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Full Length Research Article

EFFECT OF CLIMATE CHANGE ON AIRLINE FLIGHTS OPERATIONS AT NNAMDI AZIKIWE INTERNATIONAL AIRPORT ABUJA, NIGERIA

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ABSTRACT
Weather is the most immediate impact related to meteorological conditions. There are a range of different weather-related developments that could lead to alterations in flight operations. For example, increased fog, harmattan haze and thunderstorm could result in more diversions of flight cancellations. The aim of this study is to examine the effect of climate change on airline flights operations with specific reference to aviation delays, diversion and cancellation at Nnamdi Azikiwe International Airport. Abuja, Nigeria. Monthly records of occurrence of fog, thunderstorm, harmattan haze and flight diversion, delay and cancellation for Abuja international airport were collected from secondary sources for a period of eighteen (18) years (2000-2017). The statistical analyses employed were trend, correlation and multiple regression analysis using econometric software (Eviews9). Results indicated that, harmattan haze occurred most followed by thunderstorm while Fog had the least occurrences in the Airport, annual tends revealed steady increase of thunderstorm and fog occurrences while very slight decrease in harmattan haze occurrence was recorded within 2000-2017 in Abuja airport. The study reveals positive statistical relationship between weather elements and flight operations (flight cancellation, delay and diversion) at 95 % confidence level. The impacts of weather elements (harmattan haze, fog and thunderstorm) were statistically significant on flight cancellation only.

Keywords: Aviation, Flight operations, Fog, Harmattan haze, Thunderstorm, Weather.

INTRODUCTION

The aviation industry and related operations are considerably influenced by weather. Aircraft safety, efficiency and capacity are susceptible to weather, and adverse weather can have negative impacts on the operations of aircrafts (Sasse & Hauf, 2003). The International Air Transport Association (IATA) stated that 71 % of air accidents in Nigeria are caused by poor weather conditions. Weather conditions affect all aspects of aerodrome operations such as aircraft fuelling, cleaning, baggage handling, catering, aircraft maintenance and the scheduling of flights. The functioning capacity of airports, and even a region's entire airspace, can be notably reduced due to bad weather, leading to delays, diversions and cancellations of flights (Sasse & Hauf, 2003).

Even with the relatively conducive weather of Nigeria, there has been a steady increase in the cases of recorded flight delays, diversions and cancellations, which largely are caused by poor weather conditions (Spyrou, 2010). Most of the air crashes, delays and cancellations were caused by poor weather conditions such as thunderstorm, poor visibility (associated with fog, dust haze etc.) wind shear and squall (Weli & Ifediba, 2014). 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. Weli & Emenike (2016).

The Nigerian aviation industry witnessed its darkest period between 2003 and 2010 when several aircraft accidents occurred, resulting in loss of lives. Aviation Safety Reporting System (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 and mechanical failure (Koetse & Rietvield, 2009; Knecht, 2005). Generally, flight delays, cancellations, and air craft accidents affect the Nigerian Aviation Industry as Ayoade (2004) has noted that 'the vagaries of weather with references of the various meteorological parameters act maliciously against most of man's socio-economic activities'. 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 occurring in rainy season while fog and harmattan dust haze are dry season events. This implies that the phenomena are tied to the two major seasons in Nigeria. National Oceanic and Atmospheric Administration NOAA (2004) affirmed that weather affects flight operations. They also stated that almost 500 of lives losses 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. Griffiths (2006); NASA, ASRS (2007) and Hardy, K. (2011) attributed 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 as weather related phenomena responsible for air craft accidents globally. Nigerian Meteorological Agency NIMET (2011) reported that the year 2010 witnessed a few instances of flight operation disruptions due to severe weather conditions. However, the month of March recorded a severe dust hazy spell, which reduced horizontal visibility to between 200m- 800m for several days and this caused many disruptions in flight operations across the country. These disruption affected flight operations in Lagos, Abuja, Kano, Kaduna, Minna, Maiduguri, Sokoto, and Enugu, others were Owerri, Port Harcourt and Calabar airports. There were also cases of outright cancellations. In January and December, early morning fog was reported in Lagos, Port Harcourt and Jos, which reduced horizontal visibility to between 200m- 800m. This resulted in flight delays at these airports. In addition, thousands of Europe-bound Nigerians were stranded at the Murtala Mohammed International Airport Lagos, as heavy snow pounded European Airports in December. These harsh weather conditions affected the number of inbound and outbound flights at the Murtala Mohammed International Airport during the period.

Fog, mist, haze and smog are all phenomena that can lead to a reduction in visibility at the airport. Both advection and radiation fog occurs at Nnamdi Azikwe International Airport. (SAWS, 2012). Poor visibility is the single most important weather hazard to all forms of transportation especially air transportation (Ayoade, 2004 & Shadere, 2005), reports that poor visibility is perhaps a greater danger to safe plane landing because the control over it is more difficult than flooding on the runway. Poor visibility can be caused by thick fog, snow, rain, thunderstorm, harmattan dust, mist, volcanic ash or smoke, urban smoke, low ceilings and even smog. Study by Riehl (1965) has shown that low ceilings and visibilities cause the major traffic disruptions at airport terminals, and the problem is said to remain unchanged over the years. In addition, Smith (1975) reports that despite increasing sophistication of automatic landing equipment, poor visibility from layer of fog, mist or thick haze and low cloud ceilings is probably the major impediment to airport operations throughout the world (Ayigbe, 2006).

The operational response to a delay often varies, even under similar weather and traffic conditions, due to the multitude of factors that influence the response. Such factors include the accuracy of terminal and en-route weather forecast products, airspace design and traffic flow management, scheduling times and over-scheduling by airlines, airport procedures and constraints (Klein et al., 2009). Delays can be divided into avoidable and unavoidable. Unavoidable delays are directly related to the severity of the weather and the airspace procedures and regulations (Klein et al., 2009). The avoidable portion of delays, cancelation and diversion is related to many factors, but typically is related to the accuracy of a weather forecast (Klein et al., 2009). An over-forecast may lead to unnecessary ground delay programs, and an under-forecast can lead to last-minute air traffic flow management (ATFM) actions such as unplanned delays and re-routes, which can cause a significant ripple effect throughout the national airspace (Klein et al., 2009). According to the National Center of Atmospheric Research (NCAR), as much as 60% of today's delays and cancellations due to weather, and particularly convective weather, are potentially avoidable (Klein et al., 2009).

Despite modern avionics on-board aircraft, and automated instrumentation on the ground assisting aerodrome operations, weather is still a vital part of aircraft operations' decision making, and affects the safety and efficiency of flying (Dalton, 1992). The pilot needs, at all stages of a flight, accurate and up-to-date information concerning the weather. National weather services, as well as air traffic control (ATC) staff, are responsible for providing weather information to the aviation industry. The information is used by aircraft operators and ATC centres to contribute to efficient aircraft operations (Dalton, 1992). ATC services are very sensitive to weather hazards, specifically thunderstorms, fog and snow, and require expert advice from weather forecasters during critical conditions (Dalton, 1992).

The atmosphere which serves as a medium through which aircrafts fly is also the same medium (troposphere) in which weather occurs. Therefore, the knowledge and analysis of influence of extreme weather on air transport operation is imperative if safety is to be ensured in the aviation industry.

MATERIALS AND METHODS

The Study Area

The study area of this research work is **Nnamdi Azikiwe** International Airport in the Federal Capital Territory (FCT) Abuja, Nigeria. Abuja lies between latitude 8° 5' and 9° 0'N of the equator and longitude 6° 5' and 7° 9'E of the Greenwich meridian (Coordinates: 9.066667°N and 7.483333°E). The airport is located on latitude 09° 0'N and longitude 07° 5'E and at altitude 314.98m. The airport is about 49km away from the main town. The airport type is public, elevation is AMLS 1,123ft/342m, runways direction is 04/22 and length is 3,609m/11,842ft (Abdulazeez, 2009).

Airport Facilities

Although the Airport is the most modern in Nigeria with many world class facilities such as state of the art radar systems, watch towers, hangars, well laid runways and two terminals one for domestic flights and the other for international flight services it is yet to be completed as work is on-going with its second phase. The length of its asphalt surface runway is 3,609 m and has an elevation of 3,609.4 m. The airport has a presidential wing made up of a taxiway linking the runway, Presidential Hanger, guest chalet and the Presidential Lounge, which is fully developed. However, at its first phase, the Airport has excellent facilities.

Climate

Abuja under Koppen's climate classification (AW) features a tropical wet and dry climate. The FCT experiences three weather conditions annually. This includes a warm, humid rainy season and a blistering dry season. In between the two, there is a break of harmattan occasioned by the northeast trade wind, with the main feature of dust haze, intensified coldness and dryness. The rainy season begins from April and ends in October, daytime temperatures reach 28 °C (82.4 °F) to 30 °C (86.0 °F) and night time lows hover around 22 °C (71.6 °F) to 23 °C (73.4 °F). In the dry season, daytime temperatures can soar as high as 40 °C (104.0 °F) and night time temperatures can dip to 12 °C (53.6 °F). Even the coldest nights can be followed by daytime temperatures well above 30 °C (86.0 °F). The high altitudes and undulating terrain of the FCT act as a moderating influence on the weather of the territory. Rainfall in the FCT reflects the territory's location on the windward side of the Jos Plateau and the zone of rising air masses. Due to the hilly and mountainous nature of Abuja city, Orographic activities bring heavy and frequent rainfall of about 1,500 mm (59.1 in) during the rainy season. Beginning in March to November, the rainy season peaks in September, during which abundant rainfall is received in the form of heavy downpours.

Methods of Data Collection

Secondary source of data was used to collect information on occurrences of the weather parameters (Monthly records of occurrence of fog, harmattan haze, and thunderstorm) for the Period of ten years (2008-2018) from the Nigerian Meteorological Agency (NIMET Headquarters in Abuja and and data of flight operations were obtained from the Operational Department of Federal Airport Authority of Nigeria. Likewise data of flight operations (cancellations, diversions and delays) were obtained for a period of eighteen years (2000-2017).

Data Analysis

Statistical analyses were employed such as descriptive statistics which includes the computation of sum of the generated data to analyze the level of variability/trend of occurrence of the weather elements. Inferential statistics which employs multiple regression analysis was employed to investigate the impact of weather on flight operations and correlation was employed to investigate the nature of the relationship between weather elements and flight operations. Correlation coefficient (r) was used to determine the degree and direction of relationship of weather elements and flight operations.

Model Specification.

For ease of understanding and optimal application of the approach, it was proved scientifically that Aircraft operation is a function of weather elements Weli, (2014)

$Y = F(X_1\ X_2\ X_3)$

Where:

Y = Aircraft operation

$X_1 \ldots X_3$ = Weather Elements

It provides a linear relationship between weather and flight operations, this implies that aircraft operates well in a good weather which can only be proven scientifically. The regression model of the multiple regression analysis adopted in this study is as follows:

$Y = a + \beta_1 x_1 + B_2 X_2 + B_3 X_3 + e$

Where;

Y = Aircraft operation (Dependent Variable)

a = regression constant

β_1 = regression co-efficient

X_1= Harmattan Haze Dust (Independent Variable)

X_2= Fog (Independent Variable)

X_3= Thunderstorm (Independent Variable)

e = error term

RESULTS

Monthly Occurrence of Harmattan Haze, Fog and Thunderstorm

Comparatively, the occurrence of the three selected weather elements (fog, harmattan haze and thunderstorm) at the Airport shows that harmattan haze had the highest number of occurrence (861) followed by thunderstorm (230) and fog with the least number of occurrence (27) within the period under study. The result in figure1 implies that harmattan haze occurs more in Abuja Airport than thunderstorm and fog.

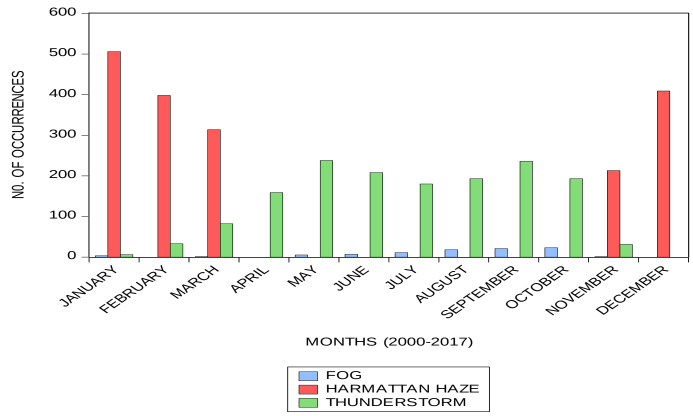

Fig 1: Annual occurrence of Fog, Thunderstorm and Harmattan Haze at the Abuja Airport (2000-2017).

The result in figure 1 shows that there is monthly variation in the yearly occurrences of the three weather elements. The rate of increase of the occurrence of thunderstorm and harmattan haze and fog goes concurrently in 2016. 2004 and 2006 has the highest occurrence of thunderstorm while 2009, 2011 and 2016 has the highest occurrence of harmattan haze and 2010 and 2016 has the highest occurrence of fog within 2000-2017.

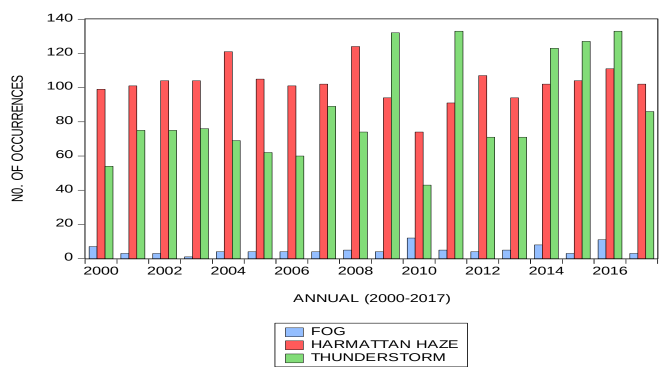

Fig 2: Annual Occurrence of Harmattan Haze, Fog and Thunderstorm at the Abuja Airport (2000-2017)

Mean Annual Trend/Variability of Fog, Thunderstorm And Harmattan Haze at the Nnamdi Azikiwe International Airport, Abuja.

Mean Annual Trend/Variability of Thunderstorm

The annual trend of thunderstorm is described by the positive trend line y = 3.0681 + 57.131, which indicate high increase in number of Thunderstorm occurrences in recent years. In 2000 thunderstorm occurred fifty four times (54) only the occurrence kept fluctuating with increasing occurrence in subsequent years, thunderstorm occurred in 2016 one hundred and thirty three (133) times showing a high increase compared to the occurrence in 2000 (fig 3).

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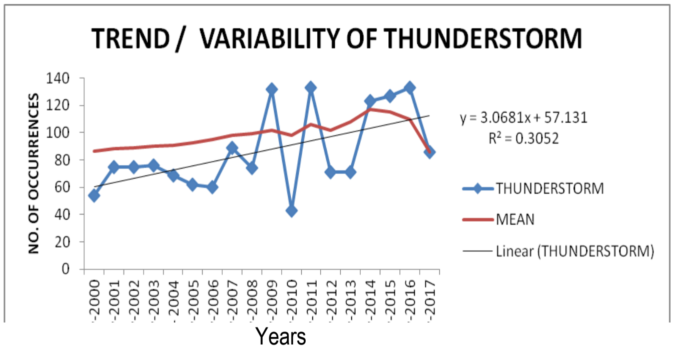

Fig 3: Mean Annual Trend/Variability of Thunderstorm Occurrence at the Abuja Airport (2000-2017)

Mean Annual Trend/Variability of Harmattan Haze
Mean annual trend/variability of harmattan haze occurrence for eighteen years at Nnamdi Azikiwe International airport, Abuja Nigeria, which is described by the negative line y = -0.2208x + 104.32 (Fig 4) which indicates a slight decrease in number of harmattan haze occurrences in recent years compared to the earlier years within the study period (2000-2017). The trend fluctuates annually and differs in occurrence from year to year

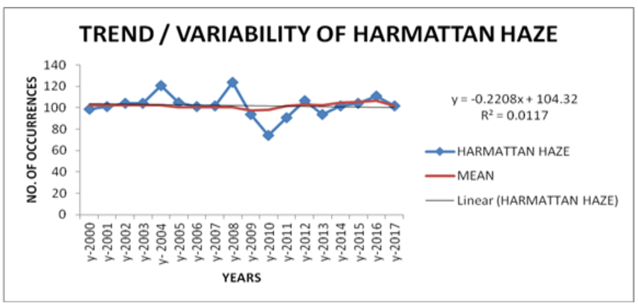

Fig 4 : Mean Annual Trend/Variability of Harmattan Haze Occurrence at the Abuja Airport (2000-2017)

Mean Annual Trend/Variability of Fog
The annual trend of Fog is described by the positive trend line y = 0.1713x + 3.3725 (fig 5) which indicates slight increase in number of fog occurrences in recent years compared to the earlier years within the study period (2000-2017) at the Abuja International Airport

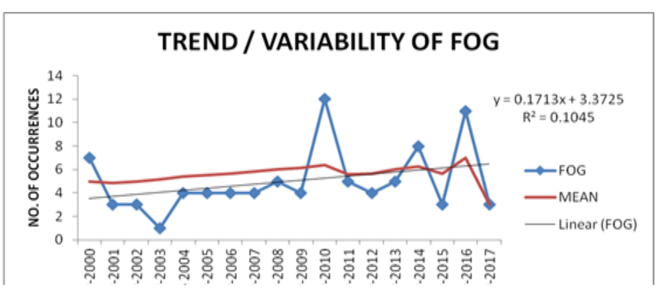

Fig 5: The mean annual trend/ variability of Fog occurrence at the Abuja Airport (2000-2017)

Correlation between Flight Diversion and weather elements
From the analysis carried out, the correlation coefficient between Fog frequency and flight diversion is r = −0.077291 (table 1). This indicates that there is a weak inverse relationship between the number of Fog occurrences and the number of flight diversions in Nnamdi Azikiwe International Airport, Abuja, where an increase in Fog frequency gives rise to a decrease in the number of flight diversions, though the strength is weak. The t-Statistic was calculated to be 0.310090 which is less than 2 and the P-value of 0.7605 (table 1) which is greater than 0.05 means the relationship between flight diversion and frequency of Fog occurrences is not significant.

The correlation coefficient between Harmattan Haze frequency and flight diversion is r = 0.103742 (table 1). This indicates that there is a weak positive relationship between the number of Harmattan Haze occurrences and flight diversions in Nnamdi Azikiwe International Airport, Abuja. This also indicates that an increase in harmattan haze occurrence increase the number of flight diversions, though the strength is weak

The correlation coefficient between thunderstorm frequency and flight diversion is r = 0.010874 (table 1). This indicates that there is a weak positive relationship between the number of Thunderstorm occurrences and the number of flight diversions in Nnamdi Azikiwe International Airport, Abuja, where an increase in thunderstorm frequency gives rise to an increase in the number of flight diversions, though the strength is weak.

Table 1: correlation coefficient between weather parameters and flight diversion

Covariance Analysis: Ordinary
Date: 09/22/18 Time: 00:14
Sample: 2000 2017
Included observations: 18

Correlation t-Statistic Probability	DIVERSION	FOG	HARMATTAN_HAZE	THUNDERSTORM
DIVERSION	1.000000 ----- -----			
FOG	-0.077291 -0.310090 0.7605	1.000000 ----- -----		
HARMATTAN_HAZE	0.103742 0.417221 0.6821	-0.343838 -1.464652 0.1624	1.000000 ----- -----	
THUNDERSTORM	0.010874 0.043498 0.9658	0.044195 0.176953 0.8618	0.054653 0.218938 0.8295	1.000000 ----- -----

Correlation between Weather Elements and Flight Delay
The correlation coefficient between Fog frequency and flight delay is r = 0.29 (table 2). This indicates a moderate positive relationship between fog frequency and the number of flight delays in Abuja. Therefore, an increase in Fog frequency amounts to a considerable increase in the numbers of flight delays inherent in Nnamdi Azikiwe International Airport. The t-Statistic was calculated to be 1.243823 which is less than 2 and the P-value of 0.2315 (table 2) which is greater than 0.05 means the relationship between flight delay and frequency of Fog occurrence is not significant

The correlation coefficient between Harmattan Haze frequency and flight delay is r = 0.03 (table 2). This indicates a weak positive relationship between Harmattan Haze frequency and the number of flight delays in Abuja. Therefore, an increase in Fog frequency amounts to a considerable increase in the numbers of flight delays in Nnamdi Azikiwe International Airport.

The correlation coefficient between Thunderstorm frequency and flight delay is r = -0.146743 (table 2). This indicates a weak negative relationship between Thunderstorm frequency and the number of flight delays. Therefore, an increase in Thunderstorm frequency amounts to a considerable decrease in the numbers of flight delays inherent in Nnamdi Azikiwe International Airport.

Table 2: Correlation coefficient between weather elements and flight delay

Covariance Analysis: Ordinary
Date: 09/22/18 Time: 00:15
Sample: 2000 2017
Included observations: 18

Correlation t-Statistic Probability	DELAY	FOG	HARMATTAN_HAZE	THUNDERSTORM
DELAY	1.000000 ----- -----			
FOG	0.296931 1.243823 0.2315	1.000000 ----- -----		
HARMATTAN_HAZE	0.053000 0.212298 0.8346	-0.343838 -1.464652 0.1624	1.000000 ----- -----	
THUNDERSTORM	-0.146743 -0.593395 0.5612	0.044195 0.176953 0.8618	0.054653 0.218938 0.8295	1.000000 ----- -----

Correlation between Weather Elements and Flight Cancellation

The correlation coefficient between Fog frequency and flight cancellation is r = -0.077905 (table 3). This means that the number of flight cancellation is negatively associated with the number of Fog occurrences in Nnamdi Azikiwe International Airport, Abuja though the relationship is weak

The correlation coefficient between Harmattan Haze and flight cancellation is r = 0.110521 (table 3). This means that the number of flight cancellation is positively associated with the number of Harmattan Haze occurrences though the relationship is weak.

The correlation coefficient between Thunderstorm frequency and flight cancellation is r = 0.289178 (table 3). This indicates a weak positive relationship between thunderstorm frequency and the number of flight delays. Therefore, an increase in Thunderstorm frequency amounts to a considerable increase in the number of flight delays inherent in Nnamdi Azikiwe International Airport.

Table 3: Correlation Coefficient between Flight Cancellation and Weather Elements

Covariance Analysis: Ordinary
Date: 09/22/18 Time: 00:20
Sample: 2000 2017
Included observations: 18

Correlation t-Statistic Probability	CANCELLATION	FOG	HARMATTAN_HAZE	THUNDERSTORM
CANCELLATION	1.000000 ----- -----			
FOG	-0.077905 -0.312572 0.7586	1.000000 ----- -----		
HARMATTAN_HAZE	0.110521 0.444807 0.6624	-0.343838 -1.464652 0.1624	1.000000 ----- -----	
THUNDERSTORM	0.289178 1.208337 0.2445	0.044195 0.176953 0.8618	0.054653 0.218938 0.8295	1.000000 ----- -----

Impact of Weather Elements on Flight Delay

The impact of weather elements on flight operations that is Delay is the proxy for flight operation treated as the dependent variable while Harmattan Haze, Fog and Thunderstorm were the weather parameters also treated as the independent variables.

$$Y= 179.6585 +0.143726X_1 + -0.479800x_2 + -0.492579X_3 \ldots\ldots\ldots 1$$

The model is significant at 95 % confidence interval.

The result shows that for every single delay of flight is caused by 47 % (0.479800) variation of fog occurrence, it means that a 47 % variation that led to every single delay of the flight is from the Fog while a P-Value of Fog 0.2246 which is more than 0.05 at 5 % confidence interval (table 4). This implies that fog does not have significant impact on flight delay.

The result further shows that for every single delay of flight is as result of 14 % (0.143726) various occurrences of Harmattan Haze, it implies that a 14 % variation that led to every single delay of the flight is from the harmattan haze. A P-Value of harmattan haze of 0.2473 (table 4) which is more than 0.05 at 5 % confidence interval means that the impact of harmattan haze on flight delay is not significant.

The result likewise shows that for every single delay of flight is explained by 49 % (0.492579) variation in the occurrences of thunderstorm, it means that a 49 % variation that led to every single delay of the aircraft is from the thunderstorm while a P-Value of thunderstorm of 0.2464 (table 4) which is more than 0.05 confidence level implying that there is no significant difference of thunderstorm on flight delay.

Table 4: Regression Result of the Impact of Weather elements on Flight Delay

Dependent Variable: DELAY
Method: Least Squares
Date: 09/18/18 Time: 23:19
Sample: 2000 2017
Included observations: 18

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	179.6585	35.78019	5.021174	0.0004
FOG	-0.479800	2.704385	-1.286725	0.2246
HARMATTAN_HAZE	0.143726	0.117640	1.221739	0.2473
THUNDERSTORM	-0.492579	0.402283	-1.224459	0.2464

R-squared	0.207361	Mean dependent var	137.8667
Adjusted R-squared	-0.008813	S.D. dependent var	27.61952
S.E. of regression	27.74097	Akaike info criterion	9.706876
Sum squared resid	8465.174	Schwarz criterion	9.895689
Log likelihood	-68.80157	Hannan-Quinn criter.	9.704865
F-statistic	0.959230	Durbin-Watson stat	2.175257
Prob(F-statistic)	0.446035		

Impact of Weather Elements on Flight Diversion

Flight Diversion is the proxy for Aircraft Operation is treated as the dependent variable while Fog, Harmattan Haze and Thunderstorm were the weather elements treated as the independent variables.

$Y= 97.40687 + 0.087729X_1 + 0.111211X_2 + -0.210610X_3$ ……. 2

The whole model is significant at 0.05 confidence level

The result reveals that for every single diversion of aircraft as a result of 11% (0.111211) variation in the occurrences of fog, it means that 11% variation that led to every single diversion of the aircraft is from Fog occurrence. It further shows that the P-Value of Fog 0.9058 (table 5) is greater than 0.05 confidence level indicating that there is no significant effect of fog on flight diversion.

The result similarly shows that for every single diversion of aircraft is explained by 8 % (0.087729) variation in the occurrence of harmattan haze, it means that a 8 % variation that led to every single diversion of the aircraft is from harmattan haze, It further reveals that the P-Value of Harmattan Haze 0.0405 (table 5) is less than 0.05 at 5 % confidence interval and the decision rule state that at such level the impact is significant.

Similarly, the result displays that for every single diversion of aircraft operation is caused by 21% (0.210610) variation in the occurrences of thunderstorm. It means that a 21 % variation that led to every single diversion of the flight is from thunderstorm and a P-Value of thunderstorm 0.1515 (table 5) which is greater 0.05 at 5 % confidence interval implies that the impact is not significant.

Table 5: Regression Result of the Impact of Weather elements on Flight Diversion

Dependent Variable: DIVERSION
Method: Least Squares
Date: 09/18/18 Time: 23:16
Sample: 2000 2017
Included observations: 18

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	97.40687	12.15445	8.014092	0.0000
FOG	0.111211	0.918673	0.121056	0.9058
HARMATTAN_HAZE	0.087729	0.039962	2.195309	0.0405
THUNDERSTORM	-0.210610	0.136655	-1.541187	0.1515

R-squared	0.386256	Mean dependent var	91.40000
Adjusted R-squared	0.218871	S.D. dependent var	10.66235
S.E. of regression	9.423543	Akaike info criterion	7.547478
Sum squared resid	976.8348	Schwarz criterion	7.736291
Log likelihood	-52.60608	Hannan-Quinn criter.	7.545467
F-statistic	2.307595	Durbin-Watson stat	2.556051
Prob(F-statistic)	0.133045		

Source: Author's Data Analysis, 2018

Impact of Weather Elements on Flight Cancellation

The regression result of the impact of weather elements on flight cancellation that is cancellation being the proxy for flight operation which was treated as the dependent variable while fog, harmattan haze and thunderstorm (weather elements) were used as the independent variables.

$Y= 57.15330 + 0.107402X_1 + -0.338851X_2 + -0.098671X_3$ ……. 3

The model is significant at 95 % confidence interval.

The result reveals that for every single cancellation of flight were explained by a 33 % variation in the occurrences of fog, it means that a 33 % variation that led to every single cancellation of the flight is from fog while a p-value of fog 0.6223 (table 6) which is greater than 0.05 at 5 % confidence interval which means that the impact is not significant. The result also shows that for every single cancellation of flight was as a result of 10 % variation in the occurrences of harmattan haze, it means that a 10 % variation that led to every single cancellation of the aircraft is from the harmattan haze while the P-Value of harmattan haze 0.0035 (table 6) which is less than 0.05 at 5 % confidence interval implies that the impact of harmattan haze on flight cancellation is significant. The result furthermore showed that for every single Cancellation of flight was caused by 9 % variation in the occurrences of thunderstorm which means that a 9 % variation that led to every single Cancellation of the flight is from the thunderstorm while P-Value of thunderstorm is 0.3425 (table 6) which is greater than 0.05 at 5 % confidence interval implies that the impact is not significant.

Table 6: Regression Result of the Impact of Weather Parameters on Flight Cancellation

Dependent Variable: CANCELLATION
Method: Least Squares
Date: 09/18/18 Time: 23:20
Sample: 2000 2017
Included observations: 18

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	57.15330	8.845565	6.461238	0.0000
FOG	-0.338851	0.668577	-0.506824	0.6223
HARMATTAN_HAZE	0.107402	0.029083	3.692946	0.0035
THUNDERSTORM	-0.098671	0.099452	-0.992141	0.3425
R-squared	0.560657	Mean dependent var		58.60000
Adjusted R-squared	0.440836	S.D. dependent var		9.171384
S.E. of regression	6.858111	Akaike info criterion		6.911920
Sum squared resid	517.3705	Schwarz criterion		7.100733
Log likelihood	-47.83940	Hannan-Quinn criter.		6.909908
F-statistic	4.679125	Durbin-Watson stat		1.595390
Prob(F-statistic)	0.024245			

DISCUSSION

The number of occurrences of the selected weather elements varies in each month and year.

The highest frequency of fog occurred in the month of October (24 times) followed by the month of September (21 times), the months of March and November had the lowest number of occurrence of fog occurring only once while the months of February, April and December had zero occurrence of fog. This finding is in disparity with the finding of Muiruri (2006) on the influence of fog on delays at JKIA for the period 2000 to 2005. His results indicated that fog occurrence at JKIA is highest in April, November and December, which coincides with the rainfall seasons. The difference in the result of Muiruri and this research could be because of the difference in period of study and (or) difference in location.

The severity and intensity of fog occurrence was more pronounced in 2010 which had the highest number of occurrence of fog while 2003 had the lowest occurrence.

Thunderstorm had the highest frequency of occurrence in the months of May and September followed by June without a single occurrence in the month of December. The frequency of thunderstorm varies within the months and years. The monthly frequency exhibited two maxima peaks, the first peak is seen in April and May with 159 and 238 respectively. The second peak occurred in September and October with 236 and 193 respectively. This indicates the two peaks of rainy season associated with thunderstorms. The finding is in agreement with the result of Maxwell (2008), who observed that the monsoon period of the year is the worst for bad weather delays due to resultant convective weather activities.

The annual occurrences reveals that 2008 had the highest number of thunderstorm occurrence which is in agreement with the result of Akanni *et al* (2016) in Lagos state whose result showed that 2008 had the highest number of thunderstorm occurrence.

The monthly occurrences of Harmattan Haze during the studied period (2000-2017) at the Nnamdi Azikiwe International Airport, Abuja varies in each month, having the month of January with the highest frequency followed by the month of February, December and March while the months of April to October had zero occurrences of Harmattan Haze. There is however no dust haze occurrence from the months of April to October. These months are the wet season during which the country is under the influence of moist tropical maritime winds from the Atlantic Ocean. These monthly variations clearly shows that harmattan dust haze is a dry and dusty seasonal weather phenomenon which blows from the Sahara desert from the months of November to March. During these months, the entire country is under the desiccating effect of dry tropical continental air mass from the Sahara interior.

The severity and intensity of harmattan dust haze occurrence was more pronounced in 2008. Similarly, its annual occurrence varies from year to year depending on the intensification of the high pressure canters especially the Azores high pressure belt and the strength of the wind at the dust source region.

Consequently, monthly and annual summaries the occurrence of the three selected weather parameters (fog, harmattan haze and thunderstorm) in Nnamdi Azikiwe international airport Abuja. It showed that among the three selected weather parameters harmattan haze had the highest number of occurrence (861) followed by thunderstorm (230) and fog with the least number of occurrences (27). Therefore the intensity and occurrence of harmattan haze is more in Nnamdi Azikiwe International Airport, Abuja within the study period compared to the occurrence of thunderstorm and fog.

The mean monthly variability and trend of the frequency of occurrence of thunderstorm and fog shows a slightly increasing trend over the months in Nnamdi Azikiwe International Airport throughout the study period. This implies that occurrence of thunderstorm is more during the middle and end of the year than the beginning of the year. The result of this study is in agreement with the result of Akanni *et al*, (2016) whose study showed that there has been trend of thunderstorm in Lagos state and showed that there has been an increasing trend in the occurrence of thunderstorm within 2004-2013 in Lagos State.

Meanwhile the result is at variance with the findings of Enete *et al.* (2015) which showed that thunderstorm occurrence was fluctuating without either a decreasing or increasing trend the difference in result of Enete *et al*, (2015) with this study could be due to the difference in the location and the period of the study.

The mean monthly variability/trend of the frequency of occurrence of Harmattan Haze shows decreasing trend over the months in Abuja Airport this implies that occurrence of harmattan haze is more during the beginning of the year than in the middle and end of the year throughout the study period (2000-2017). The mean annual variation and trend of the frequency of occurrence of the weather elements (thunderstorm, and fog) within the study area shows increasing trend while harmattan haze shows a decreasing trend over the study period, therefore fog and thunderstorm occurrence has increased while harmattan haze occurrence has decreased in recent years.

From the analysis carried out, the correlation coefficient between Fog frequency and Flight Diversion $r = -0.077291$. This indicates that there is a weak inverse relationship between the number of Fog occurrences and the number of flight diversions in Nnamdi Azikiwe International Airport, Abuja, where an increase in Fog frequency gives rise to a decrease in the number of flight diversions, though the strength is weak. In other words, flight diversions seem not to be pronounced in Abuja Airport as a result of Fog occurrences, which might be due to other factors antecedent to diversions such as technical, operational and human factors among others. The correlation coefficient between Harmattan Haze frequency and flight diversion is r = 0.103742. This indicates that there is a weak positive relationship between the number of Harmattan Haze occurrences and the number of flight diversions in Nnamdi Azikiwe International Airport, Abuja, where an increase in Harmattan Haze frequency gives rise to an increase in the number of flight diversions, though the strength is weak. The correlation coefficient between Thunderstorm frequency and flight diversion r = 0.010874, indicates that there is a weak positive relationship between the number of Thunderstorm occurrences and the number of flight diversions in Nnamdi Azikiwe International Airport, Abuja, where an increase in Thunderstorm frequency gives rise to an increase in the number of flight diversions, though the strength is weak.

The correlation coefficient between Fog frequency and flight delay is r = 0.29. This indicates a moderate positive relationship between fog frequency and the number of flight delays in Abuja. Therefore, an increase in Fog frequency amounts to a considerable increase in the numbers of flight delays inherent in the Station. The correlation coefficient between Harmattan Haze frequency and flight delay is r = 0.03. This indicates a weak positive relationship between Harmattan Haze frequency and the number of flight delays in Abuja. The correlation coefficient between Thunderstorm frequency and flight delay is r = -0.146743, it shows a negative relationship which is in disparity with the result of Weli and Emenike (2016) which shows that thunderstorm has a positive correlation with flight delay at Port Harcourt international Airport. This disparity could be due to the difference in the location of study because Portharcourt is in the southern part of Nigeria which is known to have more convective weather activities than Abuja Airport which is in the North Central.

The correlation coefficient between Fog frequency and flight cancellation is r = -0.077905. This means that the number of flight cancellation is negatively associated with the number of
Fog occurrences which agrees with the findings of Weli and Emenike (2016) whose result shows that there is no statistically significant relationship between fog and flight cancellation in Abuja International Airport. The correlation coefficient between Harmattan Haze frequency and flight cancellation is r = 0.110521. This means that the number of flight cancellation is positively associated with the number of Harmattan Haze occurrences. The correlation coefficient between Thunderstorm frequency and flight cancellation is r = 0.289178. This means that the number of flight cancellation is positively associated with the number of Thunderstorm occurrences. This implies that as frequency of thunderstorm and dust haze increases, flight delay increases in Nnamdi Azikiwe International Airport, Abuja.

The impact of weather elements on flight operations (Delay) was treated as the dependent variable while Fog, Harmattan Haze and Thunderstorm were the weather parameters treated as the independent variables. The result shows that for every single delay of aircraft operation are caused by 47% variation of fog occurrence, it means that a 47% variation that led to every single delay of the flight is from the Fog. The result further shows that for every single delay of flight is as result of 14% various occurrences of Harmattan Haze, it implies that a 14% variation that led to every single delay of the flight is from the harmattan haze. The result likewise shows that for every single delay of flight is explained by 49% variation in the occurrence of thunderstorm, it means that a 49% variation that led to every single delay of the aircraft is from the thunderstorm while a P-Value of thunderstorm of 0.2464 which is greater than 0.005 at 0.05 confidence interval means that the effect is not significant

The regression result for weather elements on aircraft diversion. Flight Diversion was treated as the dependent variable while Fog, Harmattan Haze and Thunderstorm were the weather parameters were treated as the independent variables. The result reveals that for every single diversion of flight is as a result of 11 % variation in the occurrences of Fog, it means that an 11 % variation that led to every single diversion of the flight is from the Fog. It further shows that the P-Value of Fog 0.9058 is greater than 0.05 at 5 % confidence interval and the decision state that as such the effect is not significant. The result similarly showed that for every single diversion of flight is explained by 8 % variation in the occurrence of harmattan haze, it means that a 8% variation that led to every single diversion of the flight is from the harmattan haze, It further reveals that the P-Value of Harmattan Haze 0.0405 which is less than 0.05 at 5 % confidence interval and the decision state that as such the effect is significant. Similarly, the result displays that for every single diversion of flight is caused by 20 % variation in the occurrences of thunderstorm. It means that a 20 % variation that led to every single diversion of flight is from thunderstorm a P-Value of thunderstorm of 0.1515 which is greater than 0.05 at 5 % confidence interval implies that the impact is not significant.

The regression result of the impact of weather elements on flight Cancellation. That is Cancellation being the proxy for flight operation which was treated as the dependable while Fog, Harmattan Haze and Thunderstorm were the weather parameters which were used as the independent variables. The result reveals that for every single Cancellation of flight were explained by a 33 % variation in the occurrences of Fog, it means that a 33 % variation that led to every single cancellation of the flight is from the Fog while a P-Value of Fog 0.6223 which is greater than 0.05 at 5 % confidence interval means that the impact is not significant. The result also shows that for every single cancellation of flight was as a result of 10 % variation in the occurrences of harmattan haze, it means that a 10 % variation that led to every single cancellation of the flight is from harmattan haze while a P-Value of harmattan haze 0.0035 which is less than 0.05 at 5 % confidence interval implies that the impact is significant. The result further showed that for every single cancellation of flight was caused by 9 % variation in the occurrences of thunderstorm which means that a 9 % variation that led to every single cancellation of the flight is from the thunderstorm while a P-Value of thunderstorm of 0.3425 which is greater than 0.05 at 5 % confidence interval implies that the impact is not significant.

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