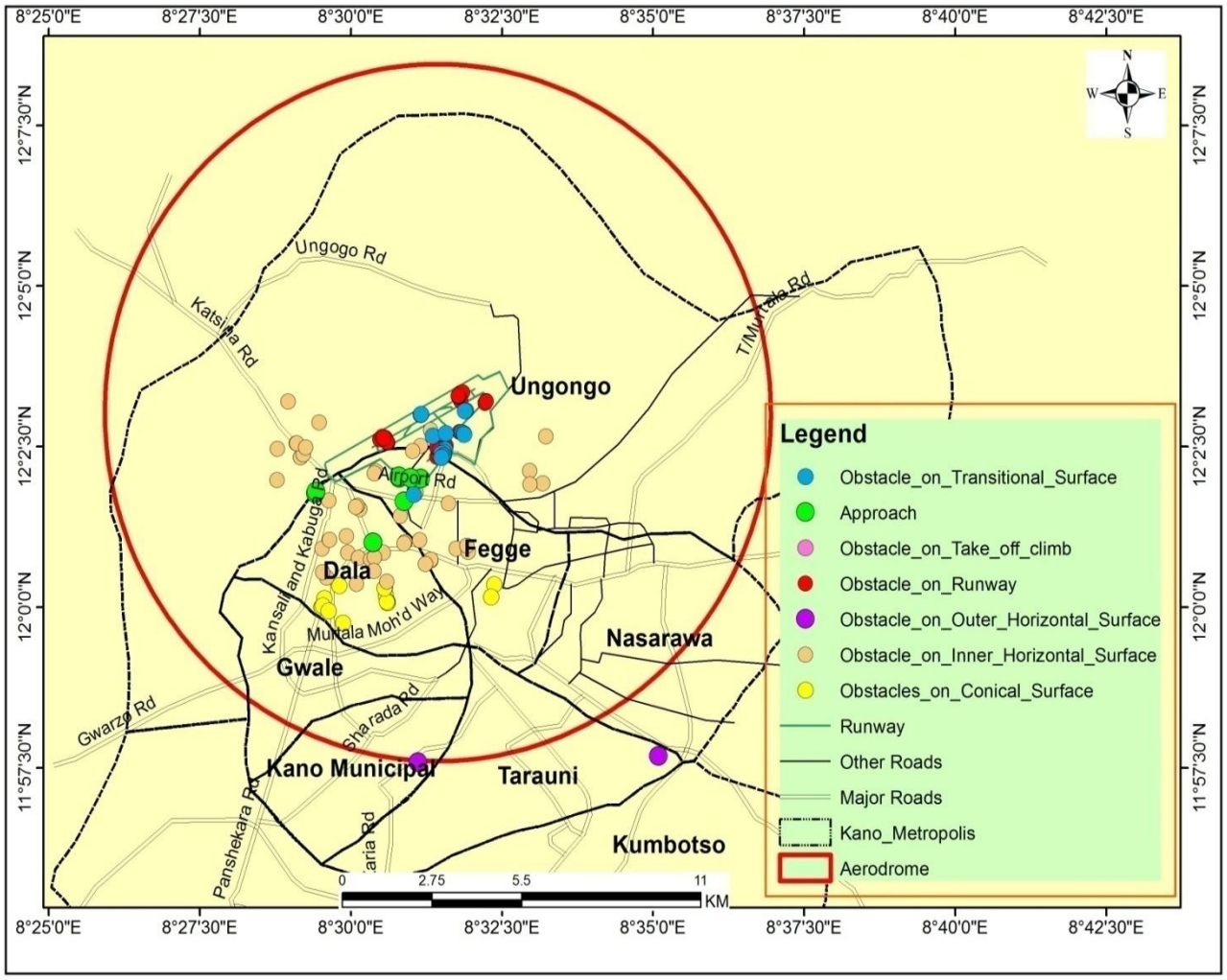

Figure 4.1: Distribution of Aerodrome Obstacles in the Study Area
Source: Author's Analysis, 2015

Table 4.1: Types of Aerodrome Obstacles at MAKIA

Type of Obstacle	Frequency	%
Antenna	2	1.5
Building	4	3.0
Concrete Pillar	2	1.5
Instrument Landing System	36	26.7
Mast	81	60.0
Tree	20	14.8
Hill	1	0.7
Pole	1	0.7
Total	**147**	**100**

Author's Analysis, 2015

Table 4.2: Distribution of Obstacles within different surfaces

Surface	Frequency	%
Approach	10	6.8
Take-off Climb	3	2.0
Runway	46	31.3
Outer Horizontal Surface	2	1.4
Inner Horizontal Surface	55	37.4
Conical Surface	15	10.2
Transitional Surface	16	10.9
Total	147	100

Author's Analysis, 2015

It can be seen from Table 4.1that 60.0% of the obstacles at the MAKIA aerodrome were communication mast which were place for the resident within aerodrome for communication. 26.7% of the obstacles were the ILS (i.e. lighting that aids the landing of an airplane approaching the aerodrome's runway). According to ICAO set recommended practices and regulations stated that if an object or a proposed object which intrudes into navigable airspace requires, or will be required to be provided with, obstacle lighting. It can also be seen that 14.8% of the obstacle constitutes of trees. Only four were building which contributes about 3.0% of the obstruction. Antenna, concrete pillar, hill and pole contributes 1.5%, 1.5%, 0.7% and 0.7% respectively.

Table 4.2 represents the distribution of obstacles on different obstacle limitation surfaces. It observed that 37.4% of the obstacles were found in the inner horizontal surface, followed by the runway with 31.4%. 10.9% of obstacles were found on the transitional surface. While conical surface, approach, take-off climb and outer horizontal surface constitute 10.2%, 6.8%, 2.0% and 1.4% respectively.

2.2 Obstacles on Approach Surface of the Aerodrome

The approach surface is an inclined plane or combination of planes which originate from the inner edge associated with each runway threshold, with two sides originating at the ends of the inner edge (ICAO, 2013). The spatial distribution and the type of obstacles on the approach surface of the aerodrome is presented in Table 4.3 and Figure 4.2:

Table 4.3. Obstacles on the Approach Surface

Obstacle	Frequency	%
Communication Mast	6	60
Tree	3	30
ILS	1	10
Total	**10**	**100**

Source: Author' Analysis, 2015.

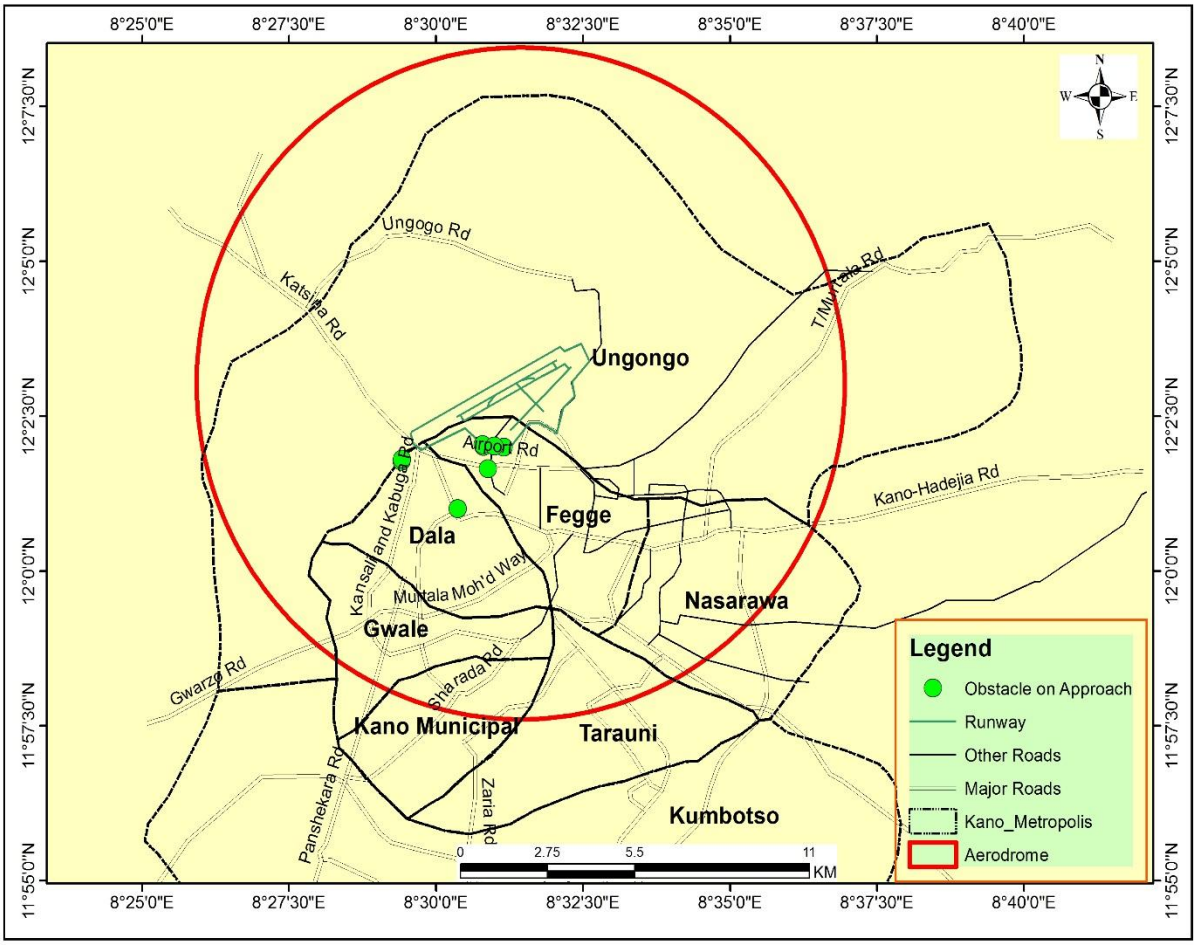

Figure 4.2: Obstacles on the Approach Surface of the Aerodrome
Source: Author's Analysis, 2015

It can be seen from Figure 4.2 that 10 obstacles were observed on the approach surface of the aerodrome. 60% of the obstacle were telecommunication mast, 30% were found to

trees, and 10% was found to be light (Instrument Landing System ILS). According to ICAO any object be it man-made or natural on approach surface of an aerodrome may endanger the safety of an aircraft when preparing for landing.

4.2.3 Obstacles on Take-Off Climb Surface of the Aerodrome

The take-off climb surface of aerodrome is defined by an inclined plane (or other shape in the case of curved take-off) located beyond the end of the runway or clearway. Table 4.4 Figure 4.3 arepresents the obstacles identified on the Take-off climb of the aerodrome.

Table 4.4: Obstacles on Take-Off Climb Surface

Obstacles	Frequency	%
Mast	2	66.7
ILS	1	33.3
Total	**3**	**100**

Source: Author' Analysis, 2015.

Figure 4.3: Obstacles on Take-Off Climb Surface of the Aerodrome
Source: Author's Analysis, 2015

Figure 4.3 shows that three obstacles were found on the take-off climb of the aerodrome of which 67.7% of the obstacle were mast and 33.3% was found to be an instrument landing system (light).

4.2.4 Obstacles on Runway Surface of the Aerodrome

A runway is a defined rectangular area on a land aerodrome prepared for the landing and take-off of an aircraft. The obstacles on the runway of the aerodrome was identified and the result is presented in Table 4.5 and Figure 4.4.

Table 4.5: Obstacles on Runway Surface

Obstacle	Frequency	%
Mast	3	6.5
Tree	6	13.0
ILS	32	69.6
Building	3	6.5
Concrete Pillar	2	4.3
Total	**46**	**100**

Source: Author' Analysis, 2015.

Figure 4.4: Obstacles on Runway Surface of the Aerodrome
Source: Author's Analysis, 2015

The data Figure 4.4 showed 46 observed obstacles on the runway of MallamAminu Kano International Airport, Kano. 69.6% of the obstacles identified were Instrument Landing Systems (ILS), 13.0% were trees, mast, buildings and concrete pillar were identified to be 6.5%, 6.5% and 4.3% respectively. The high percentage of ILS (lighting) could be as a result of the instruction of civil aviation regulations which stated that an object or a

proposed object which intrudes into navigable airspace requires, or will be required to be provided with, obstacle lighting (ICAO, 2013).

4.2.5 Obstacles on Inner Horizontal Surface of the Aerodrome

An inner horizontal surface is a horizontal plane located above an aerodrome and its environs. It represents the level above which consideration needs to be given to the control of new obstacles and the removal or marking of existing obstacles to ensure safe visual manoeuvring of airplanes in the vicinity of the aerodrome. The outcome of the DGPS surveys identifies 55 obstacles within the aerodrome and result is presented in Table 4.6 and Figure 4.5. It can be seen from the result of the study that 94.6% communication mast were within the inner horizontal surface of the aerodrome, 1.8% were hill, and 3.6% was found to be trees.

Table 4.6: Obstacles on Inner Horizontal Surface

Total	**Frequency**	**%**
Hill	1	1.8
Mast	52	94.6
Tree	2	3.6
Total	**55**	**100**

Source: Author' Analysis, 2015.

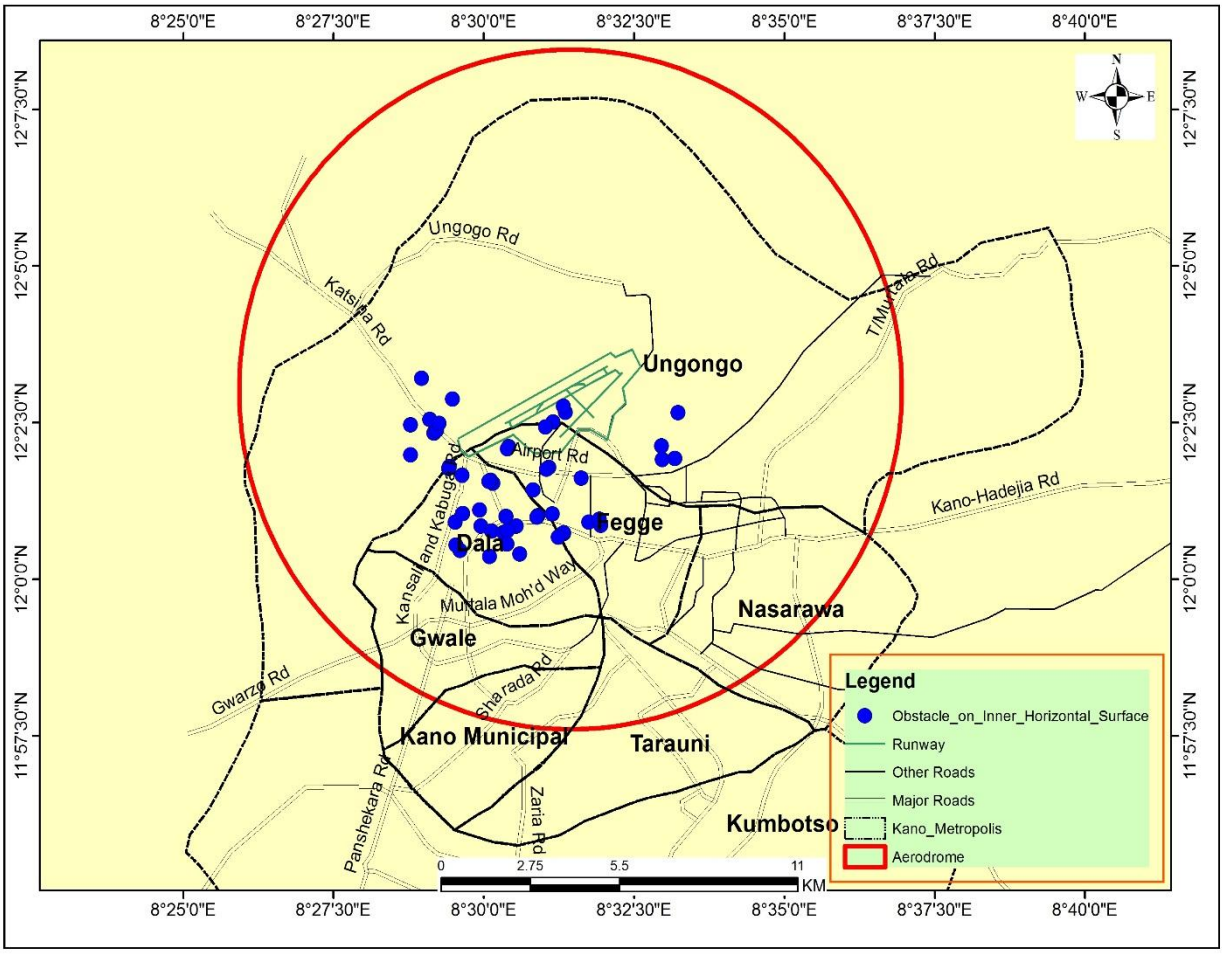

Figure 4.5: Obstacles on Inner Horizontal Surface of the Aerodrome
Source: Field Survey and Author's Analysis, 2015

4.2.6 Obstacles on the Outer Horizontal Surface of the Aerodrome

An outer horizontal surface is a specified portion of a horizontal plane around an aerodrome beyond the limits of the conical surface. It represents the level above which consideration needs to be given to the control of new obstacles in order to facilitate practicable and efficient instrument approach procedures, and together with the conical and inner horizontal surfaces to ensure safe visual maneuvering in the vicinity of an aerodrome. Table 4.7 and Figure 4.6 represents the obstacles on the outer horizontal surface. The result identified two obstacles of which both of them were communication mast

Table 4.7: Obstacles on the Outer Horizontal Surface

Obstacle	Frequency	%
Mast	2	100
Total	2	100

Source: Author' Analysis, 2015.

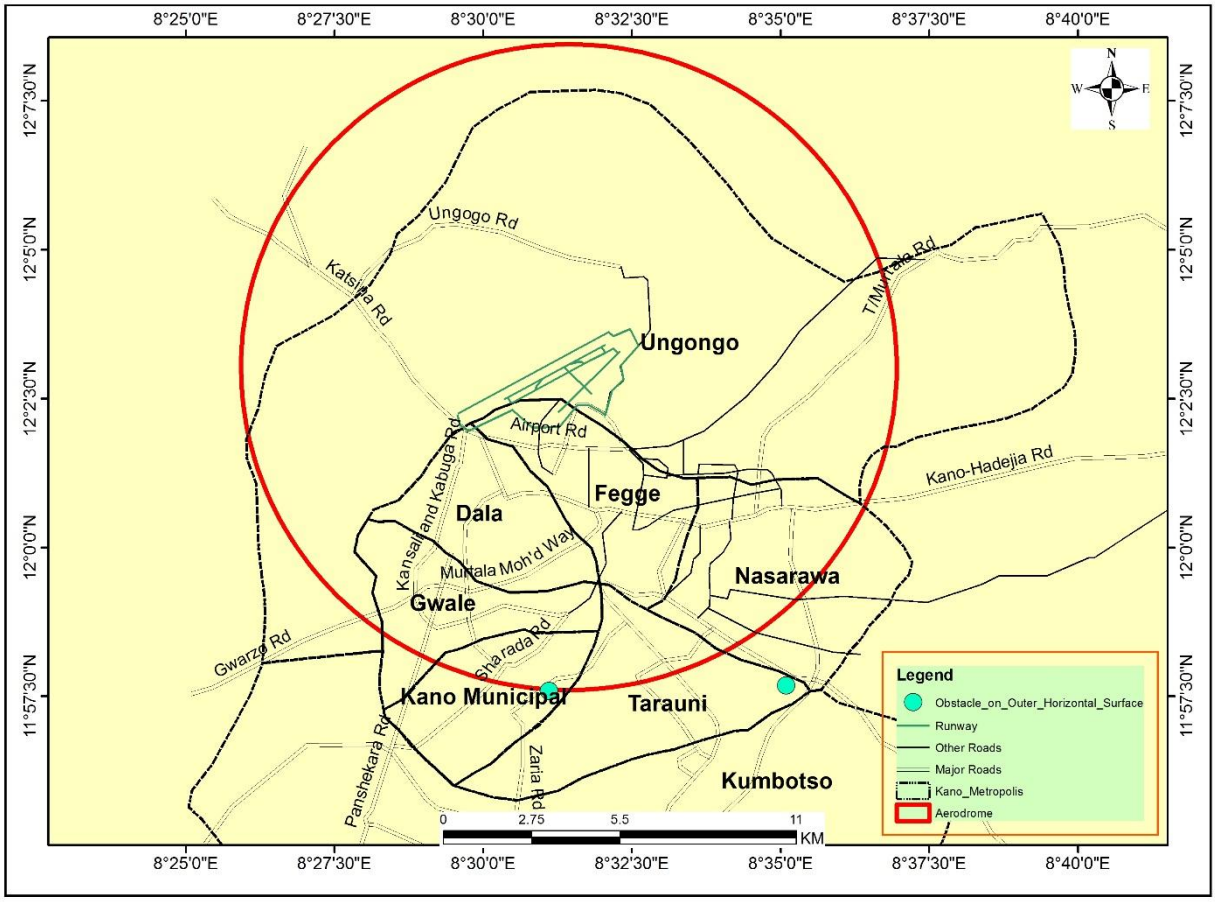

Figure 4.6: Obstacles on the Outer Horizontal Surface of the Aerodrome
Source: Field Survey and Author's Analysis, 2015

4.2.7 Obstacles on the Conical Surface of the Aerodrome

The conical surface comprises both straight and curved elements, which slope upwards and outwards from the edge of the inner horizontal surface to a specified height above the inner horizontal surface. The study identified a total of 15 obstacles within the aerodrome

of which 86.6% of them are communication mast, 6.7% was building and 6.7% was found to be antenna.

Table 4.8: Obstacles on the Conical Surface

Obstacles	Frequency	%
Mast	13	86.6
Building	1	6.7
Antenna	1	6.7
Total	**15**	**100**

Source: Author' Analysis, 2015.

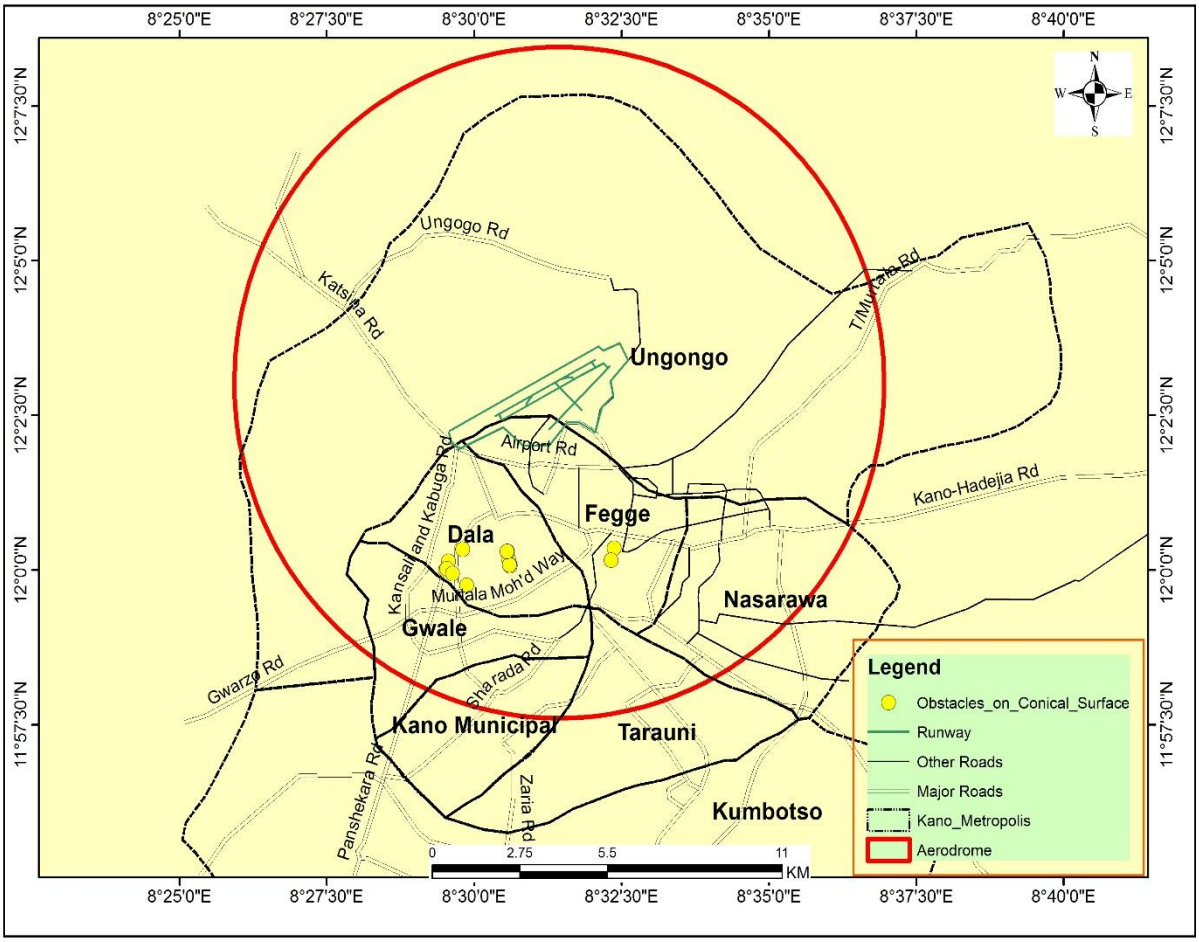

Figure 4.7: Obstacles on the Conical Surface of the Aerodrome
Source: Field Survey and Author's Analysis, 2015

4.2.8 Obstacles on the Transitional Surface of the Aerodrome

The transitional surface is a complex surface along the side of the runway strip and from part of the side of the approach surface that slopes upwards and outwards to the inner horizontal surface. It is established for every runway intended to be used for landing. The spatial distribution of the obstacles is presented in Figure 4.8. 56.25% of the obstacles were observed to be trees, followed by communication mast which is 18.75%. 12.5% are instrument lighting systems. 6.25% and 6.25% are antenna and pole respectively observed on the transitional surface of the aerodrome during the surveys.

Table 4.8: Obstacles on the Transitional Surface

Obstacles	**Frequency**	**%**
Mast	3	18.75
Antenna	1	6.25
Pole	1	6.25
ILS	2	12.5
Tree	9	56.25
Total	**16**	**100**

Source: Author' Analysis, 2015.

Figure 4.8: Obstacles on the Transitional Surface of the Aerodrome
Source: Field Survey and Author's Analysis, 2015

4.3 PATTERN OF THE AERODROME OBSTACLE ON FLIGHT OPERATIONS

In order to analyse the pattern of the distribution of aerodrome obstacles at MAKIA and its immediate environment, the average nearest neighbour in spatial statistic toolbox of ArcGIS version 10.1environment was utilized in analysing the pattern. The average nearest neighbour analyses calculates the nearest neighbour index (which is a measure of the distance between each obstacle centroid and its nearest neighbor's centroid location. It then averages all these nearest neighbor distances), the z-score and the p-value. These parameters were used as the basis for the determining whether the distribution is

clustered, dispersed or random. The overall pattern of distribution is presented in Figure 4.9 and summary of the average neighbour analysis is shown in Table 4.9

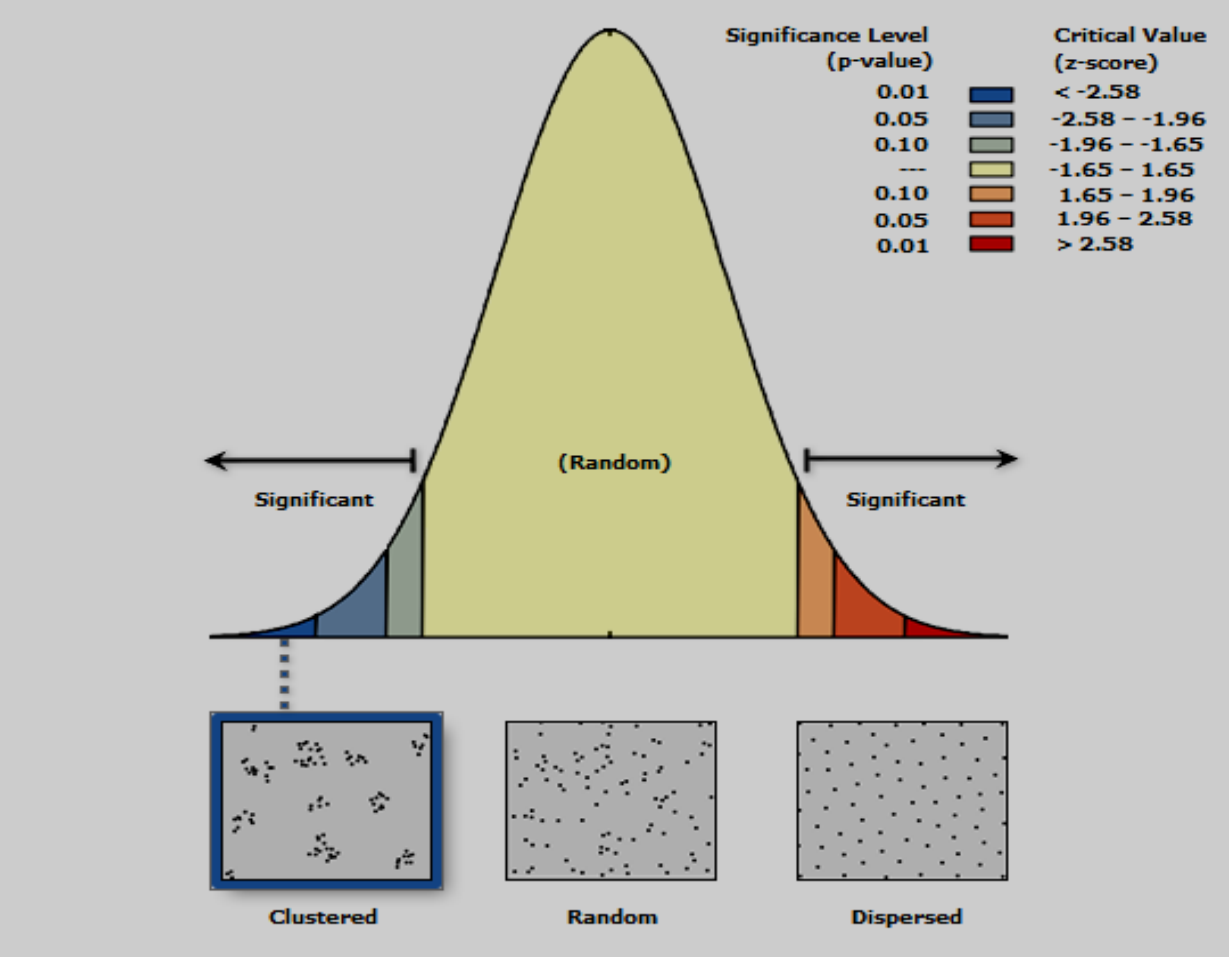

Figure 4.9: Overall Spatial Pattern of Distribution of Obstacles.
Source: Author's Analysis, 2015

Table 4.9: Overall Average nearest neighbor Statistic

Observed Mean Distance:	210.2 Meters
Expected Mean Distance:	427.6Meters
Nearest Neighbor Ratio:	0.491672
z-score:	-11.790535
p-value:	0.000000

Source: Author's Analysis, 2015.

From table 4.9, it is observe that the observed average distance is 210.2m and the expected average distance is 427.6m. The nearest neighbour index was estimated from the two parameters and was calculated as 0.491672 and a z-score of -11.790535. According to Clark and Evans (1954), if the index (average nearest neighbor ratio) is less than 1, the pattern exhibits clustering. If the index is greater than 1, the pattern is toward dispersion. Based on this assertion, the result shows clustering in the overall spatial distribution of obstacles in the vicinity of MAKIA.

Table 4.10: Summary of Average Nearest Neighbour

Surface	Nearest Neighbor Ratio	Z-Score	P-Value	Description
Approach	0.413655	-3.54719	0.000389	Clustered
Take-off Climb	8.794884	25.82862	0	Dispersed
Runway	0.356475	-8.34978	0	Clustered
Inner Horizontal Surface	0.670626	-4.67306	0.000003	Clustered
Outer Horizontal Surface	171.9516	462.5077	0	Dispersed
Conical Surface	0.582206	-3.09556	0.001964	Clustered
Transitional Surface	0.736391	-2.01721	0.043674	Clustered
Total obstacle for all surfaces	0.490189	-11.8249	0	Clustered

Author's Analysis 2015

The equations used to calculate the average nearest neighbor distance index and z-score are based on the assumption that the obstacles being measured are free to locate anywhere within the study area (for example, there are no barriers, and all obstacles are located independently of one another). The nearest neighbour ratio, z-score and p-value for the various surfaces is summarized in Table 4.10

The result from Table 4.10 indicates that the obstacles on approach surface, runway, inner horizontal surface, conical surface and transition surface were clustered. This is because the nearest neighbour ration is less than 1, while those obstacles on the take-off climb and the outer horizontal surface were dispersed because they are greater than 1. From the

study both clustered and dispersed pattern of distribution can be disastrous on the safety of an aircraft. However, the clustered obstacles may easily be avoided by both the pilot and the air traffic controllers while the obstacles that showed the disperse pattern has to be reduced to a minimal level or completely remove as the case may be, in order to avoid the risk of aircraft-obstacle collision in MAKIA.

4.4 CHARACTERIZATION OF THE POTENTIAL AERODROME OBSTACLES AS RELATES TO ICAO STANDARDS AND RECOMMENDED PRACTICES (SARPS)

In conformity with the level of compliance of the locations of obstacles of the aerodrome on the various obstacle limitation surface (OLS) was compared with the ICAO set standard and recommended practices. This was done by characterizing the obstacles into authorized and unauthorized obstacles. Table 4.3 represents the number of authorized and unauthorized obstacle within the vicinity of the MAKIA aerodrome while the spatial distribution of the authorized and unauthorized obstacle in MAKIA aerodrome and its immediate environment is shown in Figure 4.10.

Table 4.3: Authorized and Unauthorized Aerodrome Obstacles in MAKIA

Surface	**Authorized**		**Unauthorized**	
	Freq.	%	Freq.	%
Approach	1	2.4	9	8.5
Take-off Climb	1	2.4	2	1.9
Runway	34	82.9	12	11.3
Outer Horiz. Surface	0	0.0	2	1.9
Inner Horiz. Surface	0	0.0	55	51.9
Conical Surface	1	2.4	14	13.2
Transitional Surface	4	9.8	12	11.3
Total	**41**	**100**	**106**	**100**

Source: Author's Analysis, 2015

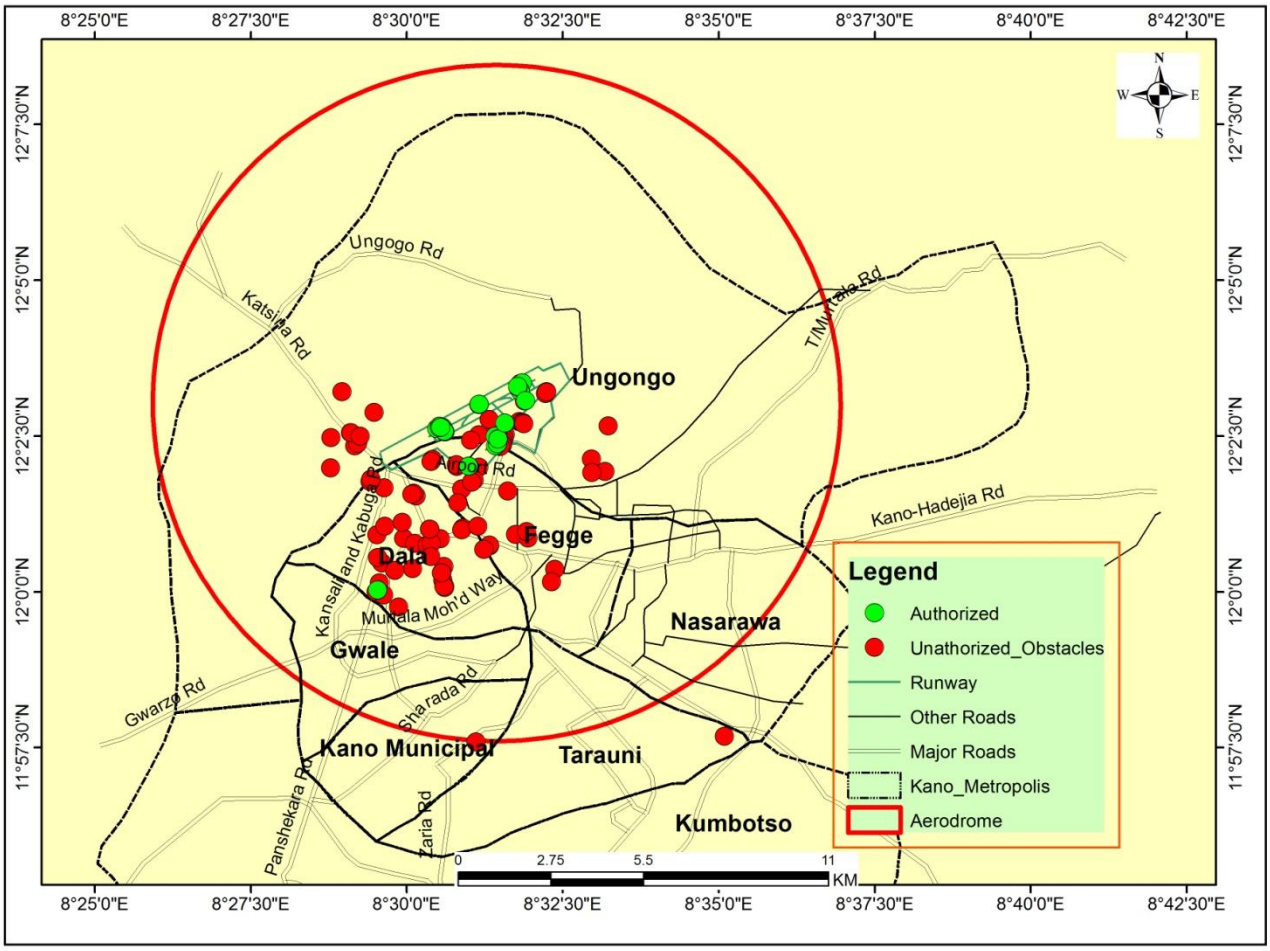

Figure 4.10: Authorized and Unauthorized Aerodrome Obstacle
Source: Author's Analysis, 2015.

From Table 4.3 and Figure 4.10, the result indicates that of the 147 obstacles identified in the study area, only 41 were authorized obstacles, and these obstacle were found in the runway and transitional surface and are basically lighting/ILS for an aircraft approaching the runway. On the other hand, the number of the unauthorized obstacles was 106 with most of it was found on the inner horizontal surface 51.9%. The conical surface have 13.2% unauthorized obstacles, the runway and transitional surface have 11.3% each ofunauthorized obstacle while the approach, take-off climb and the outer horizontal surface have 8.5%, 1.9% and 1.9 respectively.

For the authorized obstacles under the ICAO standard and recommended practice, an object or a proposed object which intrudes into navigable airspace requires, or will be

required to be provided with, obstacle lighting. Responsibility for the provision of obstacle lighting on a building or structure rests with the owner of the building or structure. Within the limits of the obstacle limitation surfaces of an aerodrome, responsibility for the provision of obstacle lighting on natural terrain or vegetation, where determined necessary for aircraft operations at the aerodrome, rests with the aerodrome operators.

For the unauthorized obstacles it is recommended by ICAO that objects which do not project through the take–off/approach surface but which would nevertheless adversely affect the optimum siting or performance of visual or non–visual aids should, as far as practicable, be removed. And also anything which in the opinion of the certifying authority after aeronautical study, endanger aircraft on the movement area or in the air within the limits of the outer surface should be regarded as an obstacle and should be removed in so far as practicable.

CHAPTER FIVE:SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

This chapter highlights the summary of findings, conclusion and the recommendation made in order to minimize the risk of aircraft / obstacle collision in MAKIA aerodrome.

5.2 SUMMARY OF FINDINGS

This study which was embarked upon to analyse the spatial threat of aerodrome obstacles on flight operations in the study area, was done by identifying and mapping of the aerodrome obstacles, examining the pattern of distribution of the obstacles and examining the level conformity of locations of the obstacles, with the ICAO standards and recommended practices. The major findings of the study include the following

a) The study identified 8 types obstacles which include antennas, trees, building, instrument landing systems, communication mast, hill, pole and concrete pillar on the different obstacle limitation surface.

b) The study also revealed that 60.0% of the obstacles at the MAKIA aerodrome were communication mast, 26.7% of the obstacles were the ILS (i.e. lighting that aids the landing of an airplane approaching the aerodrome's runway). It can also be seen that 14.8% of the obstacle constitutes of trees. Only four were building which contributes about 3.0% of the obstruction. Antenna, concrete pillar, hill and pole contributes 1.5%, 1.5%, 0.7% and 0.7% respectively.

c) The study shows that the obstacles on the approach surface, runway, inner horizontal surface, conical surface and transition surface were clustered while those obstacles on the take-off climb and the outer horizontal surface were dispersed.

d) The result of the findings further shows that total of 147 obstacles lies within the study area, of only 41 were authorized obstacles, and these obstacle were found in

the runway and transitional surface and are basically lighting/ILS for an aircraft approaching the runway. On the other hand, the number of the unauthorized obstacles was 106 with most of it was found on the inner horizontal surface constituting about 51.9%. The conical surface have 13.2% unauthorized obstacles, the runway and transitional surface have 11.3% each oftheunauthorized obstacle while the approach, take-off climb and the outer horizontal surface have 8.5%, 1.9% and 1.9% respectively.

5.3 CONCLUSION

The International Civil Aviation Organization set Standards and Recommended Practice for obstacle limitation surface in which Contracting States have to comply in order to prevent aircraft from being involved in aircraft / Obstacle collision. However, from the findings of this study and with the rapid development of aviation technology, it has become increasingly necessary for aerodrome operators to review and ease the existing regulations for obstacle limitation surface. Therefore the present study have used remote sensing, GIS and ground surveys for visual inspections of all areas around the aerodrome in order to be sure that construction activity or natural growth likely to infringe any of the obstacle limitation surfaces is discovered before it becomes a problem.

5.4 RECOMMENDATIONS

Based on the findings of this research of study, the following recommendations are hereby made:

- The study revealed that Nigeria being ICAO member state be recommended to be ICAO e-TOD complaint (i.e. electronic terrain and obstacle data). The obstacle data acquired from this study can equally serve as a source of data for the ICAO e-TOD concept where the software will be installed in the cockpit for the pilot

consumption via the screen. In order to ensure regularity, efficiency and above all safety in aviation industry.

- The aerodrome operator should make use of the obstacle data collected and conduct periodic data analysis. This will allow the aerodrome operator to review the overall effectiveness of the obstacle control process. Through such analysis, the aerodrome operator will also be able to identify potential risks and hotspots, and develop mitigating measures to address them.
- The aerodrome operator should seek continuous improvement in the obstacle control process to ensure that safe aircraft operations can be carried out safely and efficiently at his aerodrome. The aerodrome operator should review the process and ensure that it is in compliance with the ICAO's requirements at all times.
- Each aerodrome operator should designate a member of its staff to be responsible for the continuing process of ensuring that aerodrome approach, departure and manoeuvring areas remain clear of obstacles which may jeopardize safety. The aerodrome operator must maintain constant vigilance to prevent erection of obstacles around the aerodrome. The aerodrome operator should establish a programme of regular and frequent visual inspections of all areas around the aerodrome in order to be sure that construction activity or natural growth likely to infringe any of the obstacle limitation surfaces is discovered before it becomes a problem.
- The obstacle data for this study will also serve as safety tools in the design of approach and take-off procedures for safe air navigation and reduces the work load for pilots and controllers same information will be available both at same time.

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Appendix I

Aerodrome Obstacles Data Survey, 2015

LAT	LONG	m	ft	Description	Easting	Northing	m	Rwy	Surface
12.05552	8.530381	484.45	1589.37	GP_HUT_OBS_LIGHT	448887.6	1332737	462.73	42179	Runway
12.05554	8.530406	492.82	1616.84	GP_24_MAST	448890.4	1332739	471.1	42179	Runway
12.05561	8.530317	484.52	1589.62	OBS_LIGHT	448880.7	1332747	462.8	42179	Runway
12.05564	8.530286	484.51	1589.59	OBS_LIGHT	448877.5	1332750	462.79	42179	Runway
12.04408	8.508628	500.9	1643.37	TREE	446517.6	1331476	479.18	42179	Runway
12.05008	8.519406	494.29	1621.67	HUT	447692.2	1332137	472.57	42179	Runway
12.04395	8.508664	511.38	1677.74	GP_06_MAST	446521.7	1331461	489.66	42179	Runway
12.04397	8.508717	499.53	1638.84	GP_HUT_OBS_LIGHT	446527.3	1331463	477.8	42179	Runway
12.0558	8.530908	487.57	1599.61	GP_24_MONITOR	448945	1332768	465.85	42179	Runway
12.04361	8.508047	502.75	1649.43	GP_06_MONITOR	446454.4	1331424	481.03	42179	Runway
12.04427	8.508708	504.47	1655.06	WINDSLEEVE	446526.6	1331497	482.75	42179	Runway
12.04399	8.509508	498.22	1634.56	PAPI	446613.7	1331465	476.5	42179	Runway
12.04392	8.509547	498.25	1634.67	PAPI	446617.8	1331457	476.53	42179	Runway
12.04384	8.509586	498.26	1634.68	PAPI	446622	1331449	476.54	42179	Runway
12.04377	8.509622	498.27	1634.73	PAPI	446626.1	1331441	476.55	42179	Runway
12.04272	8.510203	498.22	1634.56	PAPI	446689.1	1331325	476.5	42179	Runway
12.04279	8.510164	498.22	1634.56	PAPI	446684.7	1331333	476.5	42179	Runway
12.04286	8.510125	498.25	1634.66	PAPI	446680.4	1331341	476.53	42179	Runway
12.04294	8.510083	498.27	1634.73	PAPI	446676	1331349	476.55	42179	Runway
12.05386	8.530225	484.31	1588.91	PAPI	448870.5	1332554	462.59	42179	Runway
12.05379	8.530264	484.3	1588.88	PAPI	448874.7	1332546	462.57	42179	Runway
12.05372	8.530303	484.27	1588.8	PAPI	448878.9	1332538	462.55	42179	Runway
12.05365	8.530342	484.26	1588.76	PAPI	448883	1332530	462.54	42179	Runway

12.0547	8.529767	484.35	1589.05	PAPI	448820.6	1332646	462.63	42179	Runway
12.05477	8.529728	484.28	1588.82	PAPI	448816.3	1332654	462.56	42179	Runway
12.05484	8.529689	484.29	1588.87	PAPI	448812.1	1332662	462.57	42179	Runway
12.05491	8.529647	484.31	1588.91	PAPI	448807.8	1332670	462.59	42179	Runway
12.04382	8.508847	499.08	1637.38	CONCRETE_PILLAR	446541.7	1331447	477.36	42179	Runway
12.04395	8.509094	499.05	1637.28	CONCRETE_PILLAR	446568.6	1331462	477.33	42179	Runway
12.04202	8.526333	502.88	1649.84	TREE	448444.5	1331244	481.16	42147	Runway
12.04098	8.525506	506.38	1661.33	TREE	448354.4	1331130	484.66	42147	Runway
12.03997	8.524656	504.2	1654.19	TREE	448261.5	1331018	482.48	42147	Runway
12.03958	8.524214	504.13	1653.95	GP_05_MAST	448213.3	1330975	482.41	42147	Runway
12.04551	8.530025	501.98	1646.9	TREE	448847.1	1331629	480.26	42147	Runway
12.04003	8.524636	504.62	1655.57	TREE	448259.5	1331025	482.9	42147	Runway
12.03904	8.5237	494.67	1622.92	GP_05_MONITOR	448157.3	1330916	472.95	42147	Runway
12.03955	8.524261	499.45	1638.58	DME	448218.4	1330972	477.72	42147	Runway
12.04136	8.523869	492.16	1614.67	PAPI	448176.3	1331172	470.44	42147	Runway
12.04142	8.523811	492.15	1614.66	PAPI	448169.9	1331179	470.43	42147	Runway
12.04148	8.523753	492.18	1614.75	PAPI	448163.6	1331185	470.46	42147	Runway
12.04153	8.523694	492.03	1614.24	PAPI	448157.2	1331191	470.31	42147	Runway
12.04086	8.524381	492.06	1614.34	PAPI	448231.8	1331117	470.34	42147	Runway
12.04081	8.524439	492.07	1614.37	PAPI	448238.1	1331111	470.35	42147	Runway
12.05304	8.537058	481.21	1578.75	BUILDING	449614	1332461	459.49	42147	Runway
12.05351	8.537322	481.85	1580.86	BUILDING	449642.7	1332513	460.13	42147	Runway
12.05339	8.537344	480.43	1576.2	BUILDING	449645.1	1332500	458.71	42147	Runway
12.0295	8.490278	551.38	1808.98	MAST	444517.6	1329867	529.66	42179	Approach
12.03001	8.490408	543.05	1781.62	MAST	444531.7	1329923	521.32	42179	Approach
12.02744	8.5147	520.82	1708.7	COMMS_MAST	447175.5	1329635	499.1	42147	Approach
12.0333	8.519239	503.66	1652.42	TREE	447670.6	1330282	481.94	42147	Approach
12.01674	8.506133	547.59	1796.54	COMMS_MAST	446241	1328452	525.87	42147	Approach

12.0335	8.513389	512.95	1682.88	TREE	447034	1330305	491.23	42147	Approach
12.03393	8.513228	517.58	1698.07	TREE	447016.5	1330353	495.86	42147	Approach
12.01674	8.506131	548.38	1799.13	COMMS_MAST	446240.4	1328453	526.66	42147	Approach
12.01675	8.506139	548.05	1798.03	COMMS_MAST	446241.4	1328454	526.33	42147	Approach
12.03355	8.516533	505.5	1658.45	05_LOCATOR	447376.2	1330310	483.78	42147	Approach
12.0295	8.490278	551.38	1808.98	MAST	444517.6	1329867	529.66	42179	Take Off Climb
12.03001	8.490408	543.05	1781.62	MAST	444531.7	1329923	521.32	42179	Take Off Climb
12.03355	8.516533	505.5	1658.45	05_LOCATOR	447376.2	1330310	483.78	42147	Take Off Climb
12.05002	8.519275	503.46	1651.74	MAST	447677.9	1332131	481.74	42179	Transitional
12.05012	8.5194	501.93	1646.74	OLD_DME	447691.3	1332142	480.21	42179	Transitional
12.04442	8.522617	528.5	1733.89	MAST	448040.4	1331511	506.77	42147	Transitional
12.04099	8.525989	507.51	1665.03	TREE	448406.7	1331130	485.79	42147	Transitional
12.04028	8.525606	511.34	1677.6	TREE	448364.9	1331052	489.62	42147	Transitional
12.03987	8.524981	506.96	1663.22	TREE	448296.9	1331007	485.23	42147	Transitional
12.03939	8.525636	509.34	1671.05	TREE	448368.2	1330954	487.62	42147	Transitional
12.03916	8.525339	506.82	1662.76	TREE	448335.9	1330928	485.1	42147	Transitional
12.03885	8.524997	505.27	1657.68	TREE	448298.6	1330894	483.55	42147	Transitional
12.02928	8.517406	524.16	1719.65	COMMS_MAST	447470.3	1329838	502.44	42147	Transitional
12.0451	8.526175	499.32	1638.18	WINDSLEEVE	448427.9	1331585	477.6	42147	Transitional
12.0453	8.530678	502.99	1650.22	TREE	448918.1	1331606	481.27	42147	Transitional
12.04514	8.531086	506.27	1660.97	TREE	448962.3	1331588	484.55	42147	Transitional
12.0449	8.531272	508.3	1667.62	TREE	448982.6	1331562	486.58	42147	Transitional
12.05108	8.531725	492.14	1614.62	ANTENNA	449033.1	1332246	470.42	42147	Transitional
12.05096	8.531483	492.3	1615.13	POLE	449006.9	1332232	470.58	42147	Transitional
12.04442	8.522617	528.5	1733.89	MAST	448040.4	1331511	506.77	42179	Inner Horizontal
12.04603	8.522053	526.82	1728.39	MAST	447979.3	1331689	505.1	42179	Inner Horizontal
12.03534	8.506917	526.2	1726.34	TREE	446329.9	1330510	504.47	42179	Inner Horizontal
12.03478	8.5065	524.29	1720.1	TREE	446284.3	1330448	502.57	42179	Inner Horizontal

12.02556	8.502494	526.26	1726.57	COMMS_MAST	445846.4	1329429	504.54	42179	Inner Horizontal
12.03309	8.47965	549.09	1801.46	COMMS_MAST	443361.3	1330267	527.37	42179	Inner Horizontal
12.03897	8.486186	554.12	1817.94	COMMS_MAST	444074.1	1330915	532.4	42179	Inner Horizontal
12.04116	8.479725	549.96	1804.32	COMMS_MAST	443371.1	1331159	528.24	42179	Inner Horizontal
12.04254	8.48505	547.69	1796.86	COMMS_MAST	443951	1331310	525.97	42179	Inner Horizontal
12.01417	8.508956	576.05	1889.9	COMMS_MAST	446547.6	1328168	554.33	42179	Inner Horizontal
12.02636	8.501839	533.26	1749.52	MAST	445775.3	1329518	511.54	42179	Inner Horizontal
12.02609	8.501378	539.52	1770.06	MAST	445725.2	1329487	517.8	42179	Inner Horizontal
12.02773	8.493942	559.36	1835.14	COMMS_MAST	444916	1329670	537.64	42179	Inner Horizontal
12.0295	8.490278	551.38	1808.98	MAST	444517.6	1329867	529.66	42179	Inner Horizontal
12.03001	8.490408	543.05	1781.62	MAST	444531.7	1329923	521.32	42179	Inner Horizontal
12.03897	8.486186	554.55	1819.36	MAST	444074.2	1330915	532.83	42179	Inner Horizontal
12.03968	8.486894	544.48	1786.34	MAST	444151.3	1330993	522.76	42179	Inner Horizontal
12.04254	8.485061	548.51	1799.54	MAST	443952.3	1331311	526.79	42179	Inner Horizontal
12.04154	8.487583	550	1804.44	COMMS_MAST	444226.7	1331199	528.28	42179	Inner Horizontal
12.05346	8.482756	557.69	1829.66	COMMS_MAST	443703.7	1332518	535.97	42179	Inner Horizontal
12.04798	8.491333	545.16	1788.57	COMMS_MAST	444636.2	1331911	523.44	42179	Inner Horizontal
12.04192	8.519222	527.81	1731.65	COMMS_MAST	447670.4	1331235	506.09	42179	Inner Horizontal
12.04054	8.517086	529.49	1737.16	COMMS_MAST	447437.7	1331082	507.77	42179	Inner Horizontal
12.02983	8.518078	524.97	1722.33	COMMS_MAST	447543.6	1329897	503.25	42179	Inner Horizontal
12.03217	8.552931	524.67	1721.35	MAST	451337.8	1330151	502.95	42179	Inner Horizontal
12.03546	8.549303	528.53	1734	MAST	450943.5	1330515	506.81	42179	Inner Horizontal
12.03188	8.549467	524.89	1722.07	MAST	450960.8	1330118	503.17	42179	Inner Horizontal
12.04438	8.553844	533.36	1749.85	MAST	451439.3	1331500	511.64	42179	Inner Horizontal
12.02928	8.517406	524.16	1719.65	COMMS_MAST	447470.3	1329838	502.44	42179	Inner Horizontal
12.01674	8.506133	547.59	1796.54	COMMS_MAST	446241	1328452	525.87	42179	Inner Horizontal
12.00612	8.501575	546.01	1791.36	COMMS_MAST	445742.5	1327280	524.29	42179	Inner Horizontal
12.00773	8.493417	553.75	1816.75	COMMS_MAST	444854.7	1327459	532.03	42179	Inner Horizontal

12.00914	8.492278	542.09	1778.5	COMMS_MAST	444731	1327616	520.37	42179	Inner Horizontal
12.01523	8.492044	541.49	1776.52	COMMS_MAST	444706.9	1328289	519.77	42179	Inner Horizontal
12.01423	8.499231	535.98	1758.44	COMMS_MAST	445489	1328176	514.26	42179	Inner Horizontal
12.01753	8.494178	538.15	1765.56	COMMS_MAST	444939.7	1328542	516.43	42179	Inner Horizontal
12.01289	8.502164	549.41	1802.49	COMMS_MAST	445807.9	1328028	527.68	42179	Inner Horizontal
12.01851	8.498794	531.44	1743.56	COMMS_MAST	445442.3	1328650	509.72	42179	Inner Horizontal
12.01247	8.505469	552.4	1812.3	COMMS_MAST	446167.8	1327981	530.68	42179	Inner Horizontal
12.01294	8.506481	543.61	1783.46	COMMS_MAST	446277.8	1328033	521.89	42179	Inner Horizontal
12.01674	8.506131	548.38	1799.13	COMMS_MAST	446240.4	1328453	526.66	42179	Inner Horizontal
12.02377	8.513633	537.36	1762.98	MAST	447058.7	1329228	515.64	42179	Inner Horizontal
12.01699	8.515008	536.31	1759.54	COMMS_MAST	447207	1328479	514.59	42179	Inner Horizontal
12.01655	8.514697	534.68	1754.18	COMMS_MAST	447173	1328430	512.96	42179	Inner Horizontal
12.02693	8.527014	524.04	1719.27	COMMS_MAST	448515.8	1329576	502.32	42179	Inner Horizontal
12.01744	8.518992	529.86	1738.37	COMMS_MAST	447640.6	1328528	508.14	42179	Inner Horizontal
12.01527	8.529111	535.96	1758.39	COMMS_MAST	448741.8	1328286	514.24	42179	Inner Horizontal
12.01435	8.532419	532.38	1746.63	COMMS_MAST	449101.7	1328184	510.66	42179	Inner Horizontal
12.01222	8.522142	534.73	1754.33	COMMS_MAST	447982.6	1327950	513	42179	Inner Horizontal
12.01602	8.532008	535.22	1755.93	COMMS_MAST	449057.3	1328368	513.49	42179	Inner Horizontal
12.01241	8.522106	535.26	1756.08	COMMS_MAST	447978.7	1327971	513.54	42179	Inner Horizontal
12.01126	8.520592	530.91	1741.82	COMMS_MAST	447813.5	1327845	509.19	42179	Inner Horizontal
12.00673	8.509967	541.32	1775.96	COMMS_MAST	446656.2	1327345	519.6	42179	Inner Horizontal
12.01675	8.506139	548.05	1798.03	COMMS_MAST	446241.4	1328454	526.33	42179	Inner Horizontal
12.00943	8.506389	538.58	1766.96	HILL	446267.2	1327644	516.86	42179	Inner Horizontal
12.00307	8.509661	543.66	1783.63	COMMS_MAST	446622.1	1326940	521.94	42179	Conical
12.00144	8.510172	553.45	1815.77	COMMS_MAST	446677.4	1326761	531.73	42179	Conical
12.00115	8.510167	547.48	1796.17	COMMS_MAST	446676.9	1326728	525.76	42179	Conical
11.9959	8.4979	579.97	1902.78	COMMS_MAST	445340.4	1326150	558.25	42179	Conical
12	8.491897	587.91	1928.81	COMMS_MAST	444687.8	1326604	566.19	42179	Conical

12.00235	8.492692	557.54	1829.18	BUILDING	444774.6	1326864	535.82	42179	Conical
12.00565	8.496764	543.42	1782.86	COMMS_MAST	445218.6	1327228	521.7	42179	Conical
12.00504	8.509381	557.44	1828.85	COMMS_MAST	446592	1327158	535.72	42179	Conical
12.00595	8.53955	586.37	1923.75	COMMS_MAST	449876.4	1327254	564.65	42179	Conical
12.00269	8.538714	608.84	1997.48	COMMS_MAST	449784.8	1326893	587.12	42179	Conical
12.00001	8.4919	593	1945.52	MAST	444688.1	1326606	571.28	42179	Conical
12.00041	8.492258	564.01	1850.41	ANTENNA	444727.2	1326650	542.29	42179	Conical
11.9991	8.493847	574.51	1884.85	COMMS_MAST	444899.8	1326504	552.79	42179	Conical
12.00145	8.509967	551.69	1809.98	COMMS_MAST	446655.1	1326761	529.97	42179	Conical
12.00501	8.509272	555.91	1823.84	COMMS_MAST	446580.1	1327156	534.19	42179	Conical
11.96134	8.584883	808.26	2651.75	MAST	454804.2	1322313	786.54	42179	Outer Horizontal
11.9598	8.5185	633.71	2079.07	MAST	447575.9	1322154	611.99	42179	Outer Horizontal

Appendix II

Rader Antenna Mast at the Tracon Centre, at MAKIA

Appendix III

Front View of MAKIA Terminal Building Attached with the Control Tower

Appendix IV

A Typical Example of Trees and Fuel Storage Tanks around the MAKIA Aerodrome

Appendix V

Overhead Water Tank Close to the Air Site at MAKIA

Appendix VI

Abandoned Fire Station with Watch Tower Close to the Apron

Appendix VII

Uncompleted New International Terminal Building at MAKIAShowing Crane

Appendix VIII

Communication Masts Scattered within the Vicinity of the Aerodrome