Effect of some Meteorological Parameters of Aviation Operations in Port Harcourt International Airport Nigeria

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Abstract

The study assessed trends of meteorological parameters and aviation operations in Port Harcourt International Airport. Records of rainfall, thunderstorm, wind speed, fog, pressure and temperature and three aspects of flight operations (flight diversions, delays and cancellations) from 2010-2018 were collected from secondary source. Multiple regression analysis was used to determine the trend of the meteorological parameters as predictors of aviation operations. The findings of the study showed that flight operations experienced more disruptions during dry season; weather elements such as rainfall, thunderstorm, fog and pressure have significant effects on flight operations between 2010 and 2018. The study also showed that when combined, the meteorological factors can be used to predict flight cancellations at 95% confidence level. The study therefore recommends the installation of precise equipment that will enable accurate prediction of weather in airports as well as in other strategic locations across the country.

1. INTRODUCTION

Airline operations began in the 1980s at the Port Harcourt International Airport. It was closed in August 2006 due to emergency and reopened later in December, 2007 with limited capacity. The single asphalt-surface runway measures 9,846ft in length and 197ft in width. Meteorological parameters influence a vast aspect of aviation and its operations. Aircraft safety, efficiency and capacity are susceptible to environmental conditions chiefly as a result of adverse meteorological impacts on aircraft operations (Sasse and Hauf, 2003). Extreme meteorological factors have long known events or errors that occur beyond the influence of the flight crew, increase operational complexity. Each year, more than half of all accidents and incidents recorded are weather related.

In Air Transport, the most critical issue is safety (Trogeler, 2010). The negative effects have direct and indirect damageable impacts on the society and environment (Callum, 2000; Janic, 2007). Direct impact embraces aircraft noise around airports, air pollution and wastes, air traffic incidents and contamination of source of drinking water and soil during fuel dumping (Janic, 2010). According to the International Air Transport Association (IATA, 2015) 71% of air accidents in Nigeria are caused by poor weather conditions. The functioning capacity of airports, and even a region's airspace, can be reduced due to bad weather, leading to delays, diversions and cancellation of flight (Sasse and Hauf, 2003). The statistics of air mishaps in Nigeria are mainly due to meteorological hazards, with the inclusion of human errors, ageing aircraft and deficiency in safety management system (Weli and Emenike, 2016). The first major air crash in Nigerian aviation history is that of a Federal Government owned DC-10 aircraft from London to

Lagos, which crashed during landing phase on the 20th of November, 1969 killing all 867 passengers and crew.

The glooming days of Nigerian aviation industry, which is regarded as the darkest was between 2003 and 2010 when a bulk of accidents were recorded resulting in loss of lives, investigations revealed that the air crashes which occurred between 2003 and 2006 were traceable to bad weather and wind shear which has remained a serious meteorological hazard. Ayoade (2004) reported that flight cancellations, disruptions and aircraft incidents affect the industry in Nigeria and also noted that the Vagaries of weather with references to the various meteorological parameters, act maliciously against most of the economic activities.

The peculiar meteorological hazards predominant within Nigeria pose great danger to safety and the environment, these include hail as fog, harmattan dust Haze, thunderstorm. Nigerian Meteorological Agency (NIMET) reported that the year 2010, witnessed a few instances of flight operation disruptions due to severe weather conditions. Severe dust haze which impeded horizontal visibility to less than 1000m in fog was a major reason for disruptions in flight operations. In January and December of 2010-2018, fog reported in Port Harcourt reduced horizontal visibility to less than 500m. This resulted in flight delays and hundreds of air travelers were left stranded,(NIMET,2019). The frequency of delays, diversions and outright cancellations occasioned by poor weather, affected the Nigerian aviation industry and serious safety implications. Akani (2016). Extreme weather and climatic events have been classified into thermal, moisture and aerodynamic events, Ogunsanya (2005).

Aderemo (2006) identified in his study that human and natural factors affected flight operations. The natural factors were weather related with rainfall as the most critical, Aderinto (2001). Advection Fog, mist and smog are meteorological conditions that cause poor visibility and it is the most important meteorological hazard to all forms of air transportation (Ayoade, 2004 and Shadere, 2005). Poor visibility poses more dangers to aircraft landing as compared to a wet runway. Poor visibility is caused by a range of parameters such as thick fog, rain, thunderstorm, dust haze and mist (Klein, 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 corrective weather, are potentially avoidable. Abubakar and Nurudeen (2011), identified flight delays and cancellations as the resultant effects of poor visibility. The environment which birth the only medium by which aviation must thrive, also place extreme conditions on its operations and it can never be a cliché approach to understand the meteorological hazards to ensure safety. Aircraft flight operations are characterized into important phases of takeoff, cruise and landing. These incidents depicts landing as an unpredictable phase of flight operations.

Investigations by Edeghe (2006) into the crash of Bellview and Sosoliso airlines in 2005 and ADC airline in 2006 in Nigeria, revealed that Port Harcourt was host to a couple of these accidents which occurred between takeoff and landing and caused by wind shear (aberration or variation – in the wind direction and speed reported in Port Harcourt Airport). Weather is the sum total of the atmospheric condition of a given place at a time, also described as an everyday experience (Stringer, 1989), it has the propensity to change. Bisiriyu (2006) also reports that in aviation, weather has remained the important parameter in determining safety, regularity and efficiency of aviation operations. It is because of the importance of weather reports to flight operations that the Federal Government of Nigeria in 2007 announced her willingness to acquire state of the Art equipment to ensure safety compliance in Lagos and Abuja only. This would have reduced the spate of uncertainties about weather reports in Port Harcourt. Capital to aviation operations acquired from the ground surface are visibility, pressure, temperature, dew point, wind speed and direction, precipitation accumulation. Other parameters include, severe turbulence, thunderstorm, microburst, wind shear.

MATERIALS AND METHODS

The Study Area

Port Harcourt International Airport, Rivers State, Nigeria lies between latitude 04˚ 49′27″N and longitude 07˚ 2′1″E and on latitude above 91ft (27.7m) mean sea level (coordinates; 4.824167N and 7.033611E). Port Harcourt has a density of 2,700/km^2 (7,100/m^2) with a population of 2,000,000 as at 2006 census (Nigeria population Census Board, 2006).

It is a public airport operated by the Federal Airports Authority of Nigeria (FAAN), currently undergoing final phases of reconstruction of physical structures with two terminals for domestic and International flights. The single asphalt-surfaced runway at the airport has a length of 9,846ft (3,00/m) and a width of 197ft(60m).

Port Harcourt has a tropical climate. Rainfall is significant most months of the year and the short dry season has significant effect. The average annual temperature is 26.4^{o}C/79.SF precipitation here is about 2708mm per year. The driest month is January, with 36mm of rainfall. The warmest month is February with an average temperature of 27.6°C; August is the coldest month with temperature averaging 25.2C.

Data Analysis

Data analysis is the process of systematically applying statistical and/or logical technique to describe and illustrate, condense recap, and evaluate data. Data analysis involves goals, relationships decision making and ideas in addition to working with actual data itself.

Statistical analysis which includes the computation of sum of the generated data to analyze the level of variability and trend of occurrence of the meteorological parameters were employed.

Inferential statistics which employs multiple regression analysis was employed to investigate the impact of meteorological hazards and parameters on flight operations and correlation was employed to investigate the nature of the relationship between meteorological parameters and flight operation and direction of relationship of these parameter and flight operations.

The model equation of the stepwise multiple regression analysis is as follows:

Model Specification

The application of Aircraft operation as a function of weather parameter (Weli, 2004)

$$Y = F\ (x_1 x_2 x_3 â€¦)$$

$$Y = a + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + e \qquad (1)$$

Where:

$X_1 \dots X_4$ = MeterologicaL Hazards/Parameters

$Y =$ Aircraft Operation (dependent variable)

$a =$ Regression constant

$\beta_1 - \beta_3$ = Regression co-efficient

X_1 = Rainfall

X_2 = Thunderstorm

X_3 = Wind speed

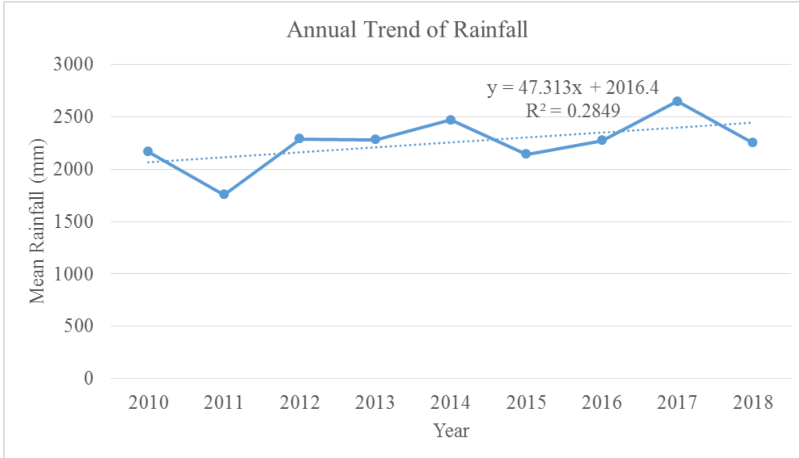
X_4 = Fog

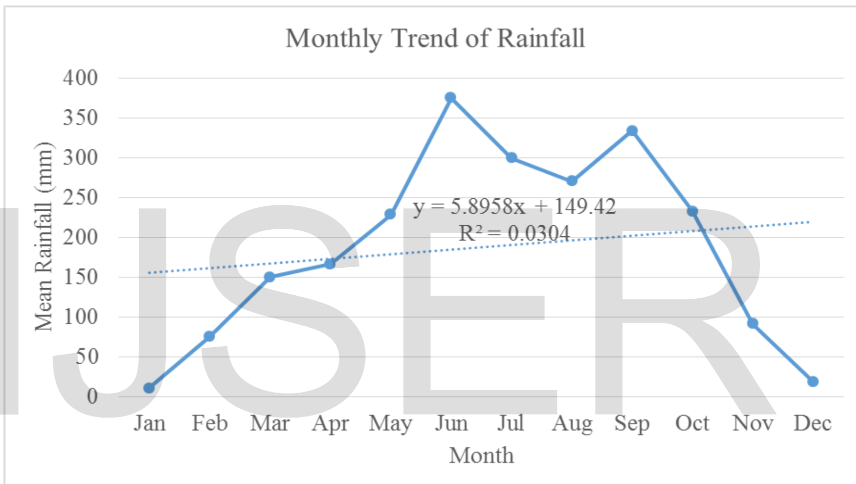
e = error term

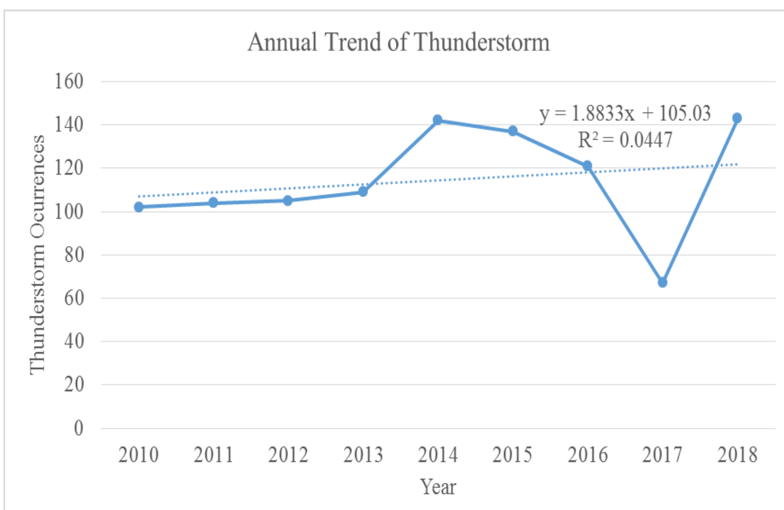
The above equation provides a linear relationship between meteorological hazards and flight operations, this relates to efficiency in aircraft operation in good weather. The T-test was similarly employed to examine the difference in the seasonal influences of incidents prone weather conditions.

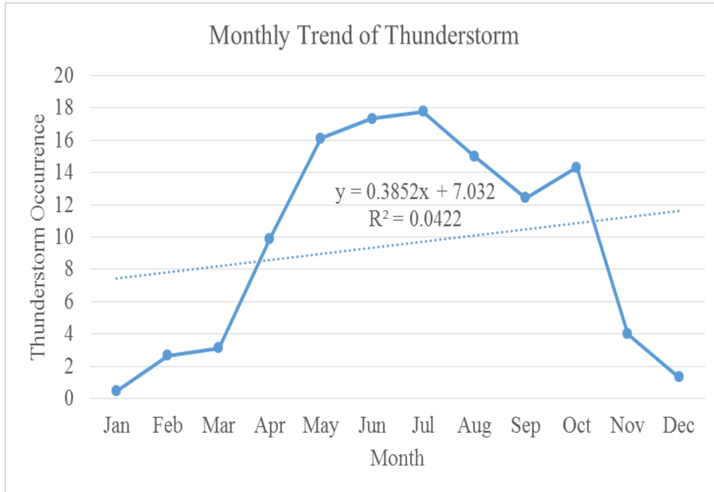
RESULTS

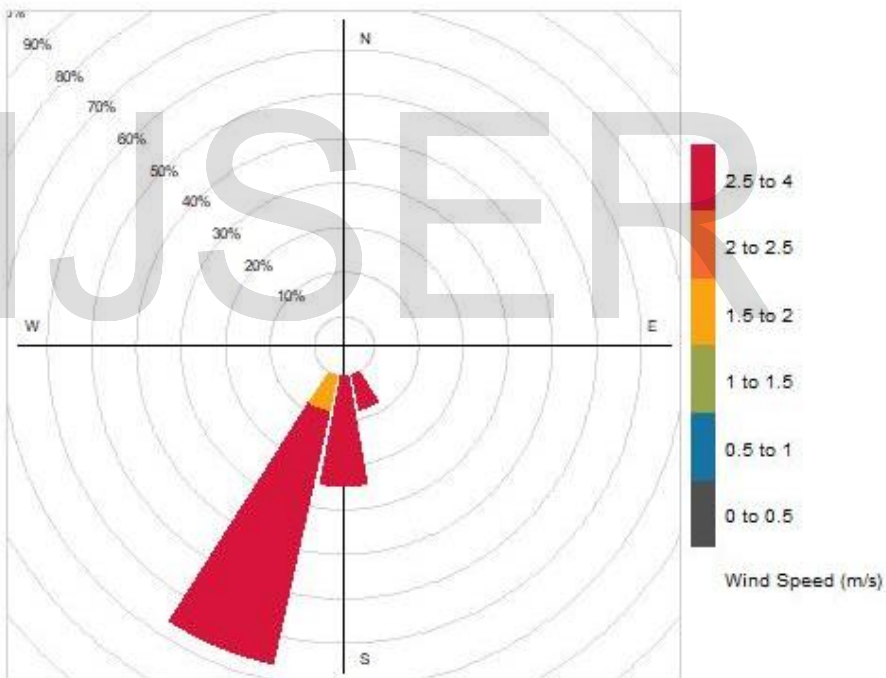
The results for meteorological parameters and Hazards in the study area are presented in Figs 4.1 – 4.13 and appendices 1-8. Rainfall, thunderstorm, fog, wind speed, pressure and temperature varied considerably within the period under review (2010 – 2018). The annual and monthly variations in each of the measured parameters were shown in the Figs. The trend analysis is represented by trend lines which display the equation of the line and R-squared values, thus showing the direction and strength of the trend line respectively. Meteorological parameters such as rainfall and thunderstorm showed variations across the seasons of the year. Rainfall and thunderstorm were higher during the rainy season, from June to September than in the dry season from November to March. Fog showed several fluctuations during the year, with peaks at December and November and high levels in January and July. Wind Speed and temperature recorded an almost even spread throughout the year and were not dependent on seasonal variations. Pressure at the station recorded highest value of 79.5mmHg in January and lowest value of 75.3mmHg in April. The result also showed wind roses for the period under review. The wind roses which are shown in Figs 4.5a-i revealed the average speed and direction of the wind for each year.

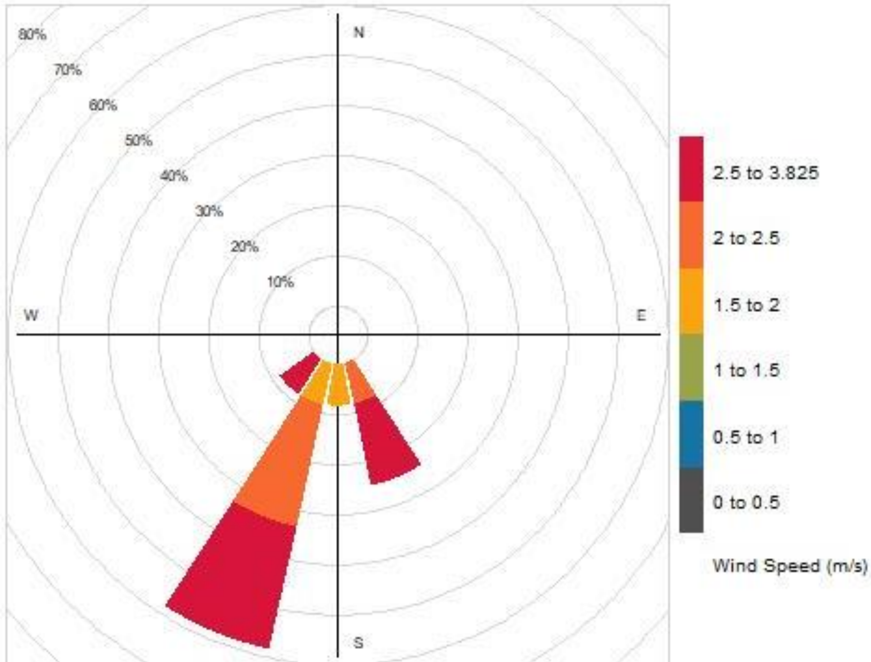

Annual Trend of Rainfall
y = 47.313x + 2016.4
R² = 0.2849
Mean Rainfall (mm)
3000
2500
2000
1500
1000
500
0
2010
2011
2012
2013
2014
2015
2016
2017
2018
Year

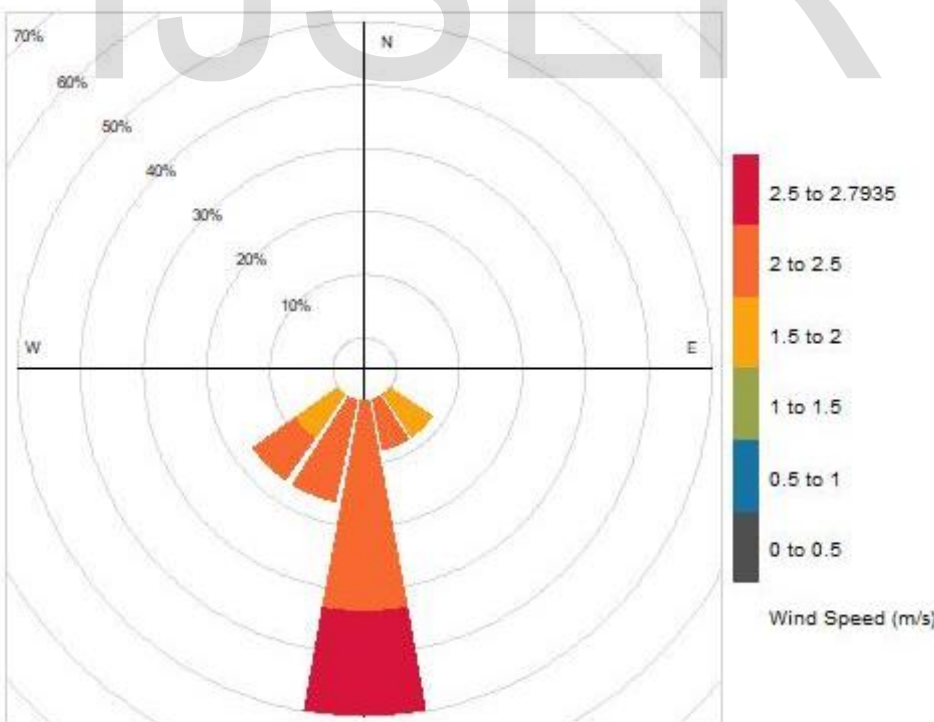

Monthly Trend of Rainfall
y = 5.8958x + 149.42
R² = 0.0304
Mean Rainfall (mm)
400
350
300
250
200
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

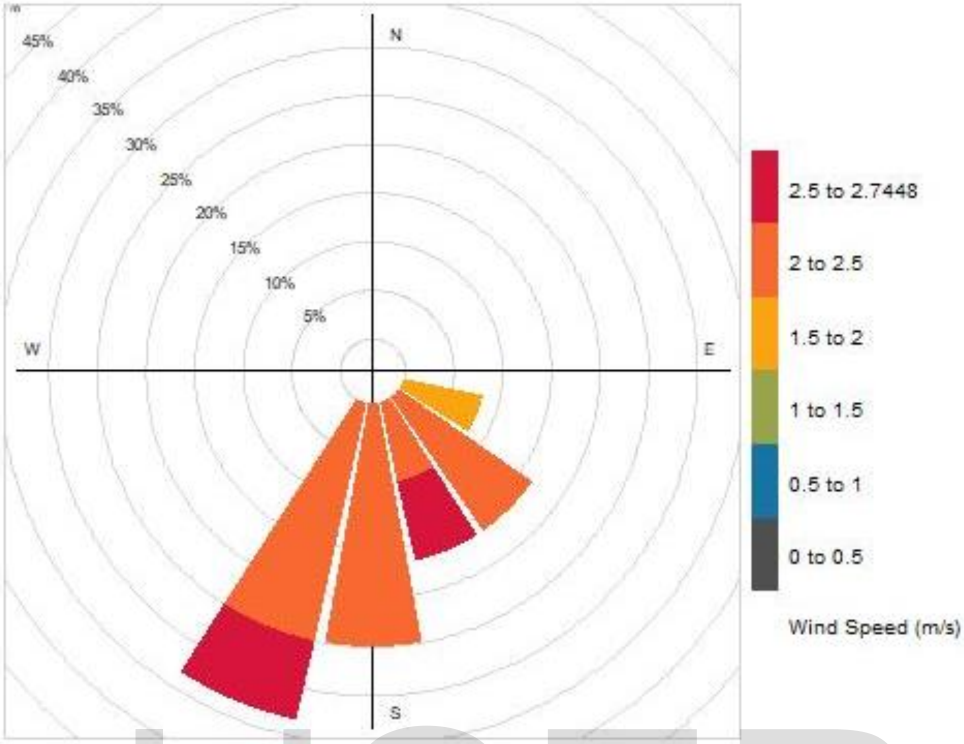

Annual Trend of Thunderstorm
y = 1.8833x + 105.03
R² = 0.0447
Thunderstorm Ocurrences
160
140
120
100
80
60
40
20
0
2010
2011
2012
2013
2014
2015
2016
2017
2018
Year

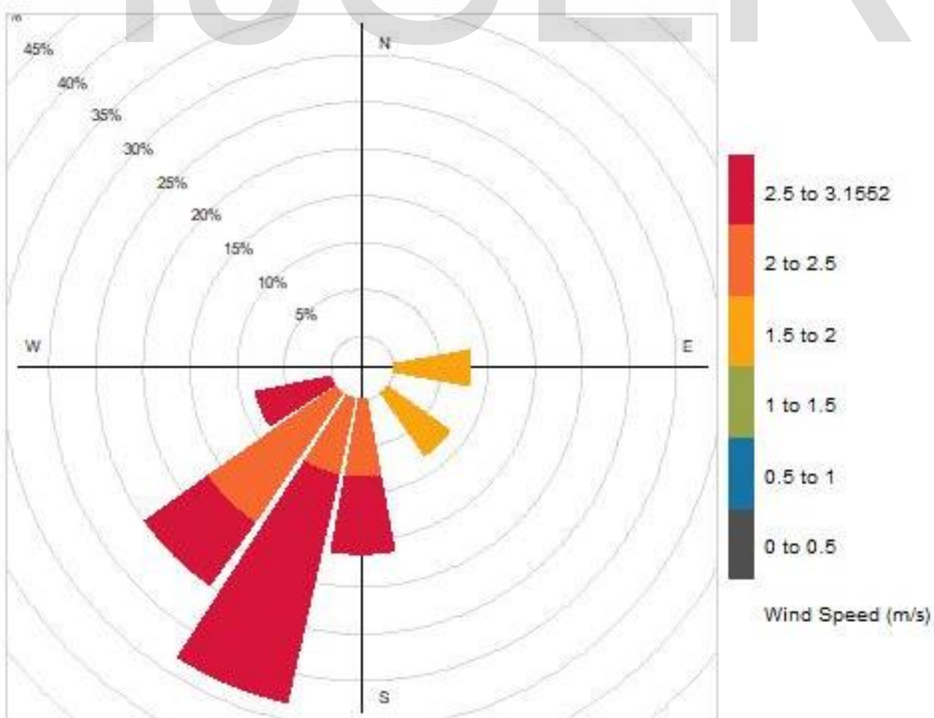

Monthly Trend of Thunderstorm
Thunderstorm Occurrence
20
18
16
14
12
10
8
6
4
2
0
y = 0.3852x + 7.032
R² = 0.0422
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month

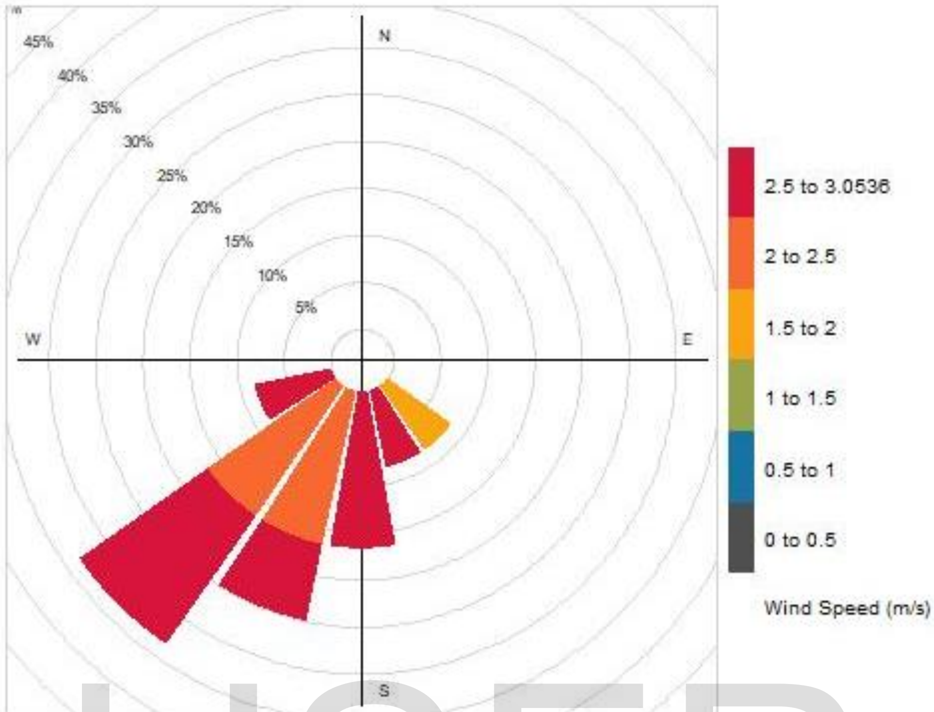

90%
80%
70%
60%
50%
40%
30%
20%
10%
N
W
E
S
2.5 to 4
2 to 2.5
1.5 to 2
1 to 1.5
0.5 to 1
0 to 0.5
Wind Speed (m/s)

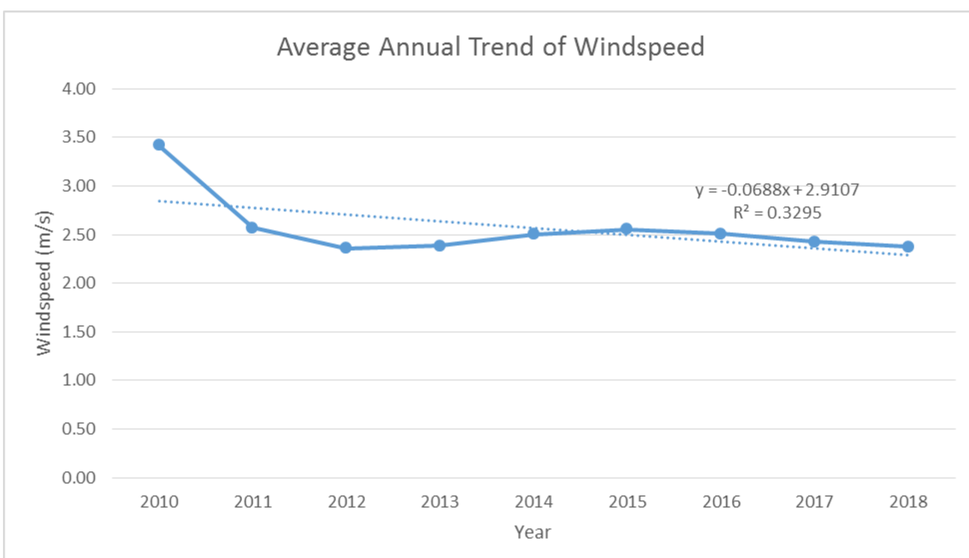

80%
70%
60%
50%
40%
30%
20%
10%
N
W
E
S
2.5 to 3.825
2 to 2.5
1.5 to 2
1 to 1.5
0.5 to 1
0 to 0.5
Wind Speed (m/s)

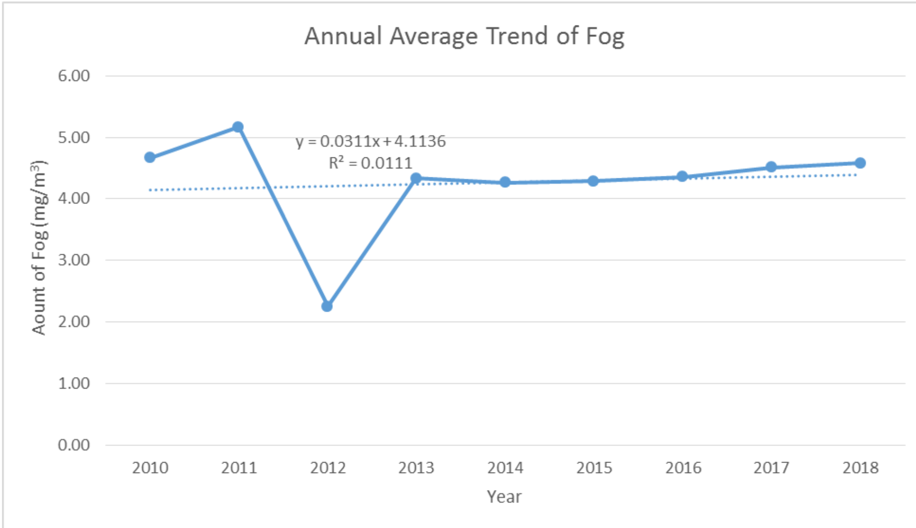

70%
60%
50%
40%
30%
20%
10%
N
W
E
2.5 to 2.7935
2 to 2.5
1.5 to 2
1 to 1.5
0.5 to 1
0 to 0.5
Wind Speed (m/s)

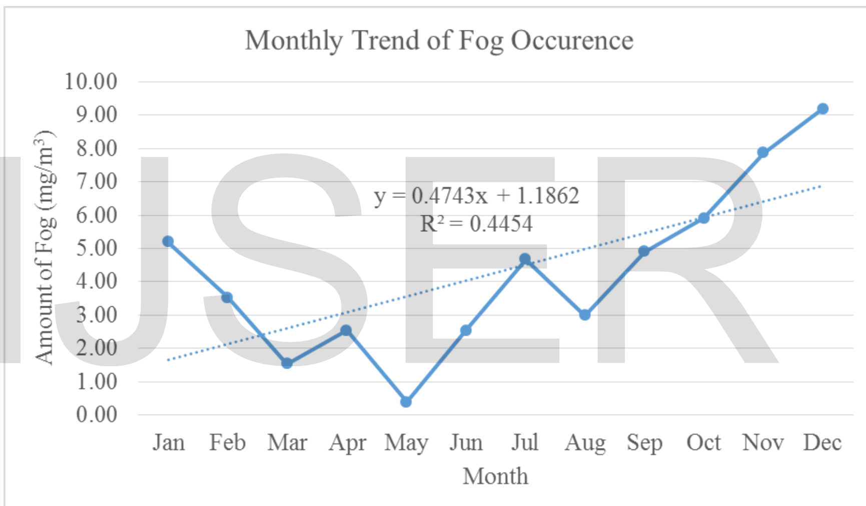

45%
40%
35%
30%
25%
20%
15%
10%
5%
N
W
E
S
2.5 to 2.7448
2 to 2.5
1.5 to 2
1 to 1.5
0.5 to 1
0 to 0.5
Wind Speed (m/s)

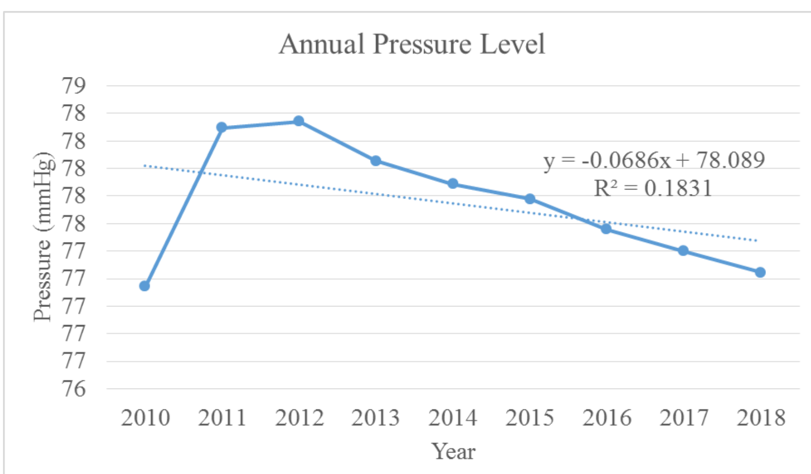

45%
40%
35%
30%
25%
20%
15%
10%
5%
N
W
E
S
2.5 to 3.1552
2 to 2.5
1.5 to 2
1 to 1.5
0.5 to 1
0 to 0.5
Wind Speed (m/s)

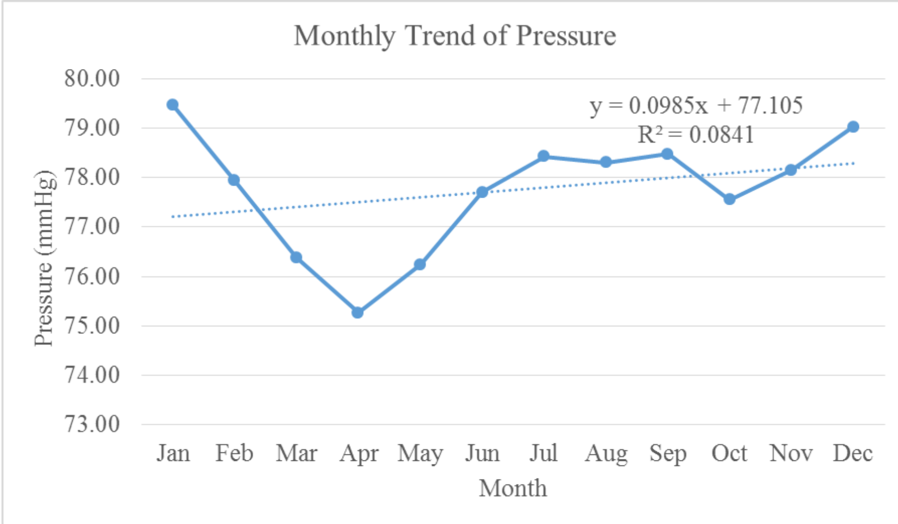

N
S
E
W
45%
40%
35%
30%
25%
20%
15%
10%
5%
2.5 to 3.0536
2 to 2.5
1.5 to 2
1 to 1.5
0.5 to 1
0 to 0.5
Wind Speed (m/s)


Average Annual Trend of Windspeed
Windspeed (m/s)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
y = -0.0688x + 2.9107
R² = 0.3295
2010
2011
2012
2013
2014
2015
2016
2017
2018
Year


Annual Average Trend of Fog
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Aount of Fog (mg/m³)
y = 0.0311x + 4.1136
R² = 0.0111
2010
2011
2012
2013
2014
2015
2016
2017
2018
Year


Monthly Trend of Fog Occurence
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Amount of Fog (mg/m³)
y = 0.4743x + 1.1862
R² = 0.4454
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month


Annual Pressure Level
79
78
78
78
78
78
77
77
77
77
77
76
Pressure (mmHg)
y = -0.0686x + 78.089
R² = 0.1831
2010
2011
2012
2013
2014
2015
2016
2017
2018
Year



Trends of Diversion, Delays and Cancellations in Aircraft Operations
The annual and monthly number of flights disruptions in the study area within the period from 2010 – 2018 are presented in Figs 4.9 – 4.14. The monthly trends of Aviation operations showed that disruptions were more frequent in the dry season, November to February. Diversions, delays and cancellation recorded their peak values in December while the lowest values occurred between April and May.

The annual trends of aviation operations showed great fluctuations in the number of diversions, delays and cancellations but did not show any consistent pattern in the variations from year to year. From the results, 2014 recorded the highest number of diversions with 91 total diversions; 2015 recorded the highest number of delayed flights with 126 total delayed flights while the maximum number of cancellations was recorded in 2017 with a total number of 168.

DISCUSSION

Meteorological Parameters at Port Harcourt International Airport
The results from the study revealed that Port Harcourt International Airport experiences very high amount of rainfall every year. It was observed that 2011 recorded the least amount of rainfall with about 1760mm of rain throughout the year while 2017 recorded the highest amount of rain with 2470mm of rainfall (Fig. 4.1). Typically, the months of June to September received the highest amounts of rainfall while November to February received the least (Fig 4.2). The Port Harcourt Internal Airport features a tropical monsoon climate with lengthy and heavy rainy seasons and very short dry seasons (Enete *et.al.*, 2015).

Thunderstorm, which is associated with rainfall is mostly common in the months of June and July and are very rare in January and December. It was observed that 2018 recorded the highest number of thunderstorm events (143 and 142 respectively) while 2017 recorded the least number (67) of thunderstorm events.

The trend for annual and monthly windspeed shown in Figs 4.5 and 4.6 respectively revealed little variation in the value of windspeed from year to year and from one month to another. However, 2010 recorded the highest average windspeed levels of 3.42 m/s while 2013 and 2018 recorded the lowest values of 2.38m/s. Within the year February and August recorded the highest average level (2.9 m/s) while November recorded the lowest level (2.0 m/s) of windspeed.

The windroses in Figs 4.5a – i revealed that in 2010 about 66% of the wind was in the SSW direction and of speed 2.5 to 4 m/s; about 25% of the wind was in the S direction with speed of 2.5 to 4m/s; about 6% was in the SSE direction and of speed 2.5 – 4 m/s; about 8% was in the SSW direction and of speed 1.5 to 2 m/s.

In 2011 about 58% of the wind was in the SSW direction and of speed 2.5 to 4 m/s; about 33% of the wind was in the SSW direction with speed of 2 to 2.5m/s; about 25% was in the SSE direction and of speed 2.5 – 4 m/s; about 8% was in the SSE direction and of speed 2 to 2.5 m/s.

In 2012 about 50% of the wind was in the S direction and of speed 2.5 to 4 m/s; about 33% of the wind was in the S direction with speed of 2 to 2.5m/s; about 18% was in the SSW direction and of speed 2.5 – 4 m/s; about 18% of the wind was in the SW direction and of speed 2 to 2.5 m/s; about 9% was in the SSE direction and of speed 1.5 to 2 m/s.

In 2013 about 25% of the wind was in the SSW direction and of speed 2.5 to 4 m/s; about 25% of the wind was in the SSW direction with speed of 2 to 2.5m/s; about 25% was in the S direction and of speed 2 – 2.5 m/s; about 12% of the wind was in the SSE direction and of speed 2.5 to 4 m/s; about 12% was in the SE direction and of speed 2 to 2.5 m/s; about 8% of the wind was in the ESE direction and of 1.5 to 2 m/s.

In 2014 about 33% of the wind was in the SSW direction and of speed 2.5 to 4 m/s; about 25% of the wind was in the SSW direction with speed of 2 to 2.5m/s; about 25% was in the SW direction and of speed 2.5 to 4 m/s; about 17% of the wind was in the S direction and of speed 2.5 to 4 m/s; about 7% was in the S direction and of speed 2 to 2.5 m/s; about 8% of the wind was in the E direction and of 1.5 to 2 m/s.

In 2015 about 33% of the wind was in the SW direction and of speed 2.5 to 4 m/s; about 17% of the wind was in the SW direction with speed of 2 to 2.5m/s; about 8% of the wind was in the WSW direction and of speed 2.5 to 4 m/s; about 16% of the wind was in the S direction and of speed 2.5 to 4 m/s; about 8% of the wind was in the SE direction and of speed 2 to 2.5 m/s; about 8% of the wind was in the SSE direction and of 2.5 to 4 m/s.

In 2016 about 41% of the wind was in the SSW direction and of speed 2.5 to 4 m/s; about 17% of the wind was in the SSW direction and of speed of 2 to 2.5m/s; about 41% of the wind was in the SW direction and of speed 2.5 to 4 m/s; about 17% of the wind was in the SW direction and of speed 2 to 2.5 m/s; about 16% of the wind was in the WSW direction and of speed 2.5 to 4 m/s; about 8% of the wind was in the WSW direction and of 2 to 2.5 m/s.

In 2017 about 50% of the wind was in the S direction and of speed 2.5 to 4 m/s; about 42% of the wind was in the S direction and of speed of 2 to 2.5m/s; about 25% of the wind was in the SW direction and of speed 2.5 to 4 m/s; about 17% of the wind was in the SSW direction and of speed 2 to 2.5 m/s; about 8% of the wind was in the SSW direction and of speed 2 to 2.5 m/s; about 8% of the wind was in the ESE direction and of 2 to 2.5 m/s.

In 2018 about 50% of the wind was in the SSW direction and of speed 2.5 to 4 m/s; about 41% of the wind was in the S direction and of speed of 2.5 to 4m/s; about 34% of the wind was in the SW direction and of speed 2.5 to 4 m/s; about 34% of the wind was in the S direction and of speed 2 to 2.5 m/s; about 8% of the wind was in the SSW direction and of speed 2 to 2.5 m/s; about 8% of the wind was in the SSE direction and of 1.5 to 2 m/s.

The annual amount of fog in the atmosphere around Port Harcourt International Airport recorded high fluctuations between 2010 and 2012 (Fig 4.7). The highest amount was recorded in 2011 with an average fog density of 5.17 mg/m^3 fog. The lowest average value of fog density in the period under review was 2.25 mg/m^3 and then increased to an average of 4.33 mg/m^3 in 2013. Fog density around Port Harcourt International Airport remained fairly constant over the next 5 years and increased slightly to an average of 4.58 mg/m^3 in 2018. Fog degrades visibility to an extent that landing an aircraft may be impossible (WMO, 2007). Fog density at the Port Harcourt International Airport attained its highest monthly average value of 9.19 mg/m^3 in December as shown in Fig 4.8. Generally, the dry season months were observed to record higher amounts of Fog. However, the month of July, with intense rains, also recorded high amounts of fog.

The highest measured average pressure level was 78.34 mmHg in 2012 while 2010 recorded the lowest average air pressure of 77.14 mmHg. The monthly trend observed revealed that April has the lowest atmospheric pressure of 75.26 mmHg while January has the highest of 79.48 mmHg.

The average maximum temperature ranged from 31.33 ^{0}C in 2013 to 32.07 ^{0}C in 2014. The average annual minimum temperature ranged from 22.56 ^{0}C in 2015 to 23.51 ^{0}C in 2010. The average maximum temperature ranged from 29.01 ^{0}C in July to 34.16 ^{0}C in February. The average monthly minimum temperature ranged from 21.24 0C in January to 23.69 ^{0}C in March.

Flight Diversion and Weather Parameters

Fig 4.9 revealed the annual trend of flight diversion for a period of 9 years at the Port Harcourt International Airport. Flight diversions varied from 56 in 2017 to 91 in 2014. The inter-annual model was in the positive direction suggesting an increase in the number of diverted flights between 2010 and 2018. The strength of the trend line is indicated as R^2 (0.1109) showing that only 11% of the variations observed are explained by the model.

Similarly, monthly trend of flight diversions showed a positive trend line indicating an increase in the number of flight diversions between January to December (Fig. 4.10). However, the R^2 (0.0439) shows that monthly variations can be used to predict only 4.4% of the fluctuations in flight diversions. The result also reveals that flight diversions are higher at the beginning and at the end of the year (from January to February, and from November to December). The peak period of diversion of flights are all in the dry season and may be so due to poor visibility during the dry season (Ike, 2019).

A correlation of flight diversion and weather predictors shows that Fog (r = 0.648), Pressure (r = 0.676) and Maximum temperature (r = 0.435) have positive correlations with flight diversion while Rainfall (r = -0.565), Thunderstorm (-0.656) and Wind Speed (r = -0.313) all correlated negatively with flight diversion (Table 4.1). The correlation of weather variables with flight diversion were significant ($p<0.05$) except Wind Speed which was not significant ($p>0.05$). The importance of this analysis is that at peak amounts of Rainfall, Thunderstorm and Wind Speed, flight diversions declines while an increase in the amount of Fog and Pressure lead to an increase in flight diversions. This is in tandem with the findings of Ayoade (2004) who revealed that the single most important weather hazard to all forms of transportation, especially air transportation is poor visibility often caused by Fog. The findings of this study also agree with Weli and Ifediba (2014) who observed that thunderstorm correlated negatively while fog correlated positively with flight diversions in Air transport in Nigeria.

Weather parameters can be used to predict flight diversions. Rainfall provides 32% explanation for the variation of flight diversion at Port Harcourt international airport (Fig 4.19). Thunderstorm provides 43% explanation for the variation of flight diversion at Port Harcourt international airport (Fig 4.20). Wind Speed provides 10% explanation for the variation of flight diversion at Port Harcourt International airport (Fig 4.21). Fog provides 42% explanation for the variation of flight diversion at Port Harcourt International airport (Fig 4.22). Pressure provides 46% explanation for the variation of flight diversion at Port Harcourt International airport (Fig 4.23).

The multiple regression analysis of flight diversion and weather parameters (Table 4.4) revealed that the predicting variables (Rainfall, Thunderstorm, Wind Speed and Fog) explain 41% (adjusted R^2) of the variations in flight diversion at the Port Harcourt International Airport using the model below:

$$\mathbf{FDV = 64.8 + 0.41Rf - 0.85Th - 0.07WS + 0.42F + 70.04}$$

(FDV = Flight Diversion, Rf = Rainfall, Th = Thunderstorm, WS = Wind Speed and F = Fog).

The result is however not significant ($p>0.5$), therefore this model fall below the 95% confidence limit in predicting changes in flight diversions.

Flight Delays and Weather Parameters

Figure 4.11 revealed the annual trend of flight delays for a period of 9 years at the Port Harcourt International Airport. Flight delays varied from 68 in 2010 and 2012 to 126 in 2015. The inter-annual model shows a positive direction for flight delays indicating an increase in delays from 2010 to 2018. The strength of the trend line is indicated as R^2 (0.1031) indicating that the annual trend has 10% predictability of flight delays.

Monthly trend of flight delays also showed a positive trend line indicating an increase in the number of flight delays (Fig. 4.12). However, monthly variations can be used to predict only 6.7% of the fluctuations observed in flight delays with an R^2 value of 0.0666.

The result revealed that flight delays peaked in January and December, and were least in April. This may be influenced by higher volume of flights during peak periods as well as the prevailing weather conditions. According to the travel agency, Wakanow, peak periods for air travel in Port Harcourt International Airport are in December and January.

A correlation of flight delays and weather predictors showed that Fog (r = 0.574) and Pressure (r = 0.683) have positive correlations with flight delay and is significant at ($p<0.05$). Rainfall (r = -0.161), Thunderstorm (-0.141) and Wind Speed (r = -0.323) all correlated negatively with flight delay and were not significant ($p>0.05$) (Table 4.2). This means that there is a statistically significant relationship between flight delay and Fog occurrence and Pressure for flights emanating from the Port Harcourt international Airport. An increase in the amount of Fog and Pressure lead to an increase in flight delays. The result of this study is at variance with the findings of Weli & Emenike (2016) whose analysis of turbulent weather events and aircraft operations at the Port Harcourt International Airport (2000 – 2012) observed that Thunderstorm and Rainfall have a statistically significant relationship with flight delay while Fog does not.

Scatter diagrams shown in figs 4.26 to 4.32 explain the relationship of each of the weather parameters with flight delays. R^2 values of 0.026, 0.0199, 0.1044, 0.3297, 0.4661, 0.0021 and 0.6959 for Rainfall, Thunderstorm, Wind Speed, Fog, Pressure, Max Temperature and Min Temperature respectively show the degree to which these parameters can be used to predict flight delays. 2.60% of the variations in flight delay are explained by the amount of Rainfall, 1.99% is explained by Thunderstorm, 10.44% by Wind Speed, 32.97% by Fog Occurrence, 46.61% by Pressure, 0.21% by Max Temperature and 69.59% is explained by Min Temperature.

The multiple regression analysis of flight delays and weather parameters (table 4.4) revealed that the predicting variables (Rainfall, Thunderstorm, Wind Speed and Fog) explain 0.5% (adjusted R^2) of the variations in flight delays using the model below:

$$\mathbf{FDL = 24.86 - 0.085Rf + 0.26Th + 0.21WS + 0.79F + 134.32}$$

(FDL = Flight Delay, Rf = Rainfall, Th = Thunderstorm, WS = Wind Speed and F = Fog).
The result is however not significant ($p>0.5$), therefore this model falls below the 95% confidence limit in predicting changes in flight delays.

Flight Cancellation and Weather Parameters

In Fig. 4.17 flight cancellations between 2010 and 2018 showed a wide range of fluctuation. The trend line shows a positive direction for flight cancellation indicating an increase in over the period. The year 2017 recorded the highest number of cancellations with 168, while 2010 recorded the least number with 34 cancellations. The Port Harcourt International Airport saw a drastic rise in flight cancellations in 2012 with 128 cancellations and a drop between 2013 and 2015 before it started rising again in 2016. The R^2 value of 0.4018 indicates the strength of the annual cancellation trend line and it can predict 40.2% of the observed variations.

Similarly, the monthly trend of flight cancellations shows a positive trend line indicating an increase towards the end of the year (Fig. 4.18). However, the R^2 value of 0.206 indicate that the monthly trend line can be used to predict only 20.6% of the fluctuations in flight cancellations. The result also reveals that flight cancellations are higher at the beginning and at the end of the year (from January to February, and from November to December). The peak periods of cancellations are all in the dry season and may be so due to higher flight volumes and poorer visibility during the dry season (Ike, 2019). May, April, June and July in that order saw the least number of cancellations at the Port Harcourt International Airport and this may be due to the weather being favourable to aviation operations within this time of the year.

A correlation of flight cancellations and weather predictors showed that Fog (r = 0.885) and Pressure (r = 0.590) have positive correlations with flight cancellations and is significant at ($p<0.05$). Max temperature correlated positively with flight cancellations (r = 0.469) but is however not significant ($p > 0.05$). Rainfall (r = -0.657), Thunderstorm (-0.717), Wind Speed (r = -0.505) and Min Temperature (-0.568) all correlated negatively with flight cancellations and were significant ($p<0.05$) (table 4.3). This means that there is a statistically significant relationship between flight cancellation and all the weather parameters except Max Temperature, for flights emanating from the Port Harcourt International Airport. Furthermore, an increase in the amount of Fog, Pressure and Min Temperature leads to an increase in flight cancellation, while increase in the amounts of Rainfall, Thunderstorm, Wind Speed and Min Temperature leads to a decrease in flight cancellations. The result of this study is at variance with the findings of Weli & Emenike (2016) whose analysis of turbulent weather events and aircraft operations at the Port Harcourt International Airport (2000 – 2012) observed that Thunderstorm and Rainfall have a statistically significant relationship with flight cancellation while Fog does not.

Scatter diagrams shown in figs 4.23 to 4.26 explains the relationship of each of the weather parameters with flight cancellation. R^2 values of 0.4318, 0.5134, 0.2549, 0.7841, 0.3486, 0.2198 and 0.3221 for Rainfall, Thunderstorm, Wind Speed, Fog, Pressure, Max Temperature and Min Temperature respectively show the degree to which these parameters can be used to predict flight cancellation. 43.2% of the variations in flight delay are explained by the amount of Rainfall, 51.3% is explained by Thunderstorm, 25.5% by Wind Speed, 78.4% by Fog Occurrence, 34.86% by Pressure, 21.98% by Max Temperature and 32.21% by Min Temperature.

The multiple regression analysis of flight cancellation and weather parameters (table 4.8) reveal that the predicting variables (Rainfall, Thunderstorm, Wind Speed and Fog) explain 91% (adjusted R^2) of the variations in flight cancellations. The model below:

$$\mathbf{FCC = 84.54 + 0.28Rf - 0.70Th - 0.10WS + 0.65F + 41.83}$$

(FCC = Flight Cancellation, Rf = Rainfall, Th = Thunderstorm, WS = Wind Speed and F = Fog).
can be used to predict flight cancellations given other parameters. The result is significant at $p<0.05$, therefore granting at least a 95% confidence level in the prediction of aviation operations as regards number of flight cancellations at the Port Harcourt International Airport.

Conclusion

This study has shown that aviation operations in Port Harcourt International Airport faces more flight disruptions in the dry season from November to February. Also, the study revealed a statistically significant relationship between flight diversion and fog, pressure, rainfall and thunderstorm at the Port Harcourt International Airport. The study also revealed a statistically significant relationship between flight delays with Fog and Pressure. Finally, the study revealed that flight cancellations at the Port Harcourt International Airport have a statistically significant relationship with Fog, Pressure, Thunderstorm, Wind speed and Min Temperature.

REFERENCES

Abubakar, S. and Nurudeen, N.A (2011). Nigeria Bad Weather Causes Flight Delays, Cancellation. Retrieved from daily Trust, the online edition January,2011 from allafrica.com.

Aderamo, A.J., (2006). Changing pattern of Air Traffic in Nigeria. Nigerian Journal of Management and Social Sciences,3 (1): 77-89.

Aderinto, S. and Dahunsi, I. (2008). The New Automated Meteorological Observation at Four Airoirts in Nigeria. Abuja. Retrieved September 13,2009.

Ayibe, F. (2006, October 20). Federal Government Releases Sosoliso Plane crash Report. *New Nigerian Newspaper.*

Ayoade, J.O. (2004a). Climate change: A synopsis of its nature, causes, effects and management. Ibadan: Vantage Publishers.

Ayoade, J.F. (2004). *Introduction to climatology for the tropics.* Ibadan: Spectrum Books Ltd.

Enete, I.C., Ajator, U. and Nwoko, K.C., (2015). Impacts of Thunderstorm on Flight Operations in Port-Harcourt International Airport Omagwa, River State, Nigeria. *International Journal of Weather*, *Climate Change and Conservation Research 1(1): 1 – 10.*

Harding, K. (2011). *Thunderstorm Formation and Aviation Hazards.* NOAA'S National Weather.

Ike, O (2019). The effect of some weather parameters on flight operations. Afribary.com: Retrieved September 29, 2020, from https://afribary.com/works/the-effect-of-some-weather-parameters-on-flight-operations.

Klein, A., Kavoussi, S and Lee, R.S., (2009). *Weather forecast accuracy; study of impact on airport capacity and estimation of avoidable costs*, Paper presented to the eighth USA/Europe Air Traffic Management Research and Development Seminar.

National Bureau of Statistics (2014). Nigeria Aviator Sector, Summary report of passenger traffic; 2010-2013 and Q1,2014.

Nigerian Meterological Agency (2011). Nigeria Climate Review Bulletin 2010. Abuja, pp. 29-31.

Oyegun and Ologunorisa (2002). Weather and climate. In Oyegun, C.U. and Adeyemo, A.A. (eds) Port Harcourt region. Paragrphics.

Sasse, M. and Hauf, T., (2003). A study of thunderstorm-induced delays at Frankfurt Airport, Germany, *Meterological Applications*, 10(1):21-30.

Weli, V.E. and Ifediba, U.E. (2014). Poor weather conditions ad Flight Operations: Implications for Air Transport Hazard Management in Nigeria. *Ethiopian Journal of Environmental Studies and Management* 7(3):235-243.

ISSN 2229-5518

Weli, V.E., and Emenike, G.C. (2016). Thunderstorm weather events and Aircraft Operations: Implications for Aviation Safety at the Port Harcourt International Airport, Nigeria. *international Journal of Weather, Climate Change and Conservation Research*, 2, 11-21.

WMO, (World Meteorological Organization), (2007). Aviation Hazards: Education and Training Programme, ETR-20. Secretariat of the World Meteorological Organization, Geneva, Switzerland. WMO/TD-No. 1390.