***Original Research Article***

# SEASONAL EFFECTS OF WEATHER ELEMENTS ON FLIGHT OPERATIONS AT NNAMDI AZIKIWE INTERNATIONAL AIRPORT ABUJA, NIGERIA


## *Abstract*

*The purpose of the study was to assess the significance of weather conditions in aviation transport in Nnamdi Azikiwe International Airport, Abuja. Records on visibility, rainfall, cloud cover; wind speed and two aspects of flight operations (flight delay and cancellation) for a period of 15 years (2000-2014) were collected from secondary source. Spearman rank correlation coefficient, coefficient of determination, t-test and multiple correlations were used to ascertain relationships between weather elements and flight operations (flight delay and cancellation). Findings in this study shows that wind speed had no effect on flight delay between 2000 and 2014 since the calculated value 1.63 was less than the tabular value 1.77. The major weather elements that influenced flight operation were cloud cover (calculated value 3.09 as against the tabular value 1.77 and monthly rainfall 3.80 as against the tabular value 1.77) respectively. Trend in visibility from 2000 to 2014 shows an upward trend of visibility which is in favour of air transportation. Individual weather elements (visibility, rainfall, cloud cover and wind speed) on their own do not have significant effects on flight operations between 2000 and 2014, however when they are combined, these weather elements affect aviation transportation tremendously. Hence there is need for the installation of reliable and well equipped weather station with precise prediction of weather elements not only in airports, but also in strategic locations across the country to enable the spatial analysis of weather records across air routes.*



Keywords: seasonal, weather and flight operations.


## Background to study

Aviation transport worldwide is greatly affected by weather. From thunderstorm to wind, fog, rainfall and wind speed every phase of flight has the potential to be impacted by weather. Kulesa, (2000) stated that weather is responsible for 70% of all delays while also being an important contributing factor in 23% all aviation accident. Mizra et. al., (2009) in their work discovered that weather phenomenon that may affect one flight might have no relevance to a flight that follows by ten minutes later, but may affect a different flight which it may encounter in the same period.

According to statistics of Aviation Safety Network (ASN) 2006 of United States in Wen-Lin Guan (n.d) from 1950 to 2000, there were 40 aviation accidents caused by turbulence or cross wind and 39 accidents caused by wind shear or down draft. The statistics also shows that from 1990 to 2000, two fatal accident was as a result of wind shear, with over 90 fatalities, while three major accidents was caused by turbulence and cross wind with over 50 fatalities. A study by Eads *et.al*., (2002) shows that poor visibility in the summer months and rain storm in winter months lead to substantial delays and a lot of cancellation.

Ranter, (2003) opined that Africa was the most unsafe continent. In 2002, Africa accounted for 27% of fatal airline accident while she is only responsible for 3% of all world aircraft departures. In the research all regions including Europe, North America, South America and Central America recorded a steadily accident rate in a moving ten years average trend over the past 11 years(1992-2002) except Africa.

Quantitative studies of the impact of weather on efficiency are however still limited to case studies and are confined to either certain aspects of the problem or to specific countries, Theusner and Röhner, (2006). Most of these studies are accomplished in the U.S., but in the past 5 years some case studies have also been done within Europe. Theusner and Röhner, (2006) investigated aviation weather hazards, aviation weather impact areas and evaluation methods in the framework of the European Integrated Project FLYSAFE. Most findings collected here are based on their report. Critical weather phenomena having an impact on efficiency and safety of air traffic are:

I. Thunderstorms and lightning

II. Low visibility, associated with cloud, mist, fog, snow or sand storms

III. In-flight icing, ground icing

IV. Wind, gusts and wind shear

V. Heavy precipitation including snow and ice as well as surface contamination (standing water, ice, or snow on take-off, landing and maneuver surfaces)

VI. Turbulence (in clouds or clear air)

VII. Volcanic ash

VIII. Sandstorms

IX. Aircraft wake vortices.

Hauf, (2002) explains that the main reasons for this are the methodological problems. These are, as he explains, related mainly to the multiple causes of the delays and difficulty in attributing them to a single cause, and that the relative weight of one factor with respect to others is difficult or impossible to assess. Another problem he points out is that information about delays and their causes is only partially determined and often lost. The methods to assess the weather impact on aviation include Theusner and Röhner, (2006).

The analysis of weather-related accidents and incidents, with respect to:

I. Type and strength of weather hazard

II. Geographical and seasonal distribution

III. Type of aircraft affected

IV. Typical conditions of occurrence.

V. A climatology of weather hazards as part of a risk analysis, with the latter defined by:

VI. Observed occurrence, e.g. of CB

VII. Necessary and sufficient conditions for the existence of the hazard, or

VIII. By issued warnings.

Two different procedures are in use for reporting visibility and these vary from one country to another:

I. Minimum visibility (This is the lowest visibility measured in any direction).

II. Prevailing visibility (This is the visibility that prevails over at least half of the horizon.)

Aviation personnel are concerned with the range at which they can see specified objects. It depends not only on the transparency of the atmosphere, but also on factors as the nature of the object and its background, the size of the object and the illumination. Outside of clouds, fog and precipitation, it is normally good except in dust, smoke or haze. It may vary with altitude (in horizontal direction) due to the unequal distribution of obscuring particles. Normal meteorological measurements are made horizontally at the ground level. They give little information about the visibility from points above the ground. On approach and landing the slant visibility is required, seen from aircraft down to the ground. The air-to-ground visibility may be much greater than the horizontal visibility at ground level, if a swallow layer of fog or haze is present.

Weather phenomena are tied to two seasons in Nigeria. During the rainy seasons there are delays and diversions of flight as a result of thunderstorm occurrences and in the dry season there is the dust haze that reduces visibility. During the period of poor visibility, flights can be diverted to alternate aerodromes after finding it difficult to land at their destination due to poor weather conditions. All these are a great risk to passengers and increased cost of flight operations as it has been experienced at the Nnamdi Azikiwe International Airport, Abuja. This study therefore is an attempt to fill the gap in knowledge by examining the importance of weather conditions in aviation transport between 2000 to 2014 at Nnamdi Azikiwe International Airport, Abuja. This study will show the proximate effect between weather element and aviation transport.

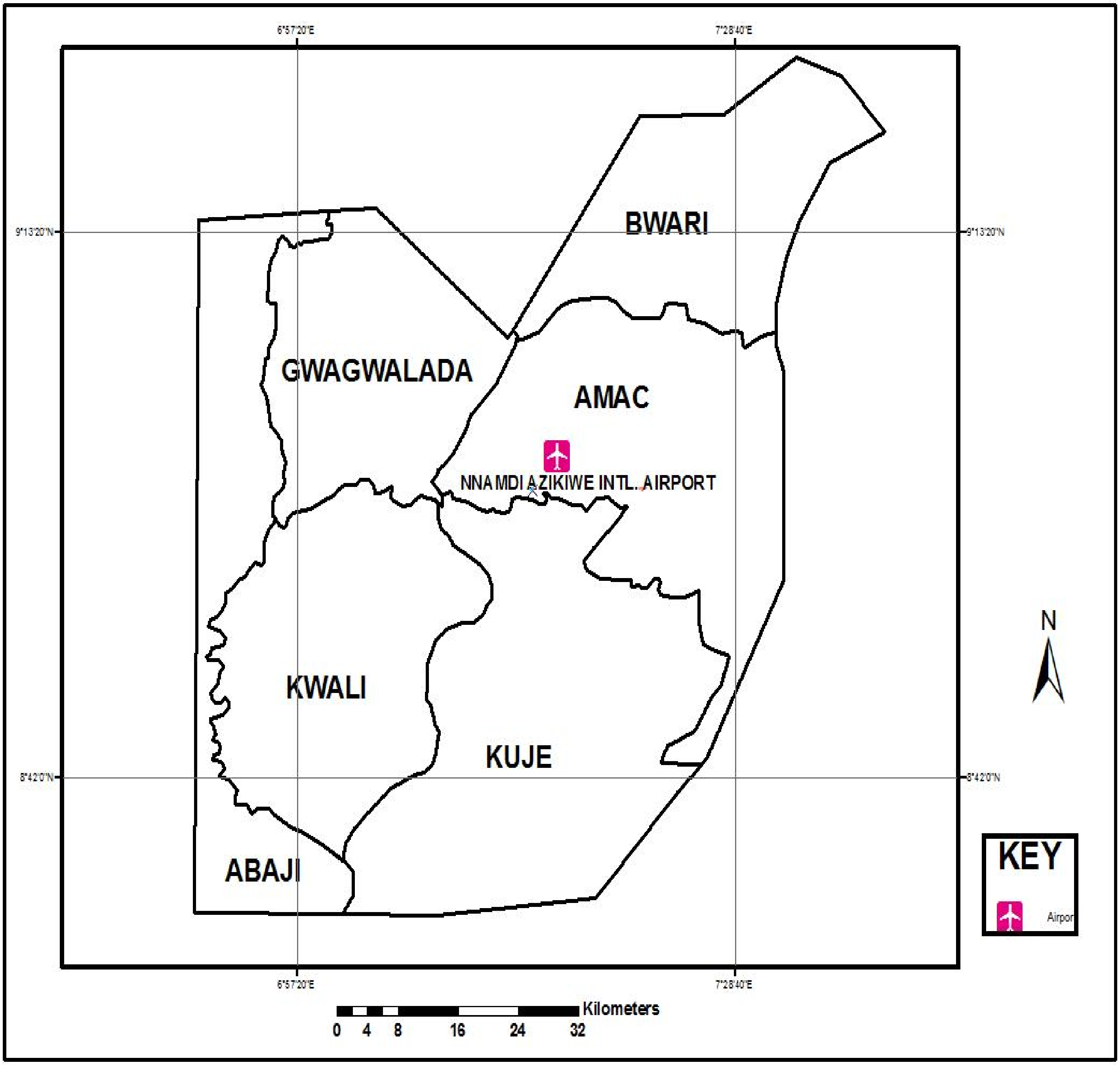
**Study Area**

Nnamdi Azikiwe International Airport is located in the Federal Capital Territory (FCT) Abuja. It is about 45km south of the city. The airport has both international wing which serve domestic and international flights and the private wing that is used for charter flights. The elevation of the airport is 1,123ft/342m above mean sea level. It has two runway directions namely 04/22 and the length is 3600m/11,842ft (Nigerian Aeronautical Information Publication (NAIP) 2013). The types of traffic permitted are instrument flight rules (IFR) and visual flight rules (VFR), (NAIP 2013).

The Nnamdi Azikiwe International Airport is located directly North-west of the Abuja city. This area lies on longitude 09°15′21E and latitude 9° 00′ 35N″ (See Fig 1.1) at an altitude of 314.98m (NAIP 2013). Nnamdi Azikiwe International Airport (**IATA**: ABV, **ICAO:** DNAA) is the main airport serving the Nigerian capital city. It was named after Nigeria's first President, Dr Nnamdi Azikiwe. It consists of an international and a domestic terminal. Both terminals share the same runway. The Airport is coded ABV by the International Air Transport Association (IATA) and DNAA by the International Civil Aviation Organization (ICAO), meaning an IATA location identifier and ICAO location indicator around the world. The IATA codes are used by the general public for airline timetables, reservations, and baggage handling (the characters prominently displayed on baggage tags attached at airport check-in desks are an example of a way these codes are used), while the ICOA codes are used by air traffic control and airline operations such as flight planning.

Abuja International Airport provides excellent flight services both to domestic and International destinations in Nigeria and elsewhere. It is a public airport operated by the

Federal Airports Authority of Nigeria.




**Source: Federal Capital Development Authority (FCDA) 2017**

**Climate of the Study Area**

The climate is generally tropical (Abomeh, 2013). It is such that its major elements have regimes that are transitional from those of the southern and northern parts of the country. Thus relative humidity is not as high as the southern part and temperatures are not as high as in the far north either Balogun (2001). In order to give full description of the climate of the FCT, its major elements such as rainfall, temperature, sunshine, wind and relative humidity will be discussed.

The onset of the rains is about the middle of March. The end of the rainy season on the other hand, is around the middle of October in the north, whereas it is about early November in the south. Consequently, the duration of the rainy season varies from about 240 days, in the south to about 190 days, in the north. The mean annual rainfall total ranges from 1,145mm to 1,631.7mm (Ujoh *et. al.,* 2010). This reflects a situation that results from the FCT's location on the windward side of the Jos plateau. This gives rise to frequent rainfalls and a noticeable increase in the mean annual total from the south to the north (Balogun, 2001).

The beginning and the end of the rainy season is characterized by frequent occurrences of squall lines. This is a weather condition that is heralded by the occurrence of cumulus-nimbus clouds. It is accompanied by lightning and thunder, followed by strong winds and rainfall of high intensity. This rainfall type may last for up to thirty minutes, and it is then followed by drizzle that may last for several hours. This weather condition is subsequently replaced by a few days of bright clear skies. Squall lines are associated with high convective activity that is often aided by relief effects. It is believed to originate from the Jos Plateau region, and moves in an east-west direction within the FCT. Squall lines often cause serious damage to buildings through the ripping-off of roofs (Balogun, 2001).

The F.C.T records its highest temperatures and greatest diurnal ranges during the dry season months, when the maximum temperature ranges between $30.40^0$C and $35.1^0$C. During the rainy season on the other hand, the maximum temperature ranges between $25.8^0$C and $30.2^0$C. Also, the diurnal range is much reduced. Two main factors strongly influence temperature patterns in the FCT. These are cloud cover and elevation. The cloud cover is much less during the dry season, hence the high temperatures at this time of the year. As a result of differences in elevation between the north and the south, the latter has higher temperatures throughout the year than the former. Furthermore, the southern and western areas are part of the Niger-Benue, through which there is a heat trap. These therefore accounts for the relatively higher temperatures in this part of the FCT (Ujoh *et. al.,* 2010).

As a result of the climate being the tropical type, the sunshine duration ranges between eight to ten hours a day in the northern parts during the dry season. However, the marked increase in cloud cover during the months of July, August and September, makes the hours of sunshine per day, drop sharply to a mean of about four hours (Ujoh *et. al.,* 2010).

The climate if FCT is largely governed by the Inter-Tropical Convergence Zone (ITCZ). This zone of convergence is normally defined by both the moisture-laden south-west winds and the north-east dry, continental winds. Rain normally occurs south of ITCZ when the ITCZ passes northwards through the FCT between the middle of March and June, it heralds the beginning of the rainy season. On its return southwards about the middle of October, it heralds the onset of the dry season. Consequently, there is a distinct rainy season that starts in April and ends in October, and a dry, cold season that begins in November and ends in March (Ujoh *et. al.,* 2010).

Abuja is easily the best place on FCT to situate a business because of its strategic location and market structure. Abuja officially became Nigeria’s capital in December 1991, following relocation from the former capital Lagos. It is one of Africa's few purpose built cities (Jibril, 2006; Adama, 2007). The City was designed to serve as a model to other Nigerian cities in the way utilities and services are managed. It has been reported that the population in some areas in Abuja is growing by as much as 20-30% per annum Jibril (2006). The University teaching hospital (UATH) is one of the oldest hospitals in the FCT. Several airlines have their head offices in Abuja. The F.C.T airport performs four broad categories of operation, which includes: Commercial Operation, Passenger Operation, General aviation Operation and Cargo/Military Operation (Ujoh *et. al.,* 2010).

## METHODOLOGY

### Mode of Data Collection

The study adopted the retrospective survey design which will involve the use of historical/archival data of weather parameters and records of flight operations from Nnamdi Azikiwe International Airport, Abuja. Weather and flight cancellation data for 15 years will be collected from Nigeria Meteorological Agency (NIMET) and Nigerian Air Space Management Agency (NAMA) at the Abuja International Airport respectively. The weather parameters collected from Nigerian Metrological Agency (NIMET) includes:

i. Rainfall data from 2000 -2014 (15 years) for Nnamdi Azikiwe International Airport
ii. Records of low horizontal visibility from 2000-2014 (15 years) for Nnamdi Azikiwe International Airport.
iii. Records of wind speed (WNSPD) on runway 04/22 for Nnamdi Azikiwe International Airport.
iv. Records of cloud cover from 2000-2014 (15 years) for Nnamdi Azikiwe International Airport.

While The Airport Operational Data which include **flight delays**, **cancellations** and **diversions** will be collected from for the same period.

**Data Analysis**

Multi regression analysis was adopted for the analysis. This is because it gives a better relationship of causative factors.

$$R=\sqrt{\frac{r^2_{yx_1}+r^2_{yx_2}-2r_{yx_1}.r_{yx_2}.r_{x_1x_2}}{1-r^2_{x_1x_2}}}$$

Where:

$r_{yx1}$ = correlation coefficient for y and x1

$r_{yx2}$ = correlation coefficient for y and x2

$r_{x1x2}$ = correlation coefficient for x1 and x2.

These relationship analyses will assist in identifying the important weather conditions that affect aviation transport.

**RESULTS PRESENTATION AND DISCUSSION**

**Relationship between Flight Cancellation and Weather Elements**

Table 1 shows the relationship between the data set of flight cancellation and visibility, rainfall, cloud cover and wind speed as weather elements. The annual and monthly relationship between flight cancellation and weather elements within the space of (14years) is as shown in table 1.. The correlation analysis and test for significance were presented.

**Table 1: Relationship between Weather Elements and Flight Cancellation**

| Annual Relationship Between Weather Elements and Cancellation | | | | | | |
|---|---|---|---|---|---|---|
| | **Correlation Analysis** | | | **Test for significance** | | |
| | **Correlation coefficient** | **Coefficient of determination** | **Remark,** | **Calculated value** | **Tabular value** | **Remark** |
| Flight cancellation and visibility | -0.64 | 0.41 | Fairly strong negative relationship | 3 | 1.77 | Rejected |
| Flight cancellation and rainfall | 0.33 | 0.11 | Positively weak relationship | 1.27 | 1.77 | Accepted |
| Flight cancellation and cloud cover | 0.7 | 0.49 | Fairly strong positive relationship | 3.56 | 1.77 | Rejected |
| Flight cancellation and wind speed | -0.52 | 0.27 | Fairly strong negative relationship | 2.21 | 1.77 | Rejected |
| **Monthly Relationship Between Weather Elements and Cancellation** | | | | | | |
| Flight cancellation and visibility | 0.32 | 0.10 | Positively weak relationship | 1.06 | 1.81 | Accepted |
| Flight cancellation and rainfall | -0.84 | 0.71 | Fairly strong negative relationship | 4.91 | 1.81 | Rejected |
| Flight cancellation and cloud cover | -0.25 | 0.06 | Negatively weak relationship | 0.81 | 1.81 | Accepted |
| Flight cancellation and wind speed | 0.04 | 0.00 | No relationship | 0.13 | 1.18 | Accepted |

**Source: Data Analysis (2017)**

The annual correlation analysis as presented shows that flight cancellation and visibility has a correlation coefficient of -0.64, with 0.41 coefficient of determination. This indicates that there is a fairly strong negative relationship between flight cancellation and visibility. The estimated coefficient of determination (0.41 or 41%) indicates that 59% of the variations in flight cancellation as correlated with visibility are determined by other related factors. The test for significance indicates that the postulated null hypothesis is rejected since the calculated value (3) is greater than the tabular value (1.77). This further indicates that at

0.05%, the correlation coefficient is significant. This confirm the study by Ayoade (2004) who revealed that poor visibility is the single most important weather hazard to all forms of transportation especially air transportation. Poor visibility can be caused by thick fog, snow, rain, dust haze, mist, smoke, low ceilings and smog among others.

The monthly flight cancellation and visibility correlation coefficient stood at 0.32, with a coefficient of determination at 0.10. This indicates a positively weak relationship. The coefficient of determination (0.10 or 10%) indicates that the undetermined proportions of variation (90%) are due to other factors. The significant test shows that at 0.05%, the correlation coefficient is not significant since the calculated value (1.06) is less than the table value (1.81). This find relevance in the work of Musa (2014) who reported that there is a relationship between weather parameter and flight operations but that the relationship was insignificant due to weather modification.

The correlation coefficient between annual flight cancellation and rainfall stood at 0.33, with 0.11 coefficient of determination. This implies a positively weak relationship between flight cancellation and rainfall amount. The coefficient of determination (0.11 or 11%) implies that 89% of the variations in flight cancellation as correlated with rainfall amount are determined by other unforeseen factors. The test for significance shows that at 0.05%, the correlation coefficient is not significant since the calculated value (1.27) is less than the table value (1.77). Furthermore, the monthly flight cancellation and rainfall analysis shows that the correlation coefficient of both variables stood at –0.84, with a coefficient of determination of 0.71. This indicates a fairly strong negative relationship between rainfall effects and flight cancellation. The coefficient of determination (0.71 or 71%) indicates that the undetermined proportions of variation (29%) are due to other related factors. The significance test shows that at 0.05%, the correlation coefficient is significant as proved by the calculated value (4.91) as against the tabular value (1.81). Enete, *et. al.,* (2015) revealed that rainfall accounted for 32% of flight cancellation with 218 occurrences from 2008-2013 in Port-Harcourt. Rainfall has a greater influence on the number of flight cancellations and delays than on diversions with the correlations.

Results of the annual flight cancellation records and cloud cover within the study period shows a correlation coefficient of 0.7, with a coefficient of determination of 0.49. This implies a fairly strong positive relationship between both variables. The coefficient of determination (0.49 or 49%) indicates that 51% of the variations in flight cancellation as correlated with cloud cover are determined by other unforeseen related factors. The test for significance indicates that the postulated null hypothesis is rejected since the calculated value (3.56) is greater than the table value (1.77). This further indicates that at 0.05%, the correlation coefficient is significant. The monthly data set of flight cancellation and cloud cover has a correlation coefficient of -0.25 and a coefficient of determination of 0.06. This implies a negatively weak relationship. The coefficient of determination (0.06 or 6%) implies that 94% of the variation in the monthly flight cancellation and cloud cover relationship are due to other factors. The test for significance shows that at 0.05%, the correlation coefficient is not significant since the calculated value (0.81) is less than the table value (1.81). Obviously, cloud cover has negative impact on flight operations in Nnamdi Azikiwe International Airport. This is agreement with the findings of Christopher (2013) that opined a positive relationship between cloud cover and flight cancellation in Abuja and Kano International Airport between 1986 and 2005.

The annual flight cancellation and wind speed stood at -0.52 with a coefficient of determination of 0.27. This indicates a fairly strong negative relationship between flight cancellation and wind speed. The estimated coefficient of determination (0.27 or 27%) indicates that 73% of the variations in flight cancellation as correlated with wind speed are determined by other related factors. The test for significance indicates that the postulated null hypothesis is rejected since the calculated value (2.21) is greater than the table value (1.77). This further indicates that at 0.05%, the correlation coefficient is significant. In contrast, the monthly data set of flight cancellation and wind speed has a correlation coefficient of 0.04 and a coefficient of determination of 0.00. This indicates that there is no relationship between monthly flight records and wind speed. The coefficient of determination (0.00 or 0%) implies that 100% of the monthly flight cancellations are not due to wind speed. The test for significance shows that at 0.05%, the correlation coefficient is not significant since the calculated value (0.13) is less than the table value (1.81).This implies that the annual relationships of these weather elements have more effect on flight cancellation than the monthly relationships of these weather elements except in the case where the monthly rainfall has more effect on flight cancellation than the annual rainfall. From table 4.1 in the annual relationship of the weather element, cloud cover has the highest relationship with flight cancellation followed by visibility and wind speed while in the monthly relationship of weather elements rainfall has the highest relationship with flight cancellation. Enete *et. al.,* (2015) concur to the fact that wind speed is the least climatic element that affects air transportation in Nigeria.

**Flight Delay and Weather Elements**

The relationship between the data set of flight delay and visibility, rainfall, cloud cover and wind speed as weather elements are presented in table 3.

**Table 2: Relationship between Weather Elements and Flight Delay**

| Annual Relationship Between Weather Elements and Flight Delay | | | | | | |
|---|---|---|---|---|---|---|
| | **Correlation Analysis** | | | **Test for significance** | | |
| | **Correlation coefficient** | **Coefficient of determination** | **Remark** | **Calculated value** | **Tabular value** | **Remark** |
| Flight delay and visibility | -0.46 | 0.21 | negative weak relationship | 1.87 | 1.77 | Rejected |
| Flight delay and rainfall | 0.44 | 0.19 | Positively weak relationship | 1.77 | 1.77 | Accepted |
| Flight delay and cloud cover | 0.65 | 0.42 | Fairly strong positive relationship | 3.09 | 1.77 | Rejected |
| Flight delay and wind speed | -0.41 | 0.17 | negative weak relationship | 1.63 | 1.77 | Accepted |
| **Monthly Relationship Between Weather Elements and Flight Delay** | | | | | | |
| Flight delay and visibility | 0.27 | 0.07 | Positively weak relationship | 0.89 | 1.81 | Accepted |
| Flight delay and rainfall | -0.77 | 0.59 | Fairly weak negative relationship | 3.80 | 1.81 | Rejected |
| Flight delay and cloud cover | 0.24 | 0.06 | Positively weak relationship | 0.78 | 1.81 | Accepted |
| Flight delay and wind speed | -0.20 | 0.04 | Very weak negative relationship | 0.64 | 181 | Accepted |

**Source: Data Analysis (2017).**

The annual correlation analysis of flight delay and visibility shows a correlation coefficient of -0.46, and 0.21 coefficient of determination. This indicates a fairly weak negative relationship between flight delay and visibility. The estimated coefficient of determination (0.21 or 21%) indicates that 79% of the annual variation in flight delay as correlated with visibility is determined by other related factors. The test for significance shows that at 0.05%, the correlation coefficient is significant since the calculated value (1.87) is greater than the tabular value (1.77). The monthly flight delay and visibility correlation coefficient stood at

0.27, with a coefficient of determination at 0.07. This indicates a positively weak relationship. The coefficient of determination (0.07 or 7%) indicates that the undetermined proportion of variation (93%) is due to other factors. The significant test shows that at 0.05%, the correlation coefficient is not significant since the calculated value (0.89) is less than the tabular value (1.81).

The annual flight delay and rainfall correlation coefficient stood at 0.40, with 0.19 coefficient of determination. This implies a positively weak relationship between flight delay and rainfall amount. The coefficient of determination (0.19 or 19%) implies that 81% of the variation in annual flight delay as correlated with rainfall amount is determined by other unforeseen factors. The test for significance shows that at 0.05%, the correlation coefficient is not significant since the calculated value (1.77) is equal to and not more than the tabular value (1.77). The monthly data sets analysis between flight delay and rainfall analysis shows that the correlation coefficient of both variables stood at –0.77, with a coefficient of determination of 0.59. This indicates a fairly strong negative relationship between rainfall effects and flight delay. The coefficient of determination (0.59 or 59%) indicate that (41%) of the variation are undetermined and occurred due to other related factors. The significance test shows that at 0.05%, the correlation coefficient is significant as proved by the calculated value (3.80) as against the tabular value (1.81).

Results of the annual flight delay records and cloud cover within the study period shows a correlation coefficient of 0.65, with a coefficient of determination of 0.42. This implies a fairly strong positive relationship between both variables. The coefficient of determination (0.42 or 42%) indicates that 58% of the variation in flight delay as correlated with cloud cover is determined by other unforeseen related factors. The test for significance indicate that the correlation coefficient is significant at 0.05% level of confidence, as proved by the calculated value (3.09) as against the tabular value (1.77). The monthly data sets of flight delay and cloud cover has a correlation coefficient of 0.24 and a coefficient of determination of 0.06. This implies a positively weak relationship. The coefficient of determination (0.06 or 6%) implies that 94% of the variation in the monthly flight cancellation and cloud cover relationship are due to other factors. The test for significance shows that at 0.05%, the correlation coefficient is not significant since the calculated value (0.78) is less than the table value (1.81).

The annual flight delay and wind speed has a correlation coefficient of -0.41, with a coefficient of determination of 0.17. This indicates a weak negative relationship between both variables. The estimated coefficient of determination (0.17 or 17%) indicates that 83% of the variation in flight delay as correlated with wind speed is determined by other related factors. The test for significance indicates that the postulated null hypothesis is accepted since the calculated value (1.63) is less than the tabular value (1.77). This further indicates that at 0.05%, the correlation coefficient is not significant. Likewise, the monthly data sets of flight delay and wind speed has a correlation coefficient of 0.20 and a coefficient of determination of 0.04. This indicates a very weak negative relationship between monthly flight delay records and wind speed. The coefficient of determination (0.04 or 4%) implies that 96% of the monthly flight delay records are due to other related factors. The test for significance shows that at 0.05%, the correlation coefficient is not significant since the calculated value (0.64) is less than the table value (1.81). From Table 4.1 and 4.2, it is clear that there is a statistical relationship between weather parameters and flight operations (cancellation and delay). Annual visibility, cloud cover and wind speed had effect on cancellation. On the other hand, rainfall did not affect flight cancellation but monthly rainfall had effect on flight cancellation. Annual cloud cover shows a higher relationship with flight cancellation followed by visibility and the least is wind speed (Table 4.1). In the case of delay, annual visibility and cloud cover have a relationship with delay. Cloud cover had the highest impact on delay followed by visibility (table 4.2). This answers the second research question that seeks to know the relationship between weather and flight operations.

**Multiple Correlations of Flight Cancellation and Weather Elements**

Table 3 shows the influence of weather elements (visibility, rainfall, cloud cover and wind speed) on annual and monthly flight cancellation and flight delay had effect respectively.

**Table 3: Multiple Relationships between Weather Elements and Flight Records.**

| | | |
|---|---|---|
| **Multiple Relationship Between Visibility, Rainfall, Cloud Cover, wind speed and Flight Cancellation** | | |
| | Multiple Correlation | Coefficient of Multiple Determination |
| Annual Correlation | 0.94 | 0.88 |
| Monthly Correlation | 0.94 | 0.88 |
| **Multiple Relationship Between Visibility, Rainfall, Cloud Cover, wind speed and flight delay** | | |
| | Multiple Correlation | Coefficient of Multiple Determination |
| Annual Correlation | 0.93 | 0.86 |
| Monthly Correlation | 0.79 | 0.63 |

**Source: Data Analysis (2017).**

Multiple correlation analysis between the various weather elements and flight cancellation shows that both the annual and monthly flight cancellation records were influenced by weather variables. The coefficient of the multiple determinations (0.88) implies that 88% of flight cancellation is determined by the combined variation of the various weather elements (visibility, rainfall, cloud cover and wind speed). This finding is contrary to that of Christopher (2013) that the effects of weather parameters on flight operations are insignificant, hence not solely responsible for fight cancellation in Nigeria in recent years. In another vein, Enete, *et. al.,* (2015) revealed that rainfall accounted for 32% of flight cancellation with 218 occurrences, 0.2% of diversion with 291 occurrences and 24% of delays with 526 occurrences at the airport from 2008-2013 in Port-Harcourt. Rainfall has a greater influence on the number of flight cancellations and delays than on diversions with the correlations.

The Multiple correlation analysis of annual and monthly flight delay records and the various weather elements (rainfall, cloud cover, visibility and wind speed), showed a high degree of association. However their degree of relationship varies, as indicated by the coefficient of multiple determinations. The annual records have a multiple determination coefficient of 0.86 (86%). This indicates that 86% of the variations in annual flight delay are due to the combined variation of weather element (rainfall, cloud cover, visibility and wind speed). Likewise, the monthly correlation of flight delay and weather elements has a multiple determination coefficient of 0.63 (63%). This indicates that 63% of the variation in monthly flight delay is due to the combined variation of weather elements (rainfall, cloud cover, visibility and wind speed).

This implies that individual elements on their own do not significantly impact flight operations, however, the combined effects of these weather elements affects aviation transportation tremendously.

Emmanuel *et. al.,* (2013) were of the view that visibility, rainfall, cloud cover, wind speed have contributed to many flight delay and aircraft accidents in the world. Visibility, rainfall, cloud cover and wind speed all restrict visibility and can result to flight delay. Adverse weather conditions causing widespread low ceilings and visibilities can restrict flying operations for days.

This finding is not farfetched from the study of Allan *et. al.,* (2001) conducted of weather related flight delays at Newark International Airport, which is located in the heart of the congested northeast corridor of the United States. It is an airport with a significant number of delays occurrences. Allan *et. al.,* (2001) found out that 68% of the cumulative flights delays on days in this period averaging more than 15 minutes are caused by convective weather either within or at considerable distances from the New York terminal area.

## SUMMARY

Four weather elements namely visibility, rainfall, cloud cover and wind speed and records of flight operations (flight delay and cancellation) were collected from the Nigerian Airspace Management Agency and Nigerian Metrological Agency. In this study, the obtained weather element was correlated was correlated with the records of the flight operations. It was found out that weather elements have a great influence on air transportation especially when they are combined. However, the statistical analysis clearly shows that wind speed has no strong degree of association or influence on flight cancellation and flight delays. This indicates that wind speed has no negative effect on air transportation due to the general absence of strong gust and stormy weather e.g. line squall in the vicinity of the airport.

## RECOMMENDATION

1. Critical examination of weather parameters should be conducted on a regular basis.
2. Flight takeoff time should be better planned alongside with the prevailing weather condition in order to prevent not only delay and cancellation of flight, but also to minimize accident associated with air transport.
3. Reliable and well equipped weather station with precise prediction of weather elements should be established not only in airports, but also in strategic location across the country to enable the spatial analysis of weather records across air routes.
4. More accurate ways of weather information should be emphasized through the training and retraining of aviation personnel.
5. 

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