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GIS-Based Assessment of Land-Use and Navigational Facilities at the Murtala Mohammed Airport, Ikeja-Lagos, Nigeria

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ABSTRACT

The study aimed at assessing the land-use and navigational facilities and their effective management at the Murtala Mohammed airport, Ikeja (MMAI) by mapping and generating an updated inventory of the utilities, creating a database and determining the status and functionality of the facilities in relation to International Civil Aviation Organization (ICAO) requirements. By applying GIS approaches in data collection and analyses, the facilities inventory and database were created for the airport. The study also identified the number of facilities that were due for either maintenance, replacement or resurfacing. Areas for further expansion were also discovered. Conclusively, the study revealed the applicational benefits of GIS tools in aviation industry in Nigeria.

INTRODUCTION

Movement of human, goods and services from one destination to the other is a key factor in the socio-economic development of any nation. Though air transportation was introduced after the land and water transportations yet, it has relatively created more positive impacts than the other two forms of transportation owing to its swift feature, long distance coverage and more comfortability. These unique advantages of the air transport promote its preferential and high patronage leading to increasing in the volume of activities which demand more space, time and absolute attention. There are several publications on the advantages and applications of air transport over other modes of movement (Budd *et al*, 2016; Budd *et al*, 2011).

Airport authorities nowadays are presented with unprecedented challenges in providing more safety and security for their esteemed clients, whilst at the same time keep improving and managing their infrastructures efficiently (Robertson 2008). Sequel to these, modern airports globally are finding an integrated technology relevant and better in the management of both air- and ground- facilities at the airports. The use of GIS tools in-flight tracking, security, information dissemination, and flight timing became more efficient. In addition, the latest enhancements to three-dimensional GIS promotes more advanced airspace modeling applications to be combined with geographic data from the surrounding environment, including land-use, building features and modified landscape within the airport thus, improving obstruction and land-use analysis in most aviation industries worldwide. Ward *et al.* (2010) reported significant development in Navigation through the integration of PLTS and GIS by building a database driven aeronautical solution for the charts enroutement for aircraft navigation. In terms of airport expansion or new construction, proper designing and planning are essential and using mapping data from the local communities, such as ground access, neighborhood constraints and environmental sensitivities, can significantly decrease the period spent in evaluating salient land-use features, especially for expansions of landlocked facilities in thickly human-populated urban places.

The goal of every stakeholder and managers of the airports is to ensure effective operations while maximizing profit. It has therefore been revealed that combining GIS with the airport facilities management has produced relatively high returns for the airport authorities. In relation to airport land-use and other facilities maintenance, the benefit of GIS cannot be overemphasized in modern airports. For example, from pavement and runway lighting systems to terminal side facilities, GIS can provide a powerful graphical component for the maintenance of any airport's critical infrastructure. Recently at the state airports in New England, the role of GIS technology has been used to improve the airports' all rights-of-way (ROW). Prior to the advent of GIS, the FAA-protected surfaces create undefined challenges in ascertaining the location of the surfaces, which zones are to be mowed of vegetation and how (Layton and Stearns, 2008). GIS was used to examine the differences between ground contours and the FAA surfaces and this measure prompted the development of compatible vegetation zones underneath the flight surfaces. Other problems associated with airports are land-use compatibility and noise pollution. At Imam Khomeini International Airport (IKIA) in Tehran, the geoinformatics tools (Remote Sensing and GIS) were used in conjunction with an Integrated Noise Model (INM) software, to determine the relative effects of aircraft noise. This study helped in building and predicting a Strategic Noise Map (SNM) scenarios of the airport operation in the years 2011, 2020 and 2030 (Sadr et al. 2014).The several cases of poor land-use management and outdated navigational infrastructures prompted this study. For instance, negligence in the airport land-use utilities has earlier posed threats to safety at the airport by the intruding of pastoralists and their animals that consequently led to flight interruptions at the Ikeja airport. Globally, airports, airlines and flight control managers have adopted and benefited enormously from the use of GIS in several ways during their operations. However, in Nigeria, little has been done on the use of GIS as a tool for airport designing, planning and decision making. This paper aimed at assessing the land-use and navigational facilities and their effective management at the Murtala Mohammed airports, Ikeja (MMAI) by mapping and generating an updated inventory of the utilities, creating a database and determining the status and functionality of the facilities in relation to International Civil Aviation Organization (ICAO) requirements.

We hypothesize that the integration of GIS techniques in land-use and navigational facilities at the MMAI has positively enhanced the airport's trajectory by increasing operational efficiency and safety. Sequel to this conceptual background we attempt to proffer answers to the following questions:

1. What are the land-use and navigational facilities at the MMAI and how important are they?

2. Which facilities are due for maintenance and how are they identified?

3. How can GIS tools be applied in the aviation industry in determining the status of the infrastructures?

4. What are the benefits of introducing GIS in airport land-use and facilities planning and management?

MATERIALS AND METHODS

Study area

Murtala Mohammed airport, Ikeja, Lagos was the focus of the study. The airport covers an area of about 30 km^2. The aerodrome reference point (that is the geographical center of the airport) is at latitude 6^0 34' 29" N and longitude 3^0 19' 07" E (Fig.1). The airport has two runways for landings and takeoffs of the aircraft. These runways 19-left and 19-right are of length 2745 and 3900 meters respectively. Both runways are instrument runways equipped with Instrument Landing System (ILS).

Murtala Mohammed airport is the hub of air travel in Nigeria. In the year 2002, about 5.2 million passengers flew in and out of Lagos in Nigeria through the airport. As of December 2002, an average of 120 landings and average of the same figure for take-offs are recorded daily. This record increased in subsequent years. The airport has a local and international wing. The international wing has a modern terminal building which was commissioned in 1979.

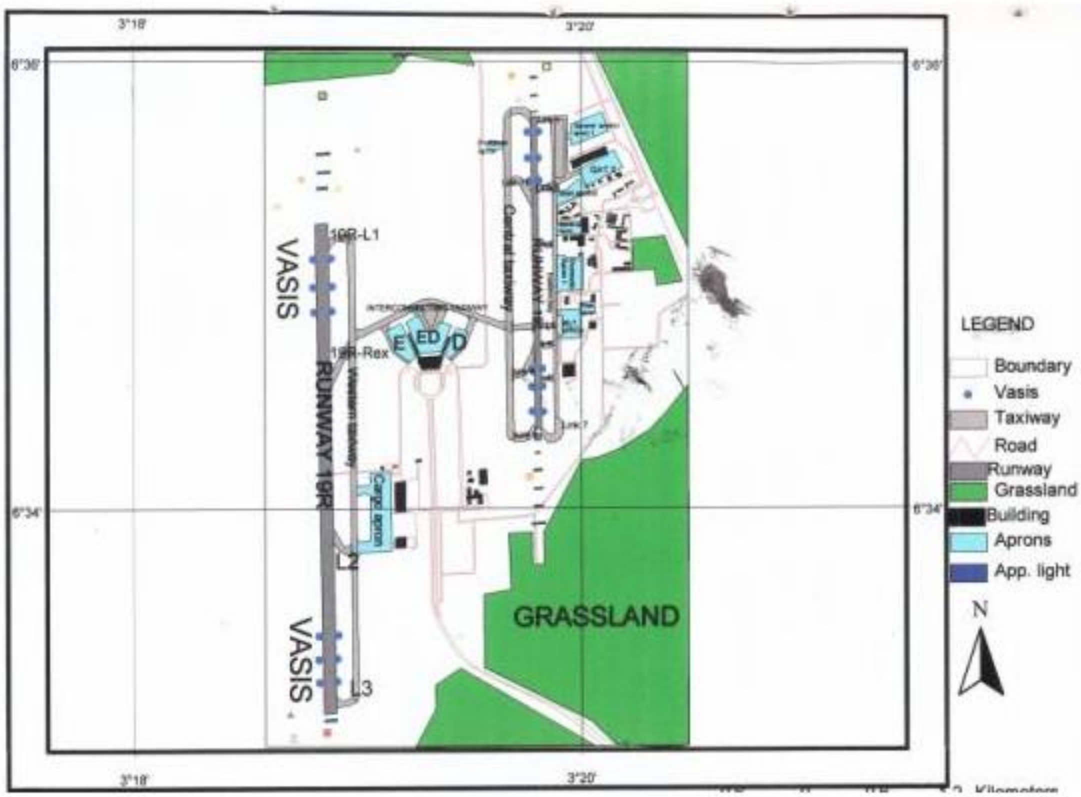

Fig. 1: Study area - Murtala Mohammed airport, Ikeja, Lagos

Data collection and sampling

The airport has many land-use and navigational facilities that are spatially distributed over the airport. The primary and secondary data were used for this study. A reconnaissance survey of the airport was first adopted to give the researchers a firsthand knowledge of the facilities and their distribution. GPS device was used to gather information about the navigational facilities. Structured interviews were conducted with the officers from Nigerian Airspace Management Agency (NAMA), Nigerian Civil Aviation Authority (NCAA), Federal Airports Authority of Nigeria (FAAN), Nigerian Air Force (NAF) and the private airlines who are responsible for the installation and maintenance of the navigational facilities. The base maps covering the land-use aerodrome layout published by FAAN and ICAO were used as the secondary data. Other included operational manuals of the navigational aids such as Radio Detection and Ranging (RADAR), Instrument Landing System (ILS) and Non-Directional Radio Beacon (NDB), Visual Approach Slope Indicator System (VASIS), the Aprons and others. Literatures released by ICAO were also consulted for necessary information about the facilities at the MMAI.

Data input and analysis

The maps data were entered into the GIS environment by scanning and digitizing while, the GPS data by interpolation using the appropriate ArcGIS tools to create various layers needed. The created features were thoroughly coded by assigning related spatial and attribute information to them. Geo-referencing and transformation were performed as to correct the spatial characteristics of the points, lines and polygons collected. The coordinates of six points captured with the GPS were identified for the georectification (Table 1).

Table 1: Coordinates used for georectification

Number	Latitude (Northing)	Longitude (Easting)
1	605873	303137
2	605748	303216
3	605519	303141
4	605718	303301
5	605748	303222
6	605966	303299

The analysis was performed by calculating the area and measurement distances using the ArchGIS software tools. The query function of the ArcGIS was used to determine the maintenance status of the Land-use facilities at the airport.

Data analysis

The collected data were grouped into four main categories namely; the grassland vegetationalLanduse-landcover, movement area (runways, taxiways, aprons), Visual navigational aids (VASIS, approach lights, runway lights), and the radio facilities (Distance Measuring Equipment-DME, Doppler Vor-DVOR, Very high-frequency Direction Finder-VDF, etc). The facilities were mapped and inventory was taken (Table 2).

To determine the maintenance status of the Land-use and navigational facilities queries were conducted using the GIS tools. Queries 1 to 7 were used to determine the status of the airport facilities in the study year. Query one was employed to adjudicate the radio facilities that were due for maintenance. Query two was applied to measure the calibration status and due date for the radio navigation utilities. Query three was used to ascertain the radio facilities due for total replacement. Query four was used to regulate the apron areas due for resurfacing. Query five helped to classify taxiways due for resurfacing. Query six was used to determine the maintenance status of all VASIS in the airport. Query seven check and confirm all VASIS that are due for replacement.

Table 2: Inventory of the Land-use and navigational facilities

Facility	Subdivision	N0. before study	Additional	N0. after study
Grassland vegetation	south	1	nil	1
	south-east	1	nil	1
	north-east	1	nil	1
	north	1	nil	1
Movement area	Aprons	9	nil	9
	Taxiways	20	nil	20
	Runways	2	nil	2
Radio facilities	DME	3	nil	3
	NDB	2	nil	2
	D-VOR	1	nil	1
	Localizers	2	nil	2
	Glideslope	2	nil	2
	RADAR	1	nil	1
	VDF	1	nil	1
Visual aids	VASIS	48	nil	24
	Approach lights	180	nil	144
	Runway lights	121	nil	108

RESULTS AND DISCUSSION

Geoinformatics (GI) technology has been widely applied in the aviation industry and airports worldwide in a variety of ways. In Nigeria, the introduction of these GI devices in the airport land-use and navigational facilities have yielded fantastic results as shown here in this section.

Grassland vegetational Land-use and land cover

The land-use/cover facility was among the utilities which covered large areas in the airport (Fig. 2). The vegetation is predominant in the south, north and eastern parts of the airport while, the western axis was relatively devoid of this facility. In addition to poor mowing negligence of the airport, land-use utilities could pose threats to safety at the airport (Layton and Stearns, 2008) as the vegetation zones need to be protected by fencing as to control unwarranted intruders. According to Ward *et al*, (2010), incompatible land uses pose danger to the utility of airports and aircraft operations, and to resolve this challenge, airports need to seldom develop land-use data of theirs as part of a master planning role, but frequently they need to rely on land-use data from public agencies. However, task for combining airport affairs into the neighborhood community land-use planning process lies with local governments (FAA, 1997).

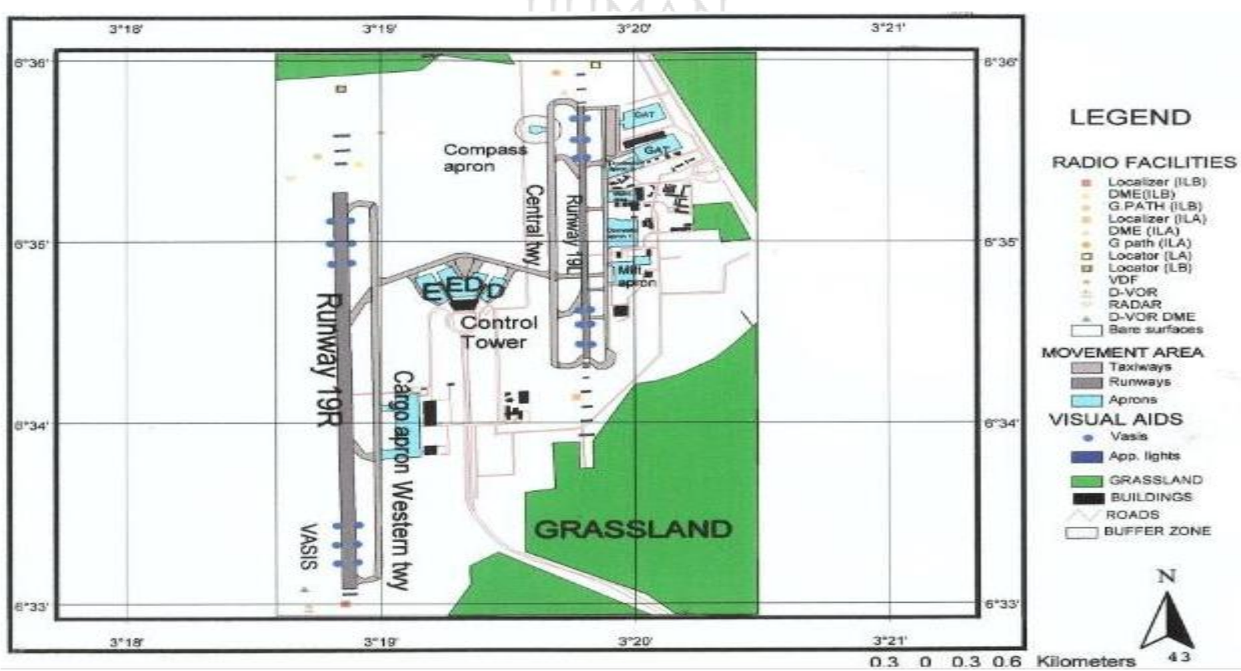

Fig. 2: Land-Use/Land Cover facilities at the airport

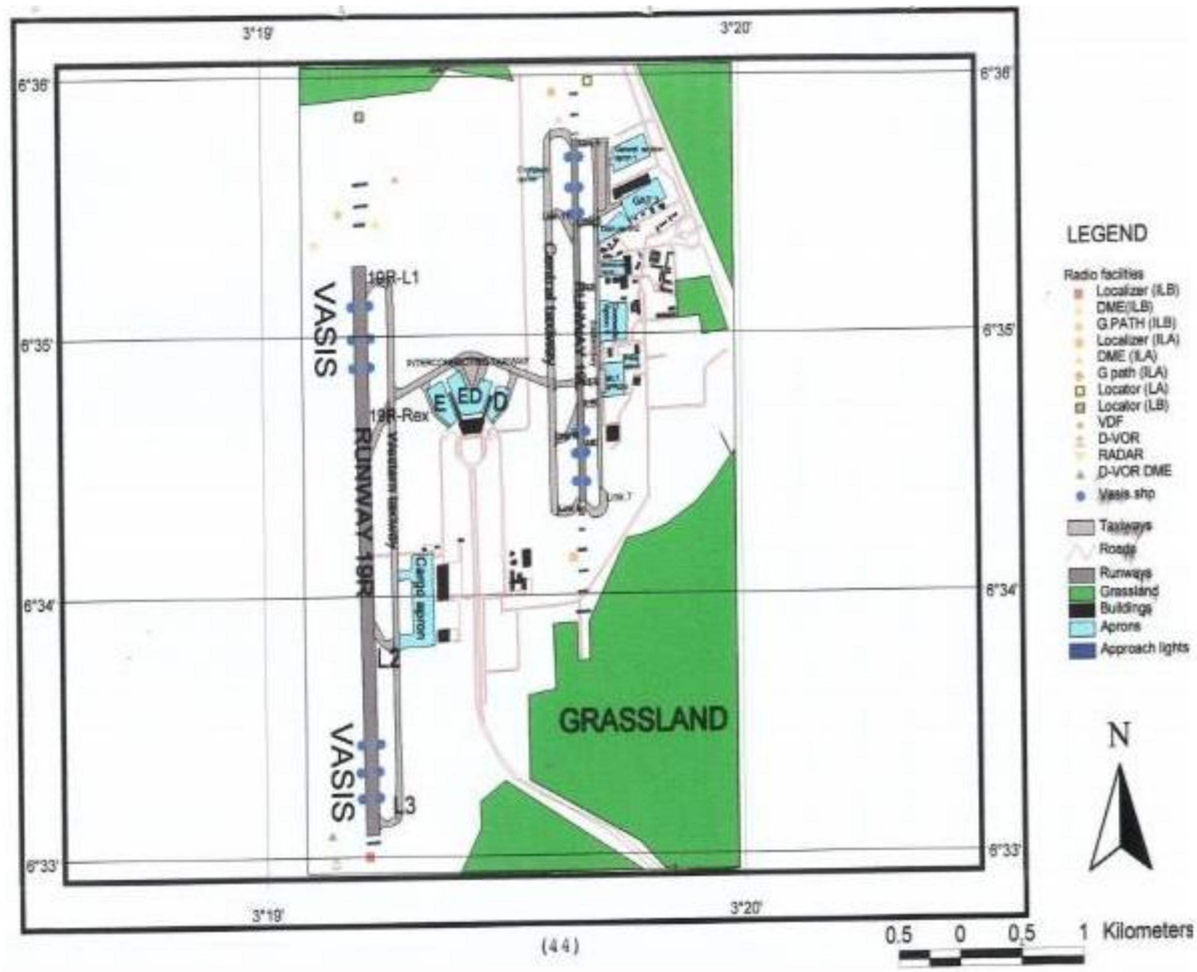

Fig. 3: Location of Navigation facilities at the Murtala Mohammed Airport Ikeja (MMAI)

Movement areas

During the study, it was observed that there was no additional number of or sizes of aprons, taxiways and runways (Table 2). The recent acquisition of more aircraft by the airline operators might be responsible as traffic congestion has become common at both the domestic and international wing of the airport (Dodo, 2003). In relation to the strength of the aprons, taxiways and runways, the study revealed that none of them had a pavement classification number (PCN) of less than 100. This, however, is in accordance with the requirements for the categories of the aircraft operating in the airport. The compass apron was situated at an optimum distance of not less than 100meters from every other parking positions, buildings, aviation fuel or communication/electrical cables. This restriction is ideally standard for security reasons. In our study, we created a buffer zone of 100m radius around the compass apron to ascertain whether these restrictions had been infringed following the recent physical development in the airport. The result indicated that no infringement on the aforementioned ICAO requirements (fig. 2). No additional number or size of the runways (19L and 19R) with 2745m and 3900m respectively. According to ICAO requirement, the length of a runway should be adequate to meet the operational need of the aeroplane of which the runway is intended. A B747 type of aircraft which is the biggest passenger-carrying aircraft with passenger capacity of over 450 persons, under high temperature requires at least a runway length of 3000 meters. Though, runway 19R satisfies this requirement yet, the study revealed that there is room for extension of the length of runway 19L to meet this requirement, particularly from the threshold to north of the airport. The cargo apron tends to be inadequate for the services of all the airlines and therefore the study reveals that there is space for the expansion of this facility so that more aircraft could be accommodated. GIS tool has also helped in this discovery as was previously applied by McNerney (1994). MMIA has a total of 20 taxiways including links. Out of this, only 4 are on runway 19R with the remaining on the shorter runway 19L making it impossible for aircraft to taxi to 01L when there is landing on 19R. This situation could be solved if more taxiways and links are constructed on 19R as revealed by the GIS analysis for utility management (Murphy 2006), besides; some of the facilities such as cargo apron are due for surfacing (Fig. 4).

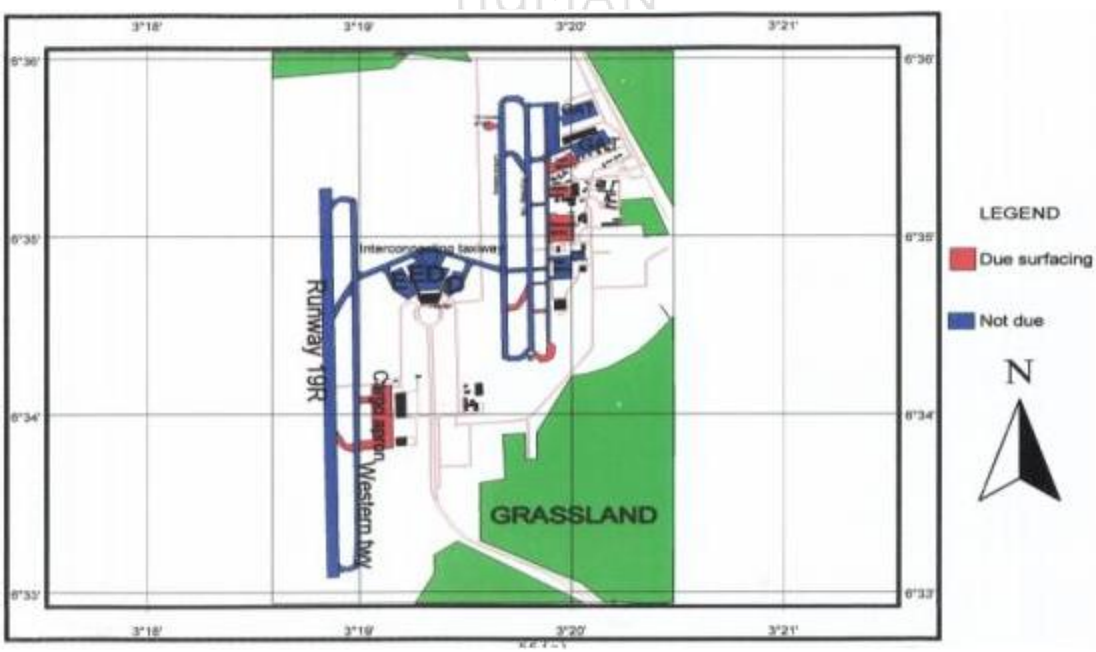

Fig. 4: Maintenance status of the mobility facility area

Radio navigational facilities

These facilities among others included DME, ILS, VDF, and RADAR (Table 2). It could be observed that most of the navigational facilities are aligned with the extended centerlines of the two runways. This is understandable because these facilities are made to guide the aircraft to a precise landing on the runways, and some of these facilities are due for maintenance (Fig.5).

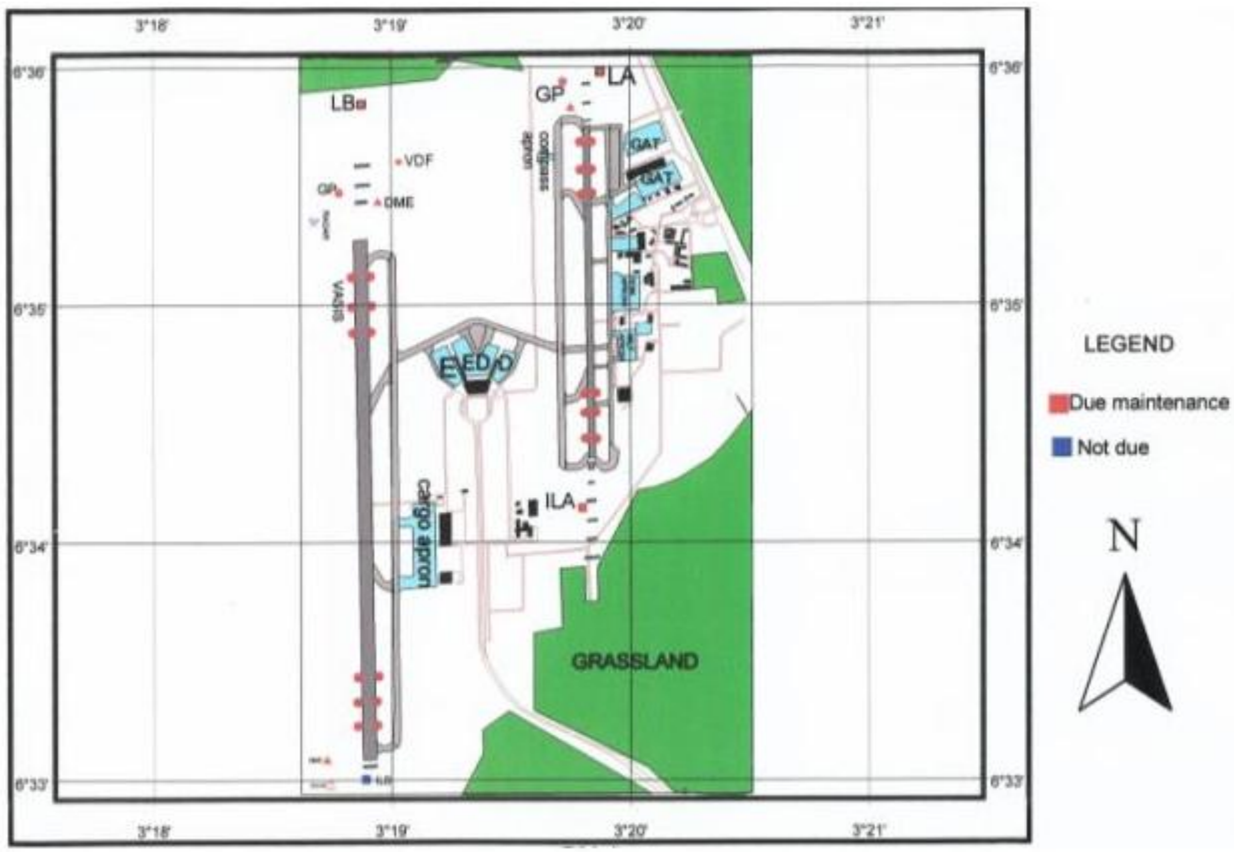

Fig. 5: Maintenance status of the radio and visual navigational utilities

Visual navigational aids

These are the runway light, approach light and VASIS which need be upgraded to the flush type which is more frangible and suitable for busy airports like MMAI besides, they are due for maintenance (Fig. 5)

Database and queries creation

The study used queries to create active database to enhance the identification of outdated facilities and promote the regular maintenance.

The query one was employed to adjudicate the radio facilities that were due for maintenance as at the time of the study and the result revealed that all radio facilities except localizer (ILB) and RADAR were due for maintenance (Fig. 6).

Query two was applied to measure the calibration status and due date for the radio navigation utilities. The study revealed that all facilities were due for calibration except D-VOR and D-VOR DME (Fig. 7).

Query three was used to ascertain the radio facilities due for total replacement. It was discovered that only RADAR was due for outright replacement as at the time of this study (Fig. 8).

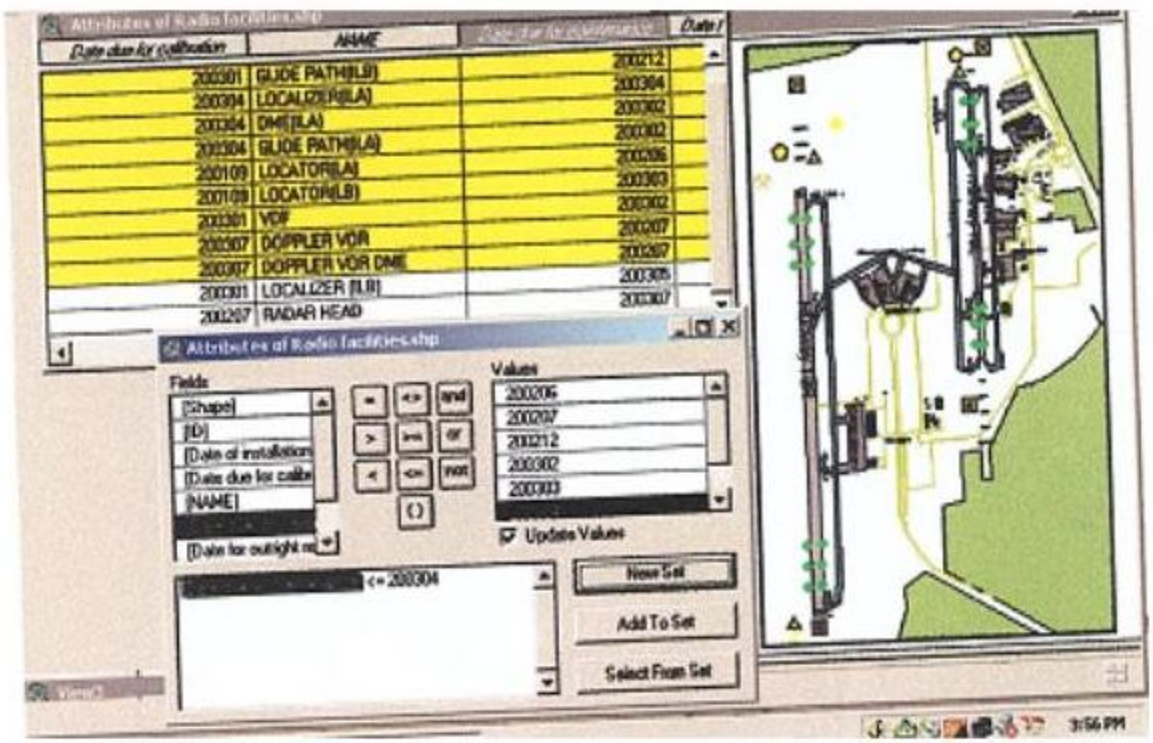

Fig. 6: Radio facilities those were due for maintenance

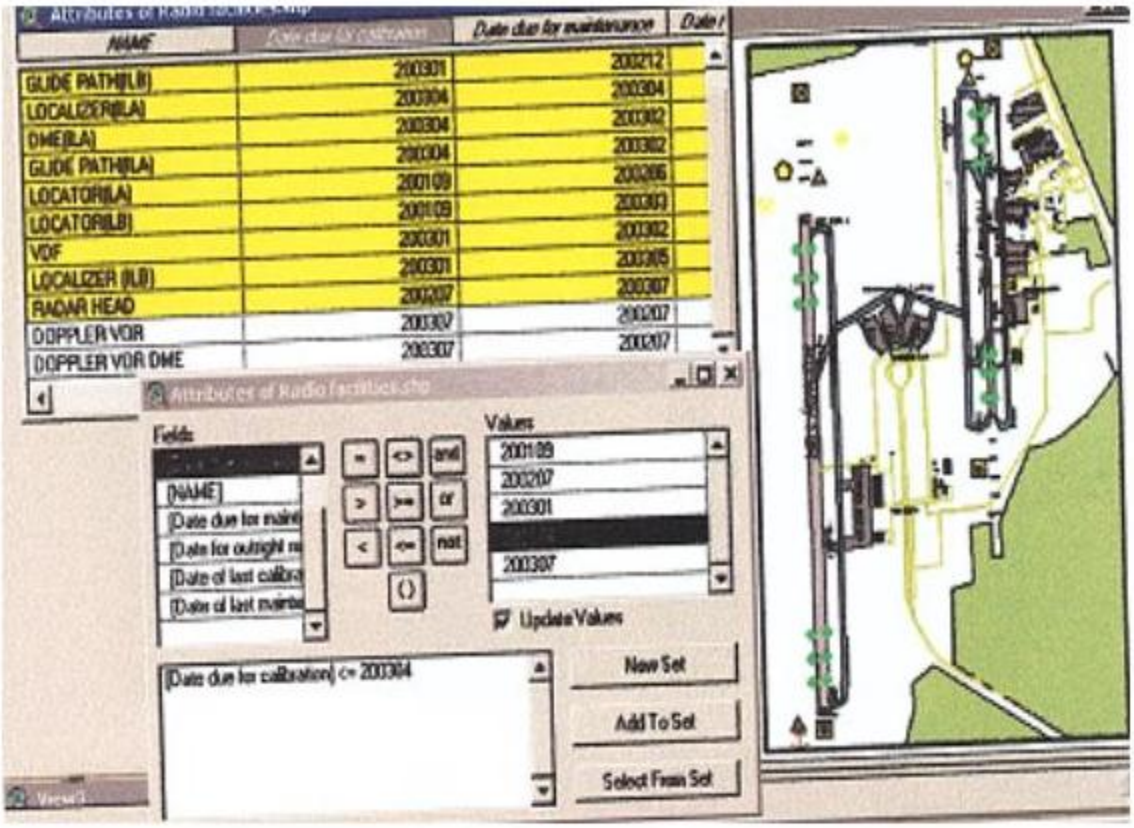

Fig. 7: calibration status and due date for the radio-navigation utilities

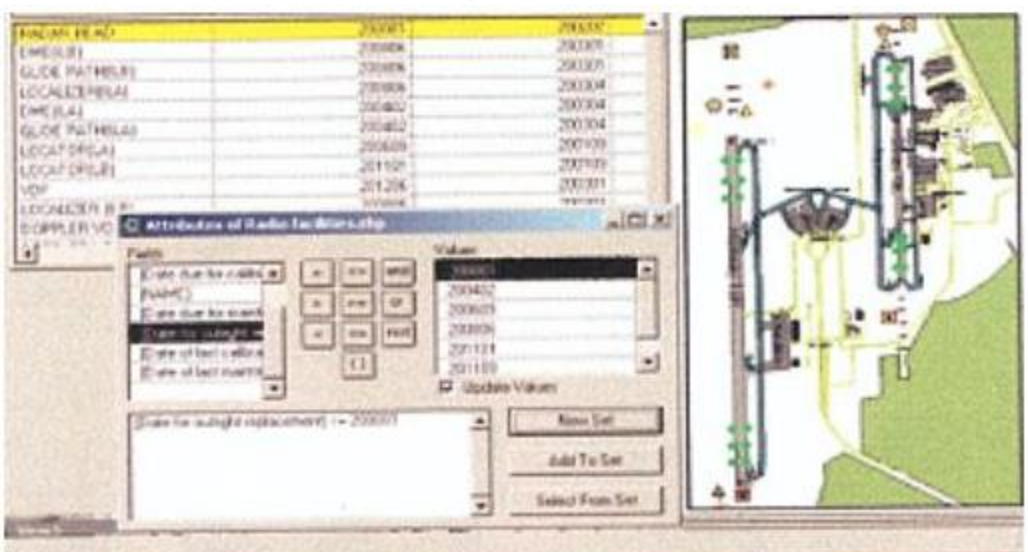

Fig. 8: Radio facilities due for total replacement

Query four was used to regulate the apron areas due for resurfacing. The result was that all part of the compass apron, domestic apron, maintenance apron, military apron and cargo apron were due for resurfacing. This indicated a total area of 3566 m^2 out of a total of 8468 m^2 that are due for resurfacing (Fig.9).

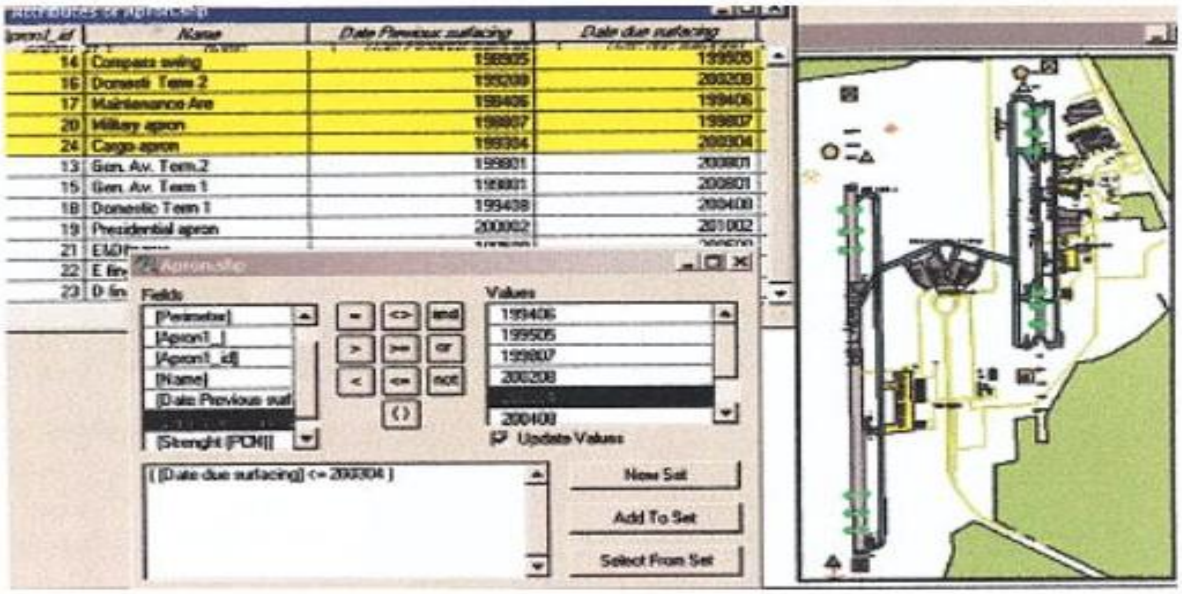

Fig.9: Apron areas due for resurfacing

Query five helped to classify taxiways due for resurfacing. The result revealed that taxiways including 19L-L6, 19R-L2 and L3 were due for resurfacing. This covered and area of 982 m2 out of 10325 m2 representing 9.5% of total cover by taxiways (Fig.10).

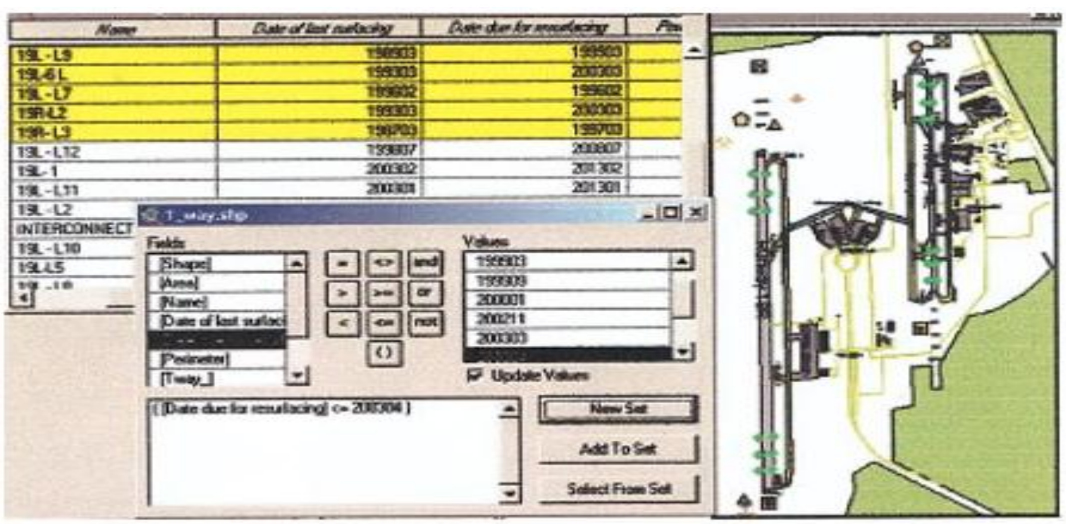

Fig. 10: Taxi-ways due for resurfacing

Query six was used to determine the maintenance status of all VASIS in the airport. The result showed that all VASIS were due for maintenance since May 1999 and were ignored even till the time of this study (Fig. 11).

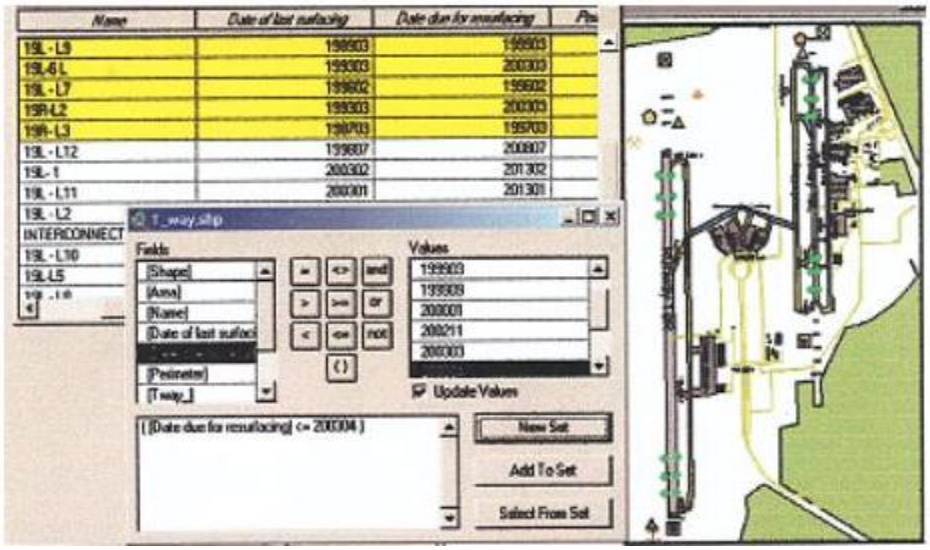

Fig. 11: VASIS due for maintenance since May 1999

Query seven was used to check and confirm all VASIS that are due for replacement. This query revealed that all VASIS on 19R and 01L were due for outright replacement while those of 19L and 01R are not due for replacement yet (Fig.12).

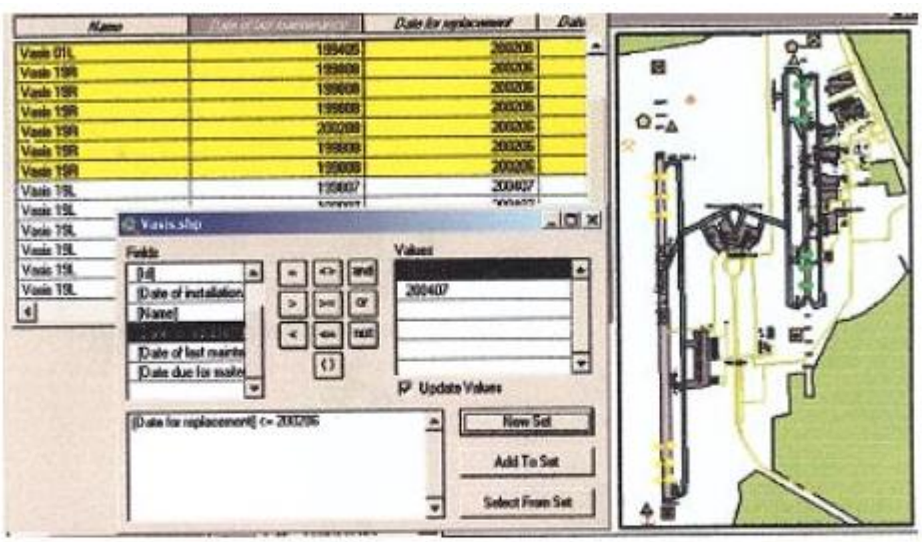

Fig. 12: VASIS those are due for replacement

Several studies have revealed the importance of GIS in the management of the airport land-use and facilities for flight effectiveness and safety (Robertson 2008; DeLeon and O'Donnell 2012; Anspach and Murphy 2012; Schwartz, 1991). For example, in a study of 172 airports in the USA, McNerney and Kelley (2007) reported that 58% of these airports have benefited immensely from the use of GIS techniques for the management of their properties and infrastructures. Furthermore, at the Turin airport, Gugliemetti (2000) implemented a GIS solution that allowed the airport to face the new challenges derived from the liberalization of airport activities, by providing a wider flexibility of use above the traditional functionality in terms of display and monitoring. In the USA, Delta airline has been reported that have been using GIS in its operations. The program allows the management and staff of the airline at one click on the mouse to pull up a color-coded map that revealed how a given area is being used (ESRI, 1997). In addition, the staff and management of the Baghdad International Airport have modernized their operations by adopting GIS which makes their tasks easier and faster with automation (Anwer and Ibraheem, 2014).

CONCLUSION

The application of GIS in the management of land-use and navigational facilities at the MMAI has enhanced the airport activities. GIS helped in the generation of an up to dated inventory of the utilities and creation of viable facilities database in relation to International Civil Aviation Organization (ICAO) requirements. A few facilities that were due for either maintenance, replacement or resurfacing were identified. Areas that require further expansion were also found and documented. The study noticed the challenges in the runways and recommended for the construction of additional taxiways on 19R to improve traffic flow especially during the peak periods. The study also revealed that there is room for extension of the length of runway 19L from 2745m to more than 3000m as to handle the B747 type of aircrafts which require a runway of at least 3000m.

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