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POOR WEATHER CONDITIONS AND FLIGHT OPERATIONS: IMPLICATIONS FOR AIR TRANSPORT HAZARD MANAGEMENT IN NIGERIA.

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Abstract
The growth of aviation industry in Nigeria and the increased adoption of air transportation as one of the best means of transport have been obstructed by various weather hazards. There is a greater need for aviation weather forecasters to deliver quality forecasts. It is therefore necessary to identify the most dangerous and most common weather hazards which are detrimental to the aviation industry so as to enhance the expertise on addressing them. This paper examined various weather hazards which include thunderstorm, fog, dust haze and line squall that affect flight operation such as flight delays, diversion and cancellation. The study revealed that fog accounted for 13.2% of flight cancellation at the airport and line squall similarly accounted for 10.1% of delays, 8.4% of diversion and 20% of cancellation from 2000-2009 at the airport. The paper recommends that with the aid of improved forecasting tools such as Meteosat Second Generation (MSG) and Radar network which provides different images of clouds every fifteen minutes, it becomes much easier to identify dangerous clouds and give prior warning to the aviation industry.

Key Words: *Flight operation, Cancellation, Diversion, Line squall, Fog, Thunderstorm*

Introduction

Despite the relatively conducive weather of Nigeria compared to other countries (such as Mauritania, Somalia, Japan etc.), there has been a marked increase in the cases of recorded flight delay, diversion and cancellation, which in most cases, are attributed to poor weather conditions (NOAA, 2005). Aircraft accident has not been an exception, but its occurrence, though resulting to very devastating losses, has been on a low rate compared to other defects, with its highest occurrence between 2003 and 2006. Most of the air crashes, delays and cancellations were caused by poor weather conditions such as thunderstorm occurrence, poor visibility (associated with fog, dust haze etc) wind shear and squall (Jones 2004b; Bazargen, 2005; Knecht, 2008).

Moreover, though there are other factors that contribute to the disruptions in flight efficiency (such as technical, operational and human factors) weather-related factors have been proven to be the highest cause of interruptions in the efficiency of flight operations in Nigeria with more devastating losses, hence, the International Air Transport Association (IATA) stated that 71% of air accidents in Nigeria are due to mainly poor weather conditions with the inclusion of human errors, ageing aircraft and deficiency in safety management system. (Punch, 2005).

In view of the above, the analysis of the weather cum meteorologically related factors that are responsible for these deficiencies in the aviation industry in Nigeria is deemed important. In the light of the above, this paper analysed the weather related variables that affect flight operations.

The Nigerian aviation industry witnessed its darkest period between 2003 and 2010 when several aircraft accidents occurred, resulting in loss of lives. ASRS (2007) noted that out of a total of 376 air fatalities that occurred in Africa in 2005 alone, Nigeria accounted for 225 of them and concluded that Nigeria accounted for 9.3% of all air accidents in Africa. However, investigations revealed that the air crashes which occurred between 2003 and 2006 were traceable to bad weather and wind shear. Most crashes were associated with poor weather conditions, pilot error, mechanical failure etc (Bazargen, 2005; Knecht, 2005). Generally, flight delay, cancellation, division and air craft accidents affect the Nigerian Aviation Industry as Ayoade (1988) has earlier noted that 'the vagaries of weather with references of the various

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meteorological parameters act malevolently against most of man's socio-economic activities'. Adefolalu, *et al*. (2010) have classified the three major bad weather phenomena which pose disaster to air transportation in Nigeria (Fog, Harmattan dust haze and thunderstorm) under the different seasons observed in the country with thunderstorm occurrence classified under rainy season while fog and harmattan dust haze were termed dry season events. This implies that the phenomena are tied to the two major seasons in Nigeria. NOAA (2004) affirmed that weather affects flight operations. They also stated that almost 500 fatalities and 200 injuries have resulted from wind shear crashes since 1964 and that since 1985; wind shear also has caused numerous near accidents in which aircraft recovered just before ground contact. Rockwell *et al*. (1981); Norman, (1996); Jones (2004) and NASA, ASRS (2007) attributed the dust haze induced visibility conditions, thunder-associated wind shear, fog and harmattan dust haze and the severe thunderstorm with associated electricity (lightning and thunder), hailstones, icing, low-level wind shear effect, Gustiness etc as weather related phenomena responsible for air craft accidents globally.

From the literature, there is dearth of empirical analysis of the influence of poor weather condition on flight operations which is a daily occurrence in the air ports in Nigeria. There is also paucity of information on the contributions of the meteorological phenomena with the most significant influence on flight operations in Lagos air space. This study therefore seeks to ascertain the air transport hazard implications of meteorological phenomena on flight operations at the Murtala Mohammed International airport in Lagos.

In order to achieve this aim, the paper examined the various weather parameters that to a large extent, seem to affect flight operations at the airport; established the relationship between the occurrences of these parameters and flight delay, cancellation and diversion; examined the nature, occurrence and variability of the weather phenomena in relation to its effects on flight operations.

Study Area

The study area covers the confines of Murtala Muhammed International Airport Lagos, located on latitude $6^0 27"$N and longitude $3^0 24"$ E and runs 22km (14 miles) North West of Lagos State. The Airport was opened in 1979 with IATA code; LOS and ICAO code, DNMM. It has two terminals which are MMIA and $MMIA_2$ (local terminal) but MMIA, which is the International terminal is of interest in this research. Moreover, the major based airlines are Aero contractors, air Nigeria, Arik Air, Bellview Airlines, Dormier Aviation Nigeria and Overland Airways.

Lagos, with the mean annual temperature distribution of between 24^0C -27^0C, total annual rainfall of over 300cm and relative humidity of over 80% in July and between 60%-80% throughout the year, is classified under the sub-equatorial south of Nigeria. Furthermore, Lagos state is under the influence of the south west trade wind at most times of the year and this accounts for its high relative humidity, and being a state in Nigeria (which lies in the tropics), it has moderate temperature throughout the year. Below is the map of Lagos showing the position of the airport (figure 1).

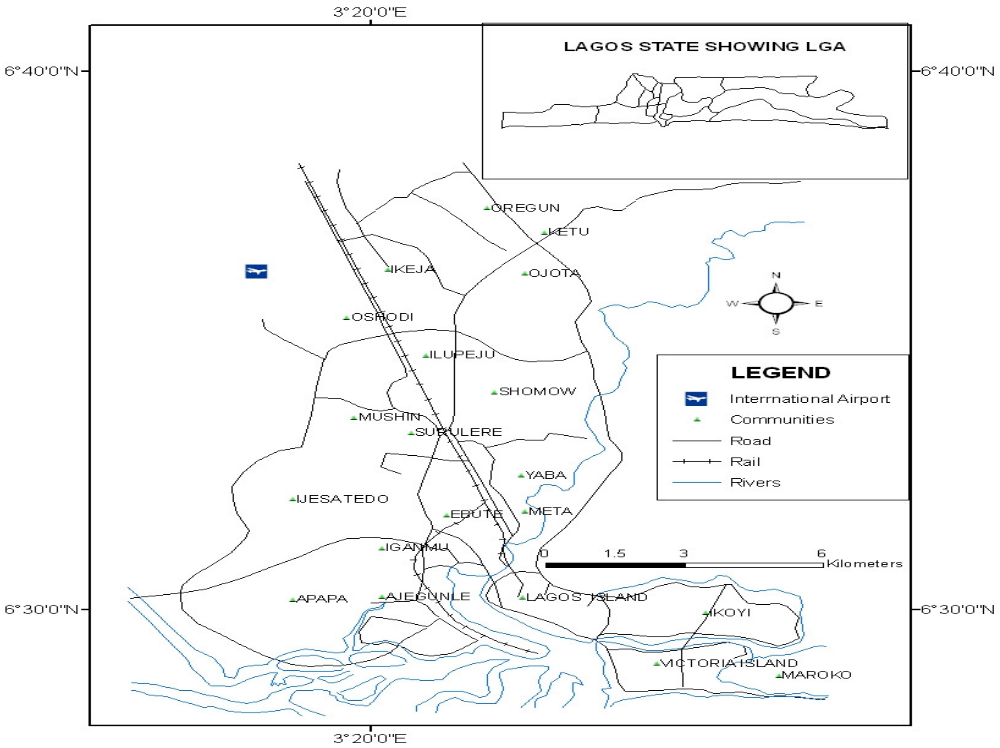

Figure 1: Ikeja Showing the Murtala Mohammed International Airport (MMIA).

Methodology

This study predominantly relied on secondary data collected over a period of ten years (2000 to 2009), they include:

1. Thunderstorms which define the number of thunder heard in each month of the specified years.
2. Visibility values: Involve the visibility figure obtained (using visibility targets) at 0900 GMT and 1500 GMT. In visibility observation, we measured the visual range and the distances as estimated.

However, some visibility ranges which were already given by surveyors as the ranges have been surveyed and the distances given as marked points from the airport were used for the analysis. The visibilities were also given in order to ascertain the type of weather parameters affecting visibility at any point in time indicating the prevailing weather.

Table 1: Visibility Ranges used for the Study

2,000m-5000m	Slight mist or haze
1,000m-1,999m	moderate mist or haze
Less than 1,000m	fog or thick dust haze

Source: QAM book of the meteorological unit MMIA Lagos, 2012.

3. Fog occurrence: This covers the monthly number of fog occurrence from year 2000-2009.
4. Haze occurrence: This involves the monthly number of haze occurrence for the period of ten years.
5. Squall lines: The monthly occurrence of squall lines for the 10 year period
6. Flight information data: This covers the delays, diversions and cancellations of flight in MMIA, Lagos.

The data used in this research were collected from the Nigerian meteorological agency and Murtala Mohammed International Airport which include: Thunderstorm, visibility values, fog occurrence, haze and squall line data while the flight information data which include; flight delays, cancellation and diversions were collected from the federal Airport Authority of Nigeria (FAAN) in Murtala Mohammed International Airport, Ikeja, Lagos.

The study employed the step-wise multiple regression as the tool of analysis of the different hypotheses stated.

The first hypothesis states that there is no significant relationship between weather hazards and flight delays in Nigeria Aviation industry with respect to Murtala Mohammed International Airport to identify the combination of hazards responsible for flight delays.

The second hypothesis w states that there is no significant relationship between weather hazards and flight diversions in MMIA Lagos were.

The third hypothesis states that there is no significance relationship between weather hazards and flight cancellations in MMIA Lagos. This is to identify the degree and nature of relationship which exist between the weather hazards and flight operations at the airport.

The multiple regression techniques is of the form

$Y = a + b_1 x_1 + b_2 x_2 + b_3 x_3 \ldots + b_i j_i + e$ - - - - eqn. (1)

Where,

Y = flight Operations,

a = Constant term

$\beta_1 \beta_2 \beta_3 \ldots \beta_j$ = Regression coefficients

$x_1 x_2 x_3 \ldots x_j$ = Independent variables (dust haze, line squall, thunderstorm and fog).

Result and Discussion

The relationship between weather hazards and flight operations

Below is the zero-order correlation matrix of the relationship between weather hazards and flight operation at the Murtala Mohammed international airport.

Table 2: Zero-order Correlation matrix of weather hazards and flight operation (delay)

		DELAY	THUNDERSTOM	FOG	SQUALL	DUST HAZE
Pearson	DELAY	1.00				
Correlation	THSTM	-.167	1.000			
	FOG	.205	-.298	1.000		
	SQUALL	.317	-.227	.149	1.000	
	DHAZE	-.130	.556	-.201	-.179	1.000

Significant at 95%

The correlation matrix of atmospheric hazards and flight delays reveals that thunderstorm and dust haze with the correlation values of -0.167 and -0.130 respectively correlated inversely to flight delays. This implies that as frequency of thunderstorm and dust haze increases, flight delay decreases. In the case of fog and line squall with the correlation values of 0.205 and 0.318, they correlated directly with flight delays. This means that as the frequency of fog and line squall increases, flight delay increases (figures 2 and 4), this is as a result of the airport's proximity to the ocean (which is a major factor in the formation of squall.). The study further showed that as the frequency of thunderstorm and dust haze increases, flight delay decreases while the increase in the frequency of fog and squall line resulted to increase in flight delay in Murtala Mohammed International Airport, Lagos. This is as a result of the dust haze which originates from N'Djamena (Chad) and advects to Nigeria hits the north-eastern parts of the country first; they tend to subside before they get to Lagos as the thick dust haze would have been reduced to suspended dust particles in the atmosphere. These accounted for the reason while dust haze did not have any significant impact on the airport. On the other hand, thunderstorm is an avoidable weather hazard as the pilot, after going through the flight folder before take-off, can avoid the cruising levels and directions of possible thunderstorm occurrence by avoiding the areas with developing cumulonimbus clouds which are the major causes of thunderstorm formation and occurrence. However, the proximity of Murtala Mohammed International Airport, Lagos to the Atlantic Ocean (which is the basis for the formation of fog and squall) places the airport at the risk of their occurrence. Similarly, fog affects flight operations due to its more common occurrence and general areal extent. (Oliver, 1973).

Table 3: ANOVA of the significance of the overall model of the relationship between weather hazards and flight operation (delay)

Model	Sum of squares	Df	Mean square	F	Sig.
Regression	37.233	1	37.233	13.230	.000
Residual	332.092	118	2.814		
Total	369.352	119			

Predictors: (Constant), SQUALL
Dependent Variable: DELAY

Table 4: Coefficients of the model of the relationship between weather hazard and flight operation.

Model	Unstandardised coefficients		standardised coefficients	t	Sig
	B	Std. Error	Beta		
(Constant)	1.463	.156		9.361	.000
SQUALL	.237	.065	.318	3.637	.000

Significant at 95%

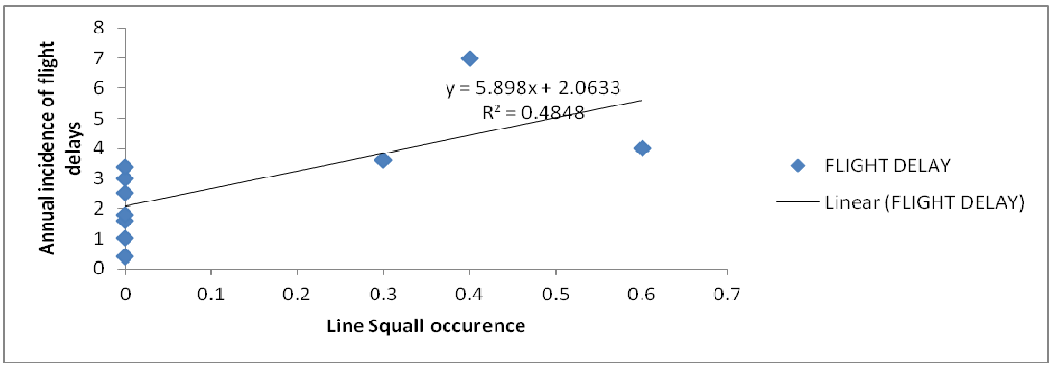

Figure 2: Scatter plot of annual incidence of Line squall and flight delays (2000-2009).

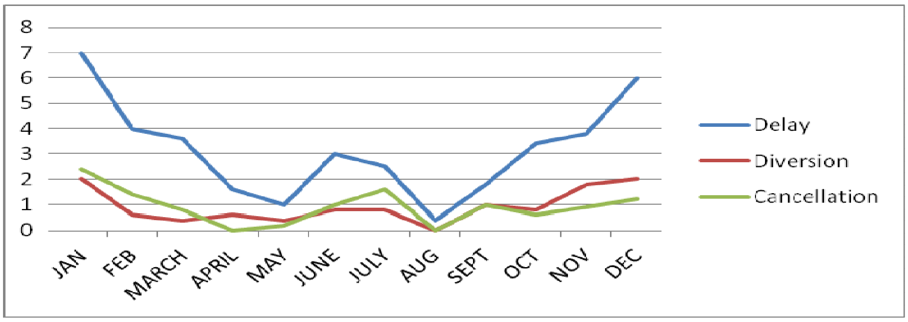

Figure 3: The graph showing the mean monthly annual flight operations from 2000-2009.

The figure 3 above reveals that there is uniformity in the occurrence of flight delays, diversions and cancellations, this show that similar weather hazards result to all of them. However, there is a slight difference in flight cancellation due to other factors not investigated. From the results of the step-wise multiple regression shown in tables 4 above, line squall was the only weather hazard which significantly caused flight delays in Murtala Mohammed International Airport, Lagos. The coefficient of determination revealed that line squall accounted for 10.1% of the variation in flight delays with an R^2 value of 0.101. Other factors other than meteorological parameters accounted for 90% which may include technical problems among others not investigated in this study.

The equation stating the relationship between weather hazards and flight delays is stated thus

$Y= 1.463 + 0.318x_1$ …………………. eqn 2

The overall model is significant at 95% significant level with an F-calculated value of 13.23 greater than the F-critical value of 3.92 (see table 3), revealed that there is a significant relationship between weather hazards and flight delay especially line squall.

Findings showed that thunderstorm with the correlation value of -0.064 correlated inversely to flight diversions. This implies that as frequency of thunderstorm and dust haze increases, flight delay decreases. However, in the case of dust haze, fog and line squall with the correlation values of 0.001, 0.147 and 0.289, they correlated directly with flight diversions. This means that as the frequency of dust haze, fog and line squall increases, flight diversion increases. Similarly, from the results of the step-wise multiple regression, line squall was the only weather hazard which significantly caused flight diversions in Murtala Mohammed International Airport, Lagos. The coefficient of determination revealed that line squall accounted for 8.4% of the variation in flight diversions with an R^2 value of 0.084. The equation stating the relationship between weather hazards (line squall) and flight diversions is stated thus:

$Y= 1.416 + 0.289x_2$ ………… eqn 3

The overall model is significant at 95% significant level with an F-calculated value of 10.762 greater than the F-critical value of 3.92, goes to show that there is a significant relationship between weather hazards and flight diversions especially line squall

Results further showed that as the frequency of thunderstorm increases, flight diversion decreases while the rate of flight diversion increases with increase in fog, dust haze and line squall. However, in the case of fog, dust haze and line squall, line squall, which is the advanced level of wind shear (a sudden increase in the wind speed and a sharp change in wind direction) is a state of instability in the atmosphere resulting from persistent wind shear. Fog drastically reduces the atmospheric visibility which can cause flight diversion (Fog occurs as a result of unsaturated cloud formed by evaporation and evapo-transpiration in dry season, as a result, the cloud occurs as fog the next morning; this is why fog is defined as a cloud on the ground) while dust haze, though not severe at the airport, but has been proven to cause flight diversion as it also reduces visibility.

Analysis of atmospheric hazards and flight cancellations reveals that thunderstorm with the correlation value of -0.163 correlated inversely to flight cancellations. This implies that as frequency of thunderstorm increases, flight cancellations decreases at the airport.

However, dust haze, fog and line squall with the correlation values of 0.205, 0.363 and 0.312 respectively correlated directly with flight cancellations. This means that as the frequency of dust haze, fog and line squall increases, flight cancellation increases at the airport (fig 5). The stepwise regression analysis revealed that fog and line squall were the only weather hazards which significantly caused flight cancellations at the Airport. The coefficient of determination revealed that line squall accounted for 20% of the flight cancellations with an R^2 value of 0.200 while fog accounted for 13.2% of the flight cancellations with an R^2 value of 0.132.

The equations stating the relationship between weather hazards and flight cancellations are stated thus

$Y= 0.291+ 0.324x_1+0.264x_2$ ....……. eqn 4

The overall model is significant at 95% significant level with an F-calculated value of 17.911 and 9.943 greater than the F-critical value of 3.92, revealed that there is a significant relationship between weather hazards and flight cancellations especially line squall and fog. However, the increasing frequency and intensity of fog, and line squall (due to the airport's proximity to the ocean) significantly led to flight cancellations while the persistent dust haze which reduced visibility led to flight cancellation but at an insignificant rate.

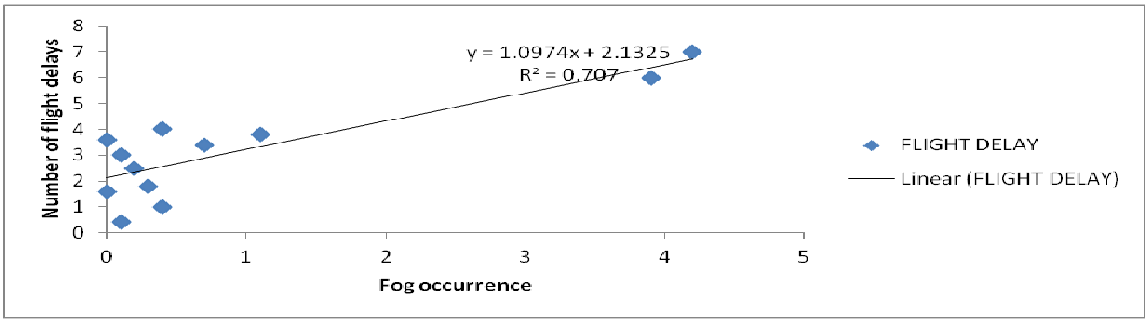

Figure 4: Scatter plot of annual incidence of fog and flight delays (2000-2009).

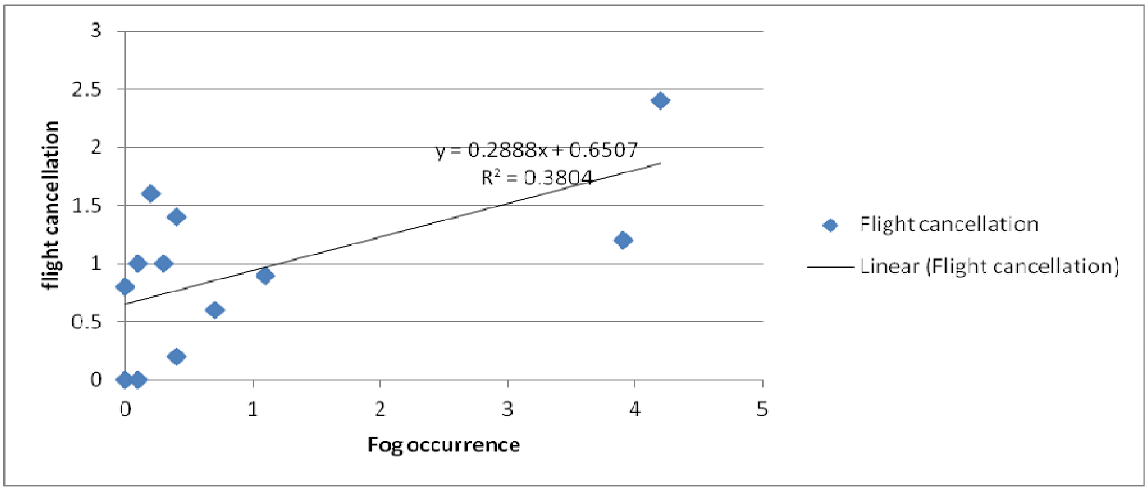

Figure 5: Scatter plot of fog occurrence and flight cancellation at the airport.

Implications for Air Transport Hazard Management

The single most important factor in general aviation flight safety is the decision of a pilot to begin or to continue with a flight in unsuitable weather conditions (ATSB, 2005). The weather forecaster's role is to advice the pilot about the prevailing and expected weather conditions en-route, but the decision to fly remains to the pilot based on his knowledge, understanding and experience. Weather has been attributed to be a major factor in most fatal accidents: over 80% of Controlled Flight into Terrain (CFIT) accidents happened when the pilot either continued flying into adverse weather or did not appreciate the actual effects of the weather conditions (ATSB, 2005).

For effective air transport hazard management, it implies that aircraft exposure and robustness will have to take stock of the knowledge on weather hazards affecting airframe, engine and systems and will identify the needed technology and capability developments pathways. There is also the need to compile knowledge on the collection, processing and communication of meteorological data related to weather hazards which will investigate the needed research on observation, forecasting tools and data assimilation and broadcasting to tackle these extreme aviation atmospheric conditions. An investigation into the existing and needed evolution on safety standard and procedures necessary to ensure safe aircraft operation and to reduce the impact of weather hazards on the air traffic management is a sure way for an effective hazard management. It also implies that the scientific support will project on the capacity of the scientific community to better understand, observe (onboard sensor, Lidar, Radar, satellites, UAS, etc.), reproduce and simulate on hazardous particles supporting the assessment performed above.

Conclusion

The study showed that the majority of the delays, diversions and cancellations at the airport which are weather related are caused by squall line. It occurs in both rainy and dry season. Its occurrence in dry season is attributed to the proximity of the airport to the Atlantic Ocean. Squall is known to be the advanced level of wind shear of which both of them have caused some plane crashes as can be seen in the literature. Moreover, fog, which has a significant relationship with flight cancellation do not have significant relationship with delays and diversion, but was responsible mainly for flight cancellation at the airport due to its large area extent in occurrence. Furthermore, dust haze and thunderstorm have no significant relationship with flight operations. While dust haze affect the flight operations, but insignificantly (due to the distance of the airport from the dust source regions), thunderstorm do not affect flight operations at the airport due to its directional occurrence and the use of flight folders by the pilots before takeoff.

Recommendations

The effective monitoring and control of fog and line squall are relevant for the effective management of air transport hazards in Nigerian airports especially Murtala Mohammed International Airport, Lagos. This will reduce the rate at which flights are delayed, diverted and cancelled and subsequent accidents arising from diversion resulting from meteorological phenomena.

The intervention of government in the aviation industry as some of the equipments used there are already outdated. These obsolete equipments can only perform six hours weather update and can be replaced with those that update weather conditions every hour. However the Nigeria Government is already working on this. The equipments installed should be maintained regularly as the country lacks maintenance culture.

The installation of line squall alert machine should be considered as it should aid the alert of occurrence and direction of occurrence of line squall as it can help ameliorate the effects of weather hazards on flight operations in Nigeria. Finally, government should embark on massive employment and training of staff in the aviation sector to drastically reduce the effects of overburden and human error in weather observation and reporting while the staff of the aviation industry should see their job as that on which people's lives depend as any mistakes they make results in loss of lives and property.

Acknowledgement

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