EFFECTS OF WIND SHEAR ON FLIGHT OPERATIONS IN SAM MBAKWE AIRPORT, IMO STATE, NIGERIA

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Abstract
This paper examined wind shear and its relationship with aircraft operations using Sam Mbakwe Airport, Imo State as a case study. Data on wind shear and aircrafts operations were collected from Nigerian Meteorological Agency (NIMET) and Nigerian Civil Aviation Authority (NCAA) of the airport respectively for the period of one and half years.Correlation and Regression Analyses were carried out for the measured wind shear and flight delays and cancellations. The study revealed that the wind shear measured at 20m above ground level had weak positive relationship with flight delays and cancellations. This implies that as wind shear increases, both flight delays and cancellations also increase. The correlation between wind shear measured at 20m above ground level and flight delays and cancellations were 0.195 and 0.392 respectively, showing that the measured wind shear was responsible for 51.4 percent and 67.1 percent of the flight delays and cancellations respectively. The regression relationship formulated was significant for the entire hypotheses because the P-values of the ANOVA were less than 0.05. Since the relationship was significant, the expressions can be used to predict the extent of flight delays and cancellations if the wind shear is known. The study therefore recommended that there should be training and retraining of the observers, meteorologists and engineers working with NIMET, so as to avert the negative effects of wind shear in the aviation industry in Sam Mbakwe Airport in particular and in various Nigerian Airports.

Keywords: Wind Shear, Flight Delays, Flight Cancellations, Thunderstorm Activity.

Introduction

Wind shear has been recognized to be responsible for delays and sometimes cancellations of flight schedules, and has caused quite a number of aircraft crashes, even in Nigeria. The case of Sosoliso Airlines and Belview Airlines plane disasters in Nigeria are typical examples (Edeagha, Esosa and Idiodi, 2005).Wilson, Goodrich and Carson (2005), in Aviation Meteorology, stated that wind shear is a change in the winds which is sufficiently abrupt to affect the performance of an aircraft so significantly that it challenges the compensation capabilities of the pilot and the aircraft, while Hong Kong Observatory in 2009, noted that wind shear is a sustained change in the wind direction and speed lasting more than a few seconds and resulting in a change in the headwind and tailwind encountered by an aircraft. Such a change will cause the aircraft to go below the intended flight path, if there is a decrease in the lift or lift the aircraft to fly above the intended flight path, if there is a positive lift.

Low level wind shear can affect aircraft airspeed during take-off and landing in disastrous ways, a condition which makes airliner pilots to be trained to avoid all microburst wind shear, that is, headwind loss in excess of 30 knots (Azad, 2011).Wind shear is caused by quite a number of factors, such as ground surface roughness, obstacles, land and sea breezes (Mathew, 2006).

Another controlling factor which influences wind shear by offsetting the pressure gradient force is friction on the earth's surface. With increasing wind speeds, friction between the air and the surface increases. Frictional resistance to wind provided by the surface of the earth is influenced by many variables such as: elevation, terrain roughness and topography (Abdulla, 2014).

In fact, there is a positive link between wind shear and thunderstorm activity; see for example, Fujita (1975), cited in U.S. Department of Transportation, Federal Aviation Administration (2005). Wind shear fuels thunderstorms and thunderstorms are one of the atmospheric phenomena that create hazardous conditions that every pilot avoids. According to Harding (2011), thunderstorm consists of thunder and lightning produced by a cumulonimbus cloud usually accompanied by rain or hail and could produce severe turbulence, low level wind shear, low ceiling and visibilities. Though thunderstorms occur anywhere on the globe but its occurrence is most frequently in the tropics. Furthermore, its intensities are much higher in the tropics than elsewhere on the globe (Ayoade, 2004). However, the critical effects which wind shear cause in flight operations are very alarming. Hence, this paper tends to address these problems.

Materials and Methods

The Study Area

Sam Mbakwe Airport is in Ngor-Okpala Local Government Area of Imo State. Ngor-Okpala Local Government Area (L.G.A) is located between latitudes $5^{0}21^{1}$and 5^{0} 71^{1}N of the Equator and between longitudes 7^{0} 101^{1} and 7^{0} 131^{1}E of the Greenwich Meridian. It is bounded to the east and west by Abia State and Ohaji-Egbema respectively and in the north and south by Owerri, AborMbaise and Rivers State respectively (Fig. 1).



Fig. 1: Map of Nigeria showing Imo State.
Source: Ministry of Lands and Survey.

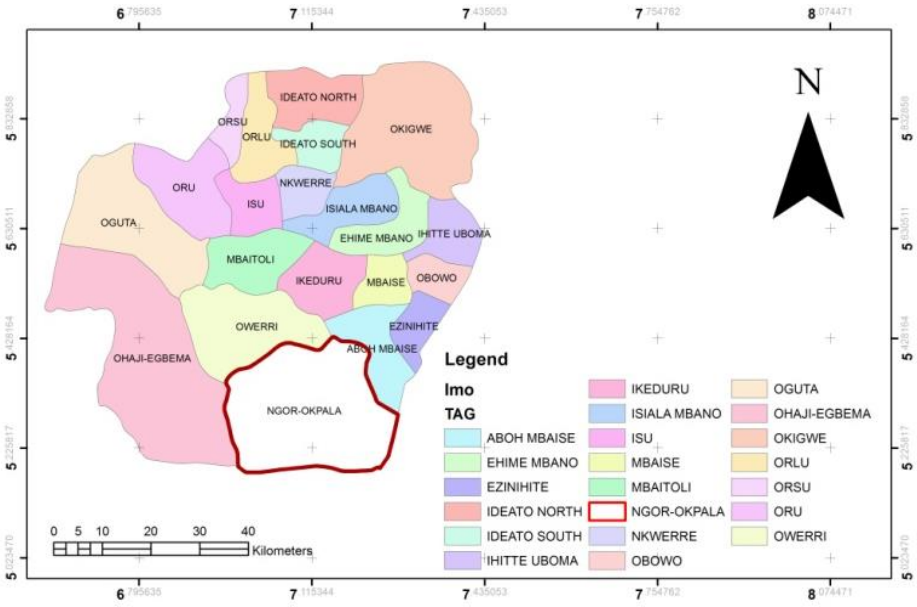


Fig. 2: Map of Imo State Showing Ngor-Okpala L.G.A.
Source: Ministry of Lands and Survey.

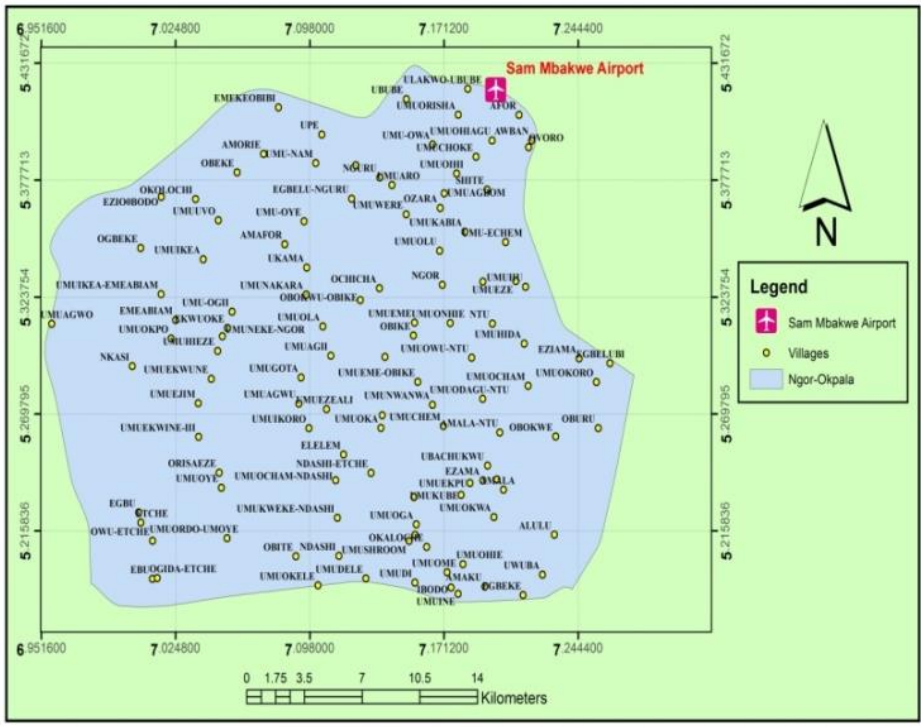


Fig. 3: Map of Ngor-Okpala L.G.A Showing Airport.
Source: Ministry of Lands and Survey.



Fig. 4: Satellite Image of Sam Mbakwe Airport.
Source: GIS Lab., Surveying and Geoinformatics Department, Unizik, Awka.

The geomorphology and geology of the study area is Coastal Plain Sands (Orajiaka, 1975). The hydrogeophysical survey revealed that the study area is underlain by Benin Formation. This Formation consists of fine sand, medium sand, coarse sand to gravel, with clay and silt lenses (Opara, Onu and Okereafor,2012). The area is a lowland area with humid tropical climate having a rainfall of over 2500 mm and mean annual temperature of 27.5^{0}C (Mathew-Njoku and Onweremadu, 2007). The mean annual relative humidity is 75 percent (Onyeagocha et al., 2014). Farming is the dominant socio-economic activity of the study area (Mathew-Njoku and Onweremadu, 2007).

Method of Data Collection

The data needed for this study were wind shear data measured at 20m above ground level and data on flight delays and cancellations at Sam Mbakwe Airport, Imo State from January 2014 to June 2015.The 20m height was chosen because this is the height at which wind shear is measured at Sam Mbakwe Airport. The study predominantly relied on secondary sources. The data on wind shear was obtained from the Nigerian Meteorological Agency (NIMET), while data on flight delays and cancellations were obtained from Nigerian Civil Aviation Authority (NCAA), both of them from Sam Mbakwe Airport, Ngor-Okpala.

Low Level Wind Shear Alert System (LLWAS) is the instrument that records wind shear at the airport. The Low-Level Wind Shear Alert System (LLWAS) was designed to detect low-level wind shear in the terminal area. The ground-based system provides both audio and visual alarms to Air Traffic Control (ATC) personnel in clearly represented numerical and

graphical form. In locations where Low-Level Wind shear is known to be experienced, LLWAS significantly increase the operational efficiency and safety of the airport.

Method of Data Analysis

To determine the proportion of flight delays and cancellations due to wind shear, the statistical technique that was employed to ascertain the relationship between wind shear frequency and flight delays and cancellations was Pearson's Product Moment Correlation method. This is because it is the most powerful correlation statistic (Anyadike, 2009).

In order to estimate the proportion of the variations in flight delays and cancellations that are as a result of the variations in wind shear, the R-square which is the coefficient of determination was calculated. To test the significance of the Correlation Coefficient, F-test (ANOVA) was employed. Regression analyses were carried out so as to determine the strength of relationship between wind shear and flight delays and cancellations. Addin Excel was employed in the entire analysis.

Hypotheses Testing

Ho: There is no significant relationship between wind shear measured at 20m above ground level and flight delays.

H_1: There is a significant relationship between wind shear measured at 20m above ground level and flight delays.

Ho: There is no significant relationship between wind shear measured at 20m above ground level and flight cancellations.

H_1: There is a significant relationship between wind shear measured at 20m above ground level and flight cancellations.

RESULTS AND DISCUSSION

The result of field data on wind shear measured at 20m above ground level and flight delays is shown in table 1.

Table 1: Wind Shear measured at 20m AGL and Flight Delay

Months	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**
Wind Shear (X)	46	30	50	84	34	46	75	175	113	44	2	2	94	96	36	121	64	9
flight Delay (Y)	8	4	3	5	5	8	10	8	9	4	6	22	39	22	25	22	18	8

Source: Researcher's work, 2015.

As the rule suggests, accept the null hypothesis if the P-value of the test is greater than 0.05, otherwise, reject.Wind shear measured at 20m is the independent variable (X) and flight delay is the dependent variable (Y).Correlation analysis was employed to show the nature of relationship and degree of relationship between the variables. The calculated relationship is shown in table 2.

Table 2: Correlation of Wind Shear and Flight Delay

	Wind Shear	flight Delay
Wind Shear	1	
flight	**0.19496**	1

Delay		

Source: Researcher's work, 2015.

Correlation between a variable and itself is perfect correlation which is 1 as shown in table 2. Correlation between Wind Shear and Flight delay is 0.195 which is less than 0.5. This implies there exists weak relationship between the variables but positive in nature. The positivity can be interpreted as a unit increase in wind shear leading to unit increase in flight delay.The illustration of field data on wind shear measured at 20m above ground level and flight delays is shown in fig. 2.

Regression model (best line of fit) performed had a standard error of 11.3. This shows that the number of flight delays estimated from the regression equation will have a 95% chance of falling within +/-11.3 of the actual value. Obviously, the low value of the standard error of the estimate indicates that the regression model used is an accurate predictor of the estimate (Table 3).

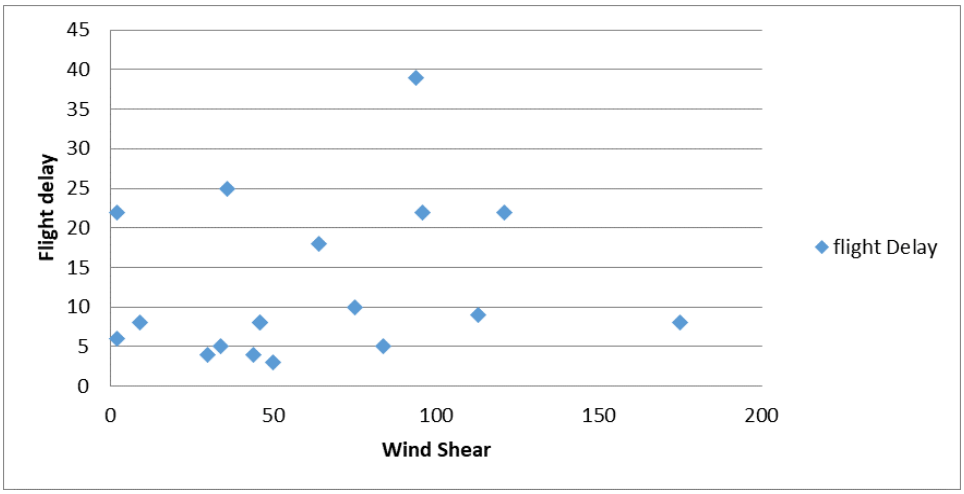


Fig.2: Scatter Plot of wind shear and flight delay of hypothesis 1

Table 3: Regression Model (Best Line of Fit)

Regression Statistics

Multiple R	0.716990236
R Square	0.514074999
Adjusted R Square	0.45525147
Standard Error	11.32373757
Observations	18

Source: Researcher's work, 2015

Again, R-Square shows percentage of variation in the dependent variable that can be explained by the independent variable. In the model used, the R-Square is 51.4% which implies wind shear is responsible for 51% of the flight delay. The result of the test of adequacy of the model using F-test (ANOVA) is shown in table 4.

Table 4: Test of Adequacy of the model using F-test (ANOVA)

	Df	SS	MS	F	Significant F
Regression	1	2306.14	2306.14	17.98482	0.000623
Residual	17	2179.86	128.227		
Total	18	4486			

Source: Researcher's work, 2015.

Regression relationship is said to be significant if the P-value of the ANOVA is less than 0.05, otherwise, the relationship is insignificant. This then mean that the P-value of the F-test is 0.0006 which is less than 0.05. There exists enough evidence to conclude that the relationship is significant.

The result for the extent of predictability of flight delays is shown in table 5.

Table 5: Model Specification

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Wind Shear	0.148219066	0.03495	4.240852	0.000551	0.07448	0.221958

Source: Researcher's work, 2015.

The model can be written as

$Y = 0.148X$

This would be interpreted to mean that a unit increase in wind shear is leading to 0.148unit increase in flight delay.

Since the relationship is significant, the expression can be used to predict the extent of flight delay if the wind shear is known. Therefore, there is significant relationship between wind shear measured at 20m and flight delay.

The result of field data on wind shear measured at 20m above ground level and flight cancellations is shown in table 6.

Table 6: Wind Shear measured at 20m AGL and Flight Cancellations

Months	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
Wind Shear(X)	46	30	50	84	34	46	75	175	113	44	2	2	94	96	36	121	64	9

Flight Cancellation(Y)	2	2	2	5	2	1	2	3	1	1	2	1	2	1	1	2	2	0

Source: Researcher's work, 2015.

As the rule suggests**,** accept the null hypothesis if the P-value of the test is greater than 0.05, otherwise, reject.

Wind shear measured at 20m above ground level is the independent variable (X) and flight cancellations is the dependent variable (Y). Correlation analysis was employed to show the nature of relationship and degree of relationship between the variables. The calculated relationship is shown in table 7.

Table 7: Correlation of Wind Shear and Flight Delay

	Wind Shear	**Flight Cancellation**
Wind Shear	1	
Flight Cancellation	0.391733	1

Source: Researcher's work, 2015.

Table 7 indicates that the Correlation between a variable and itself is perfect correlation which is 1. Correlation between wind shear and flight cancellation is 0.392 which is less than 0.5. This implies there exists weak relationship between the variables but positive in nature. The positivity can be interpreted as a unit increase in wind shear leading to unit increase in flight cancellation. The illustration of field data on wind shear measured at 20m above ground level and flight cancellations is shown in fig. 3.

Regression model (best line of fit) performed had a standard error of 1.21. This shows that the number of flight delays estimated from the regression equation will have a 95% chance of falling within +/-1.21 of the actual value. Obviously, the low value of the standard error of the estimate indicates that the regression model used is an accurate predictor of the estimate (Table 8).

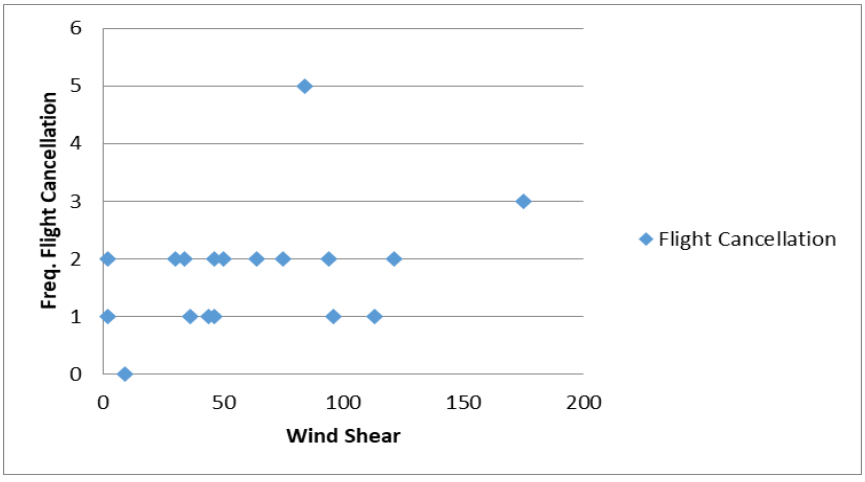


Fig.2: Scatter Plot of wind shear and flight cancellation of hypothesis 2

Table 8: Regression Model (Best Line of Fit) for hypothesis 2

Regression Statistics	
Multiple R	0.819252
R Square	**0.671175**
Adjusted R Square	0.612351
Standard Error	1.212453
Observations	18

Source: Researcher's work, 2015.

From Table 8, it could be seen that R-Square is the percentage of variation in the dependent variable that can be explained by the independent variable. In the model used, the R-Square which is the square of R was calculated as 67.1 percent which implies wind shear is responsible for 67 percent of the flight cancellation.
The result of the test of adequacy of the model using F-test (ANOVA) is shown in table 9.

Table 9: Test of Adequacy of the model using F-test (ANOVA)

	df	*SS*	*MS*	*F*	*Significant F*
Regression	1	51.00927	51.00927	34.69917	0.0000228
Residual	17	24.99073	1.470043		
Total	18	76			

Source: Researcher's work, 2015

Regression relationship is said to be significant if the P-value of the ANOVA is less than 0.05, otherwise, the model is insignificant. The P-value of the F-test is 0.000023 which is less than 0.05. There exists enough evidence to conclude that the relationship is significant.
The result for the extent of predictability of flight cancellations is shown in table 10.

Table 10: Model Specification

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Wind Shear	0.022044	0.003742	5.8906	1.78E-05	0.014148	0.029939

Source: Researcher's work, 2015.

The model can be written as

Y = 0.022X

This would be interpreted to mean that a unit increase in wind shear is leading to 0.022unit increase in flight cancellation. Since the relationship is significant, the expression can be used to predict the extent of flight cancellation if the wind shear is known. Therefore, there is significant relationship between wind shear measured at 20m and flight cancellation.

The findings are in tandem with Knecht (2008), Musa (2014), Weli and Ifediba (2014), and Enete et al. (2015) that most of flight delays and cancellations were caused by weather conditions such as wind shear, thunderstorm, poor visibility and squall. However, since flight delays and cancellations show weak relationships with wind shear, there may be other significant variables in the study area, for example operational inefficiencies.

Recommendations

To reduce the effects of wind shear on aircraft operations, there should be training and retraining of Air Traffic Controllers, Meteorologists and Engineers working with NIMET and FAAN, so as to update their knowledge on the negative effects of wind shear in the aviation industry in the country. The same should also be done in the agencies involved in the observing, forecasting and dissemination of weather information in other countries.Also, pilots and air traffic controllers should always be well trained and retrained, so that they can have good knowledge of wind shear and other hazardous weather phenomena.

Conclusion

This paper has tried to identify wind shear as one of the major effects on flight operations. The paper revealed that wind shear contributed to the delays and cancellations of flight schedules at the airport. This is because the correlation between wind shear and flight delays and cancellations were positive. It also indicated that the regression relationships between wind shear and flight delays and cancellations at the study area were significant. This is because the P-values of the F-test (ANOVA) were less than 0.

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