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 on aviation transport at 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. The Spearman rank correlation coefficient, coefficient of determination, t-test and multiple linear 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 since the calculated value 1.63 was less than the table value 1.77. The major weather elements that influenced flight operation were cloud cover. Individual weather elements on their own do not have effects on flight operations, however, when they are combined, affect aviation transportation tremendously.

Keywords: seasonal, weather elements, flight delay, flight cancellation, correlation.

Background to study

Aviation transport is greatly affected by weather. From thunderstorms 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 accidents. 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 ten minutes later, but may affect a different flight which it may encounter the weather phenomenon during the same period.

According to statistics of the Aviation Safety Network (ASN, 2006) of the United States in World Aviation 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 flight cancellations.

Ranter (2003), opined that Africa was the most unsafe continent for air travel. In 2002, Africa accounted for 27% of fatal airline accidents, while she is only responsible for 3% of all worlds' aircraft departures. All regions including Europe, North America, South America and Central America recorded a steadily decreasing accident rate over the past 11 years of (1992-2002), except Africa.

Quantitative studies on the impact of weather on the efficiency of air travel, 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 in 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 clouds, 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 aircraft 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 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 are included in Theusner and Röhner, (2006).

The analysis of weather-related accidents and incidents are affected by:

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 observed occurrence, example, cloud burst

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

VII. 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.)

Flight crews (e.g Pilots, Co-pilots, flight engineers) are concerned with the range at which they can see objects. The visibility of an object depends not only on the transparency of the atmosphere, but also on factors as such as the nature of the object and its visible background, the size of the object, and its 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 (from aircraft down to the ground) is required. The air-to-ground visibility may be much greater than the horizontal visibility at ground level, if a shallow layer of fog or haze is present.

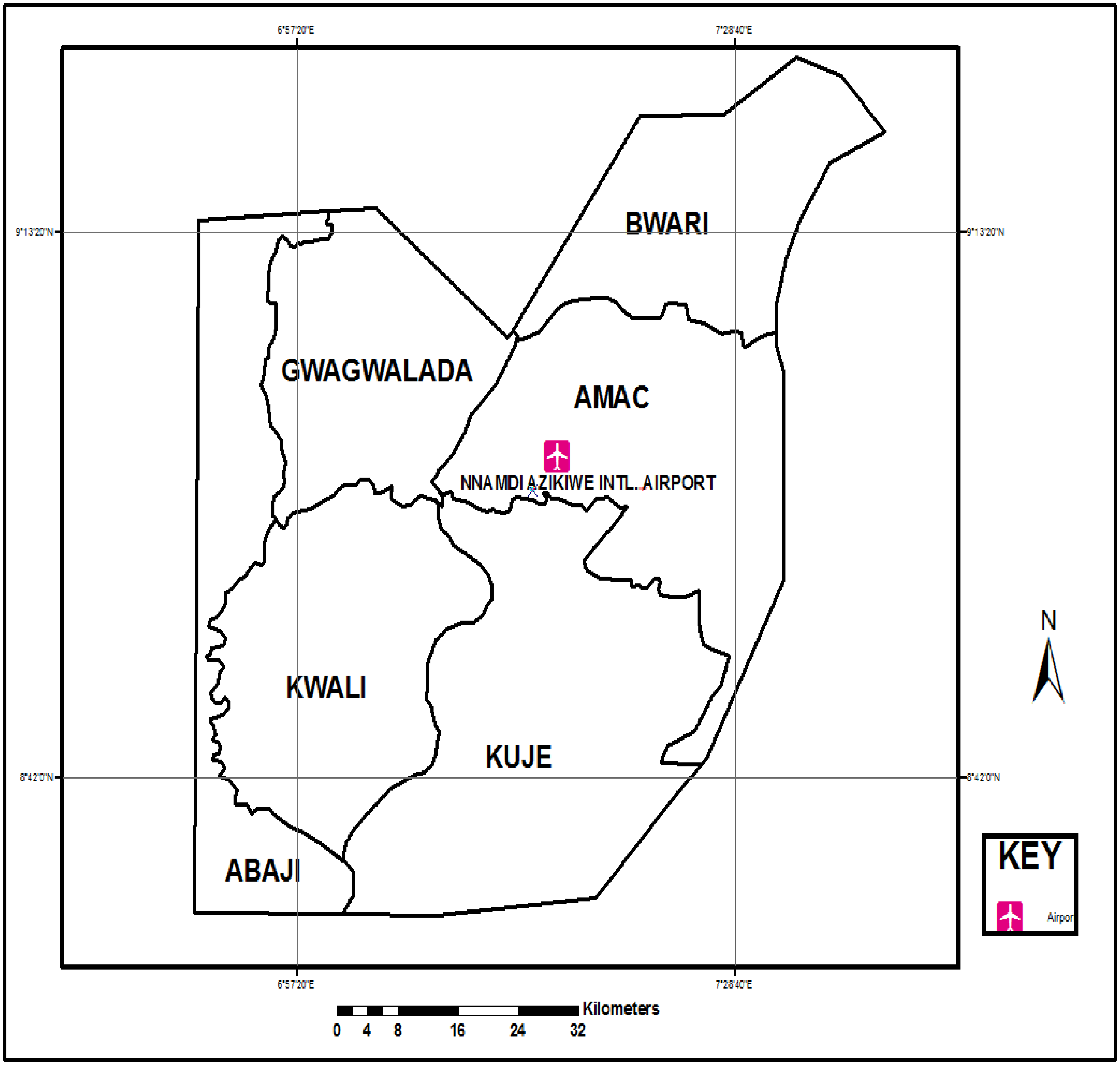
Weather phenomena are tied to two seasons in Nigeria. During the rainy seasons there are delays and diversions of flights as a result of thunderstorm occurrences, and in the dry season there is the dust haze that reduces visibility. During the period of poor visibility, flights can be diverted to alternate airports when it is difficult to land at their original destination due to poor weather conditions. All of these conditions pose a great risk to passengers, and increased cost of flight operations; this 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 elements and aviation transportation

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 area which serve domestic and international flights, and the private area 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 runway length is 3600m/11,842 ft (Nigerian Aeronautical Information Publication [NAIP], 2013).

Abuja International Airport provides flight services both to domestic and

International destinations. 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). 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).

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 FCT records its highest temperatures and greatest diurnal ranges during the dry season, when the maximum temperature ranges between 30.40^0C and 35.1^0C. During the rainy season the maximum temperature ranges between 25.8^0C and 30.2^0C. Also, the diurnal range is much reduced. Two main factors strongly influence temperature patterns in the FCT. These are cloud cover and elevation, these therefore, accounts for the relatively higher temperatures in some parts of the FCT (Ujoh *et. al.,* 2010).

Abuja is easily the best place 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).

METHODOLOGY

Mode of Data Collection

The study adopted a retrospective survey design, which involved 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 were collected from Nigeria Meteorological Agency (NIMET) and the Nigerian Air Space Management Agency (NAMA) both located 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** were collected for the same period.

Data Analysis

Multivariate analysis such as Spearman Rank Correlation Coefficient, coefficient of determination, t-test analysis and multiple correlations will be used to demonstrate the relationship.

Spearman Rank Correlation Coefficient: It is used widely in assessing the level of association between two variables when the raw data are not in absolute values but only ranked in form. In this study it will be used to assess the relationship between rainfall and flight operations (cancellation, delay and diversion), visibility and flight operations (cancellation, delay and diversion), wind speed and flight operations (cancellation, delay and diversion), and cloud cover and flight operations (cancellation, delay and diversion). It has the formula thus:

$$\mathbf{rs} = \frac{\mathbf{1\text{-}6\sum d^2}}{\mathbf{n(n^2 - 1)}}$$

Where

n= the number of pairs of occurrences being considered

d= the difference between the pairs of ranked values

d^2= summation of the squares of the difference

Multiple regression analysis was adopted for the analysis to show the extent of relationship between weather elements and flight cancellations and delays. This is because it gives a better relationship of causative factors. Every value of independent variable x is associated with a value of the dependent variable y.

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

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 AND DISCUSSION

Relationship between Flight Cancellation and Weather Elements

Table 1 shows the relationship between flight cancellation and visibility, rainfall, cloud cover and wind speed. The annual and monthly relationship between flight cancellation and weather elements in the space of (15 years) is as shown in Table 1. The Spearman rank correlation analysis and test for significance are 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**	**Critical 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

Source: Data Analysis (2017)

Table 2: Monthly Relationship Between Weather Elements and Cancellation

	Correlation coefficient	**Coefficient of determination**	**Remark,**	**Calculated value**	**Critical value**	**Remark**

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 in table 1 shows that flight cancellation and visibility has a correlation coefficient of -0.64, with 0.41 coefficient of determination. The test for significance indicates that the postulated null hypothesis is rejected since the calculated value (3) is greater than the critical value (1.77). This further indicates that at 0.05%, the correlation coefficient is significant. This findings agrees with 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 correlation coefficient between annual flight cancellation and rainfall stood at 0.33, with 0.11 coefficient of determination. 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).

Results of correlation between 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).

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

The result of correlation between monthly flight cancelations and Visisbility, rainfall, cloud cover and wind speed is shown in table 2. 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 Miner (2002) who reported that there is a relationship between weather parameter and flight operations but that the relationship was insignificant due to weather modification.

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.

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.

In contrast with the annual results, 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 3: 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**	**Critical 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

Source: Data Analysis (2017).

Table 4: 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).

Table 3 shows the correlation between flight delay and visibility, rainfall, cloud cover and wind speed. The results show that the relationship between flight delay and visibility and wind speed has a negative correlation hence weak relationship. While the correlation of flight delays on rainfall and wind speed shows a positively weak relationship.

Table 4 shows the correlation of same elements with flight delay on a monthly basis and the results shows that only rainfall and wind speed has a very weak negative relationship with flight delay. That implies that they have almost no influence on flight delay. While visibility and cloud cover have a fairly positive relationship with flight delay, implying there is a little influence on a monthly basis of these elements to flight delays.

Multiple Correlations of Flight Cancellation and Weather Elements

Table 5 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 5: 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

Source: Data Analysis (2017).

Table 6: Multiple Relationship Between Visibility, Rainfall, Cloud Cover, wind speed and Flight delay

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) noted 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 consent with Allan *et. al.,* (2001) conducted on weather related flight delays at Newark International Airport, located in the heart of the congested northeast corridor of the United States. It is an airport with a significant number of delays. Allan *et. al.,* (2001) found that 68% of the cumulative flights delays on days during 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 planned based on the prevailing weather condition in order to prevent delays, cancellations and to minimize accidents associated with air transport.
3. Reliable and well equipped weather station with precise prediction of weather stations should be established not only in airports, but also in strategic locations across the country (Nigeria) 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.

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