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ARTICLE

Assessment of the Impacts of Thunderstorm on Flight Operations at Murtala Mohammed International Airport, Ikeja, Lagos State, Nigeria

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ABSTRACT

The inefficiency of the aviation industry and the persistent rise in aviation hazards have been linked to weather phenomena. As a result, researchers are looking for better solutions to the problem. The study examined the impact of thunderstorms on flight operations at Murtala Mohammed International Airport, Lagos. The data on thunderstorms and flight operations were sourced from Nigerian Meteorological Agency (NiMet) and Nigerian Airspace Management Agency (NAMA) respectively. In order to meet the research target, descriptive statistics (mean, standard deviation, and charts) and inferential statistics (Pearson's Product Moment Correlation (PPMC) and Regression) were used. The significance level for all inferential analyses was set at 5% (0.05). The study revealed that 77.4% of thunderstorms occurred during the rainy season (April-October) while 22.6% occurred during the dry season (November-March). It also revealed some fluctuating movements of a thunderstorm in the study area. According to the findings, thunderstorms occur most frequently at the airport in June and less frequently in January and December. The study also discovered that thunderstorms at the airport are positively and significantly related to flight delays and cancellations, while the association between flight diversions and thunderstorm occurrence is positive but statistically insignificant. Furthermore, flight delays, flight diversions, and flight cancellations interact positively among themselves. The regression result of the study revealed that a 1% increase in thunderstorm occurrence leads to a 19.4% increase in flight delay, a 7.1% increase in flight cancellation, and a 4.3% increase in flight diversion. As a result, the study presented various regression models that may be utilized to make predictions. The study proposes consistent thunderstorm observation at the airport and steady forecasts using the regression models, based on the findings. However, it further recommends that pilots, air traffic controllers, and meteorologists be trained and retrained so that they can provide better and more efficient services.

Keywords: Thunderstorms; Assessment; Impacts; Flight operations; Airport

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1. Introduction

The aviation transportation industry, more than any other mode of transportation is greatly affected by weather from thunderstorms, snow storms, strong winds (squalls, wind shear), fog, thick-dust haze as well as temperature and pressure extremes; therefore, every phase of flight has the potential to be influenced by weather [1-3]. The growth of the aviation industry in Nigeria and the increased adoption of air transportation as one of the best means of transport have been obstructed by various weather hazards [4]. Thus, there is a greater need for aviation weather forecasters to deliver quality forecasts.

Thunderstorms are big, vertically extended convective clouds that frequently have their apexes near the tropopause and their bases near the top of the boundary layer [5]. Thunderstorms are ferocious, short-lived meteorological disturbances that nearly always feature lightning, thunder, dense clouds, significant amounts of rain or hail, and strong gusts of wind [6]. Layers of warm, moist air rise in a strong updraft to cooler areas of the atmosphere, whereupon thunderstorms form [6,7]. At that location, the updraft's moisture condenses to create imposing cumulonimbus clouds and, eventually, precipitation [6]. Cooled air columns then descend toward the ground, producing powerful downdrafts and horizontal winds [6,7].

In addition, electrical charges build on ice and water droplets that make up cloud particles [6,8]. When the electric charge that been collected is sufficiently high, lightning discharges happen [9]. When lightning strikes, it instantly and intensely warms the surrounding air, creating shock waves that sound like thunderclaps [6,10]. Occasionally, air vortices that are spinning and powerful enough to create tornadoes are present with intense thunderstorms [6].

Nearly all parts of the planet are known to have thunderstorms, though they are uncommon in the Polar Regions and seldom in latitudes higher than 50° N and 50° S [6,11]. However, thunderstorms are most common in tropical and temperate regions of the earth [6]. The characteristics of thunderstorms themselves are used to categorize or classify them, and these characteristics are heavily influenced by the meteorological environment in which the storms develop [5]. There are various types of thunderstorms.

When moisture is available at low and intermediate levels of the atmosphere—that is, from close to the ground's surface up to about 10,000 meters in altitude—and when there are mild winds that do not fluctuate significantly with height, isolated thunderstorms are more likely to develop [5]. These storms are sometimes known as local thunderstorms or air masses [12]. They often do not cause violent weather near the ground, are largely vertical in structure, and have a limited lifespan [6,12].

Storms with organized multiple cells, squall lines, or supercells are typically what cause violent weather on the ground, and they are known as multiple-cell thunderstorms [13,14]. Thunderstorms can occasionally form over a region with a diameter of hundreds of kilometers as a result of the formation of a mesoscale meteorological disturbance [13]. These disturbances include frontal wave cyclones, which are low-pressure systems formed by waves on fronts separating warm and cool air masses, and low-pressure troughs at higher altitudes [6]. Mesoscale convective systems (MCS) are the name for the storm pattern that results from this [6]. MCSs are usually connected with powerful multiple-cell and supercell thunderstorms [5]. Rainfall from stratiform clouds (cloud layers with a large horizontal extent) and convective clouds are frequently produced by these systems [6].

When environmental winds are favourable, a storm's updraft and downdraft organize, twist around, and reinforce each other [5]. As a result, a long-lived supercell storm forms [5,13]. These thunderstorms are the most powerful kind [5,6,13]. An anvil-shaped updraft rises, turns counterclockwise, and exits to the east [15]. Supercells have a two-to-six hour lifespan [6,16]. They are the storms that are most likely to cause noticeable wind and hail damage as well as strong tornadoes [17].

A thunderstorm is a very significant climatic element that affects all forms of transportation, such as roads, water and air. The effects of thunderstorms on flight operations at Port-Harcourt International Airport were assessed [18] utilizing simple and multiple bar charts and Pearson's product-moment correlation. Due to the meridional movement of the weather/ITD zones, the study found that thunderstorms usually occur during the rainy season months (monsoon periods), with an increasing trend over time. In addition, the study found that thunderstorms were responsible for 32% of flight cancellations (218 occurrences), 0.2% of diversions (291 occurrences), and 24% of delays (526 occurrences) at the airport between 2008 and 2013. The study also revealed that, with correlation values of r = 0.57, 0.49, and –0.04, thunderstorms have a greater effect on the number of flight cancellations and delays than on flight diversions respectively. The study came to the conclusion that thunderstorms occur during monsoon seasons in the study area and have a greater impact on delays and cancellations than on diversions.

The impact of thunderstorms on landing traffic at Frankfurt Airport (Germany) was studied [19]. The study, which considered all days, found that a thunderstorm moving over the Frankfurt airport area affects about 100 inbound aircraft within four hours of impact time with a total delay of about 1,000 minutes, or about 800 minutes longer than the typical delay for this time period. According to the report, Frankfurt Airport is significantly impacted by thunderstorms.

These studies have undoubtedly contributed to a better understanding of thunderstorm events, making it easier to detect and make predictions at Murtala Mohammed International Airport. The objectives of the study are; to determine the temporal variation of a thunderstorm at Murtala Mohammed International Airport and to determine the relationship between thunderstorms and flight delays, diversions and cancellations at Murtala Mohammed International Airport.

To the researchers' knowledge, there are few, if any, published studies that looked at the relationship between thunderstorms and flight delays, cancellations and diversions at Murtala Mohammed International Airport. As a result, this study's findings can provide some references and valuable information for similar scholars looking to better understand the impacts of a thunderstorm on flight operations.

2. Materials and methods

2.1 Study area

Murtala Mohammed International Airport, Lagos State is the study area. The major contributor to air traffic delays at Murtala Mohammed International Airport in Lagos is weather [20]. Four major weather conditions account for the occurrence of low visibility at Murtala Mohammed International Airport, and they are haze, rain, fog and mist [21]. **Figure 1** is the satellite image of Murtala Mohammed International Airport.

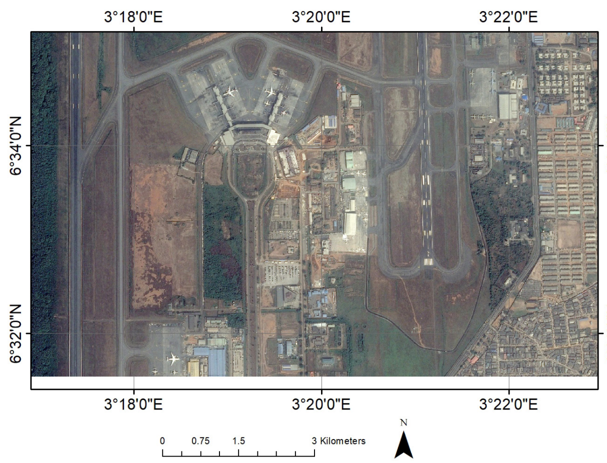

Figure 1. Satellite Image of Murtala Mohammed International Airport.

Source: Onwuadiochi et al., 2021.

Murtala Mohammed International Airport, Lagos has a tropical wet and dry climate [22]. The West African monsoon system (driven by the migration of the inter-tropical discontinuity) as well as mesoscale processes drive the rainy season, which lasts from March to November (with peaks in July and September) [23]. In August, there is a brief dry spell, followed by a prolonged dry season from December to March [24]. Murtala Mohammed International Airport (MMIA) is an international airport in Ikeja, Lagos State.

2.2 Data collection

The time-space for the thunderstorm data is from

2001 to 2020, as this research intends to examine the impact of weather, in this case, thunderstorms on flight operations. The time-space for the flight operations data is from 2008 to 2020, as this is the period of data that the researcher could access. The study basically relies on secondary data. The monthly thunderstorm data were obtained from the records of the Nigerian Meteorological Agency (NiMet). The thunderstorm detector was designated at Murtala Mohammed International Airport, Lagos State to detect thunderstorms in the terminal area. The Meteosat of Second Generation (MSG) and Real Time Imagery (RETIM) were used to monitor the development and decay of storms at the airport. The monthly data on flight delays, diversions and cancellations were obtained from the records of the Nigerian Airspace Management Agency (NAMA) at Murtala Mohammed International Airport, Lagos State.

2.3 Data analysis

The statistical analytic techniques that were employed to achieve the research target, which is the impact of a thunderstorm on flight operations (flight delays, cancellations and diversions) include descriptive statistics (such as mean, standard deviations, and charts) and inferential statistics including Pearson's Product Moment Correlation (PPMC) and Regression. All inferential analyses were judged at a 5% (0.05) level of significance.

2.3.1 Descriptive statistics

Descriptive statistical techniques were employed to describe the behaviour of the thunderstorms, flight delays, diversions and cancellations data series over the period of study. Particularly, the mean and standard deviation captured the centre and spread of the dataset, while the charts pictured the seasonal and annual trends of the data series. The temporal variation of a thunderstorm at Murtala Mohammed International Airport was ascertained by computing the descriptive statistics and also estimating the seasonal differences whereby April-October is the rainy season while the dry season period is November-March.

2.3.2 Pearson's correlation

Pearson's correlation analytic technique was employed in validating the extent and relationship among the study variables without suppressing the other. This statistical technique was considered appropriate as the data series of the variables under investigation were all converted to continuous data through log transformation. Geometrically, Pearson's correlation coefficient is generally computed as:

$$r = \frac{Cov\,(M,N)}{\sqrt{(Var\,(M))(Var\,(N))}} = \frac{\sum_{i=1}^{T}[(M-\bar{M})(N-\bar{N})]}{\sqrt{\left[\sum_{i=1}^{T}(M-\bar{M})^2\right]\left[\sum_{i=1}^{T}(N-\bar{N})^2\right]}} \quad (1)$$ [25]

where,

r is the correlation coefficient,

$Cov\,(M,N) = \sum_{i=1}^{T}[(M-\bar{M})(N-\bar{N})]$ is the covariance of M and N series,

$Var\,(M) = \sum_{i=1}^{T}(M-\bar{M})^2$ is the variance of M series,

$Var\,(N) = \sum_{i=1}^{T}(N-\bar{N})^2$ is the variance of N series.

T = Total number of observations,

$\bar{M}$ and $\bar{N}$ and mean values of series of M and N values,

M and N are variables of interest.

2.3.3 Regression analysis

The functional relationships among the selected variables were determined using the classical linear regression analytic technique. Geometrically, the relationship is represented as:

Number of Flight diversions, delays and cancellations = f(thunderstorm)

Such that:

LFDS, LFDL, LFCL = f(TSM) (2) [25]

where,

FDS = Number of flight diversions

FDL = Number of flight delays

FCL = Number of flight cancellations

L = Log-transformational operator

TSM = Thunderstorm

Analytical packages that were used include Microsoft Excel, Eviews and Statistical Package for Social Sciences (SPSS) version 25.0 for windows.

3. Results and discussion

The thunderstorm data for the year 2001 to 2020 are presented in **Table 1**. The time span for the data is because this study intends to examine the impact of weather, in this case the thunderstorms on flight operations.

As shown in **Table 1**, within the period under study, the highest thunderstorm event occurred in June with a value of 327. This is followed by September, October and July with values of 288, 262 and 254 respectively. The lowest thunderstorm event occurred in January with a value of 29. This is followed by December and February with values of 40 and 60 respectively. However, **Table 1** shows that the highest thunderstorm events occur during the rainy season while there is a decrease in thunderstorm events during the dry season. In addition, considering the cumulative thunderstorm, the highest number of thunderstorm events were experienced in the year 2019 with a cumulative value of 121. This is followed by the years 2014 (115), 2017 (114) and 2012 (110).

The data for the monthly totals of flight delays, diversions and cancellations for the year 2008 to 2020 are presented in **Table 2**.

As shown in **Table 2**, the highest number of flight delays was observed in October with a value of 83. This is followed by May and June with the values 79 and 73 respectively. The lowest number of flight delays was observed in December with a value of 18, and followed by January with a value of 21. Similarly, the highest number of flight cancellations was observed in September with a value of 41, followed by October and May with values of 40 and 39 respectively. The lowest number of flight cancellations was observed in January with a value of 15. This is followed by December and February with the values 18 and 22 respectively. Furthermore, the highest number of flight diversions was observed in July with a value of 51. This is followed by June and August with the values 47 and 40 respectively. The lowest number of flight diversions was observed in October with a value of 21, and followed by February and December with a value of 24.

Table 1. Thunderstorm Data (2001-2020).

Months													
Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
2001	0	2	3	4	7	16	9	13	14	10	4	1	83
2002	1	1	2	9	8	20	11	6	19	11	7	1	96
2003	1	4	3	8	13	17	17	7	10	15	8	4	107
2004	3	3	7	9	16	10	6	9	17	15	5	1	101
2005	0	5	8	5	15	17	11	3	10	12	7	2	95
2006	3	4	5	5	14	16	13	11	19	12	6	1	109
2007	0	0	4	6	12	16	14	12	12	10	5	3	94
2008	1	0	7	7	17	20	19	11	13	11	1	2	109
2009	1	3	6	9	12	16	9	1	11	14	3	0	85
2010	0	0	1	9	14	12	18	17	20	16	1	0	108
2011	0	3	2	7	9	21	11	6	14	14	10	0	97
2012	1	5	8	8	11	19	14	5	12	13	11	3	110
2013	5	2	6	11	16	11	17	2	14	9	12	3	108
2014	6	5	7	8	10	18	17	11	13	9	9	2	115
2015	1	5	9	8	8	16	5	12	12	17	3	1	97
2016	0	0	6	5	10	13	10	9	15	15	3	1	87
2017	1	6	7	6	14	20	18	8	13	15	2	4	114
2018	0	5	2	6	14	16	13	13	17	13	5	1	105
2019	4	6	4	7	13	17	13	7	18	22	7	3	121
2020	1	1	6	8	8	16	9	1	15	9	7	7	88
Total	29	60	103	145	241	327	254	164	288	262	116	40	

Source: NiMet, 2021.

Table 2. Monthly totals of flight delays, diversions and cancellations data (2008-2020).

Months	No of flight delays	No of flight cancellations	No of flight diversions
January	21	15	32
February	31	22	24
March	62	35	33
April	61	34	31
May	79	39	37
June	73	32	47
July	65	36	51
August	39	27	40
September	69	41	30
October	83	40	21
November	32	23	31
December	18	18	24

Source: NAMA, 2021.

3.1 Temporal variation of thunderstorm at Murtala Mohammed International Airport

The trends of thunderstorms at Murtala Mohammed International Airport were determined both annually and monthly. The results are as presented in **Figures 2** and **3**.

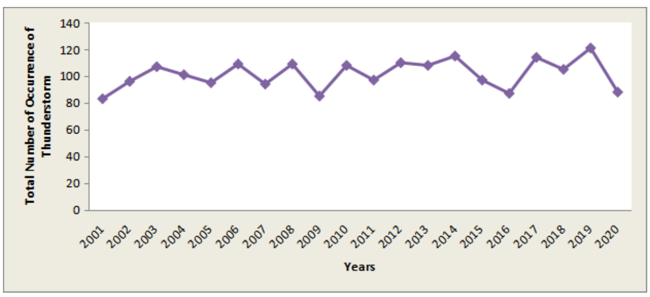

Figure 2. Annual trend measures of thunderstorm at Murtala Mohammed International Airport, Lagos.

The annual trend result of the thunderstorm as presented in **Figure 2** shows that between the years 2001 and 2003, there was an upward movement in the occurrence of the thunderstorm, that is 83, 96 and 107 respectively. However, there was a decline in the year 2004 down to 2005 with respective values of 101 and 95. Similarly, from the year 2006 through the year 2020, there has been an up and down movement in the annual occurrence of a thunderstorm at Murtala Mohammed International Airport. It shows an abrupt downward movement after having the highest cumulative thunderstorm events in 2019 with a value of 121.

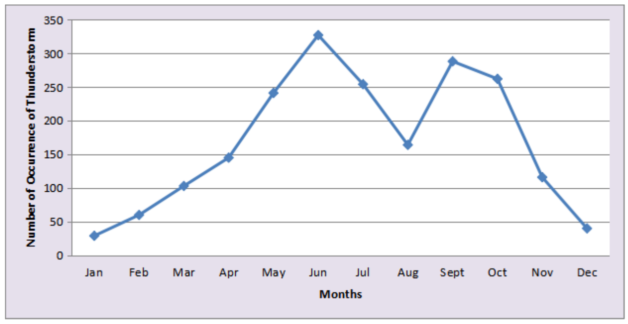

Figure 3. Monthly trend measures of thunderstorm at Murtala Mohammed International Airport, Lagos, from 2001 through 2020.

The monthly statistics of the occurrence of a thunderstorm at Murtala Mohammed International Airport, Lagos, covering the period from 2001 to 2020 as shown in **Figure 3**, indicates that from January through June, the number of occurrence of a thunderstorm at the airport are usually on a steady rise. The corresponding values are 29, 60, 103, 145, 241 and 327. However, in July (254) and August (164), it usually drops and rises again in September (288). From October, through to December, the frequency of occurrence of a thunderstorm at the airport drops substantially. The corresponding values are 262, 116 and 40. However, a thunderstorm is most experienced at the airport in June and less experienced in January and December during the year.

The descriptive statistics as presented in **Table 3** describe the monthly behaviour of the data series of the study variables. The result shows that from the year 2008-2020, an average of 52.75 ± 23.14 flights have been delayed at Murtala Mohammed International Airport, Lagos; an average of 30.17 ± 8.91 flights have been cancelled, while an average of 33.42 ± 9.08 number of flights have been diverted. However, the minimum number of flight delays that have been experienced for the period was 18 while the maximum was 83. The minimum number of cancelled flights was 15 while the maximum was 41. Also, the minimum number of the diverted flight was 21 while the maximum was 51. The series of flight delays and cancellations are skewed to the left (negatively skewed) while that of flight diversions is skewed to the right (positively skewed). Meanwhile, there was no excess kurtosis in the series of FDL, FCL and FDS for the period of study.

Consequently, the monthly average frequency of occurrence of a thunderstorm at the Murtala Mohammed International Airport, Lagos, from 2001 through 2020, ranges from 29 to 327. The mean stood at 169.08 with a standard deviation of 102.72, an indication of high volatile nature. The skewness estimate is positive (Sk = 0.76) while the kurtosis statistic is –1.476. Hence, the series is positively skewed and without excess kurtosis.

The seasonal statistics as presented in **Figure 4** shows that the number of occurrence of a thunderstorm during the rainy season is more than twice that of the dry season. Specifically, out of the total occurrence of a thunderstorm during the period, about 77.4% occurred during the rainy season while 22.6% occurred during the dry season.

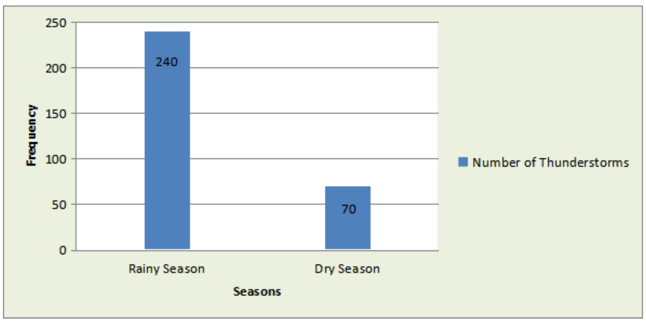

Figure 4. Seasonal variation of occurrence of thunderstorm at Murtala Mohammed International Airport, Lagos (*Rainy Season: April-October; Dry Season: November-March*) from 2001 to 2020.

3.2 Relationship between thunderstorm and flight delays, diversions and cancellations

The relationship between the occurrence of thunderstorms and flight delays, diversions and cancellations was estimated using Pearson's correlation statistics. The correlation matrix is presented in **Table 4**.

From the correlation result, flight delays and flight cancellations are positively and significantly associated with thunderstorms at the airport ($r > 0.50$, $p < 0.05$). Meanwhile, the relationship between flight diversions and the occurrence of a thunderstorm is positive but statistically insignificant ($r = 0.483$, $p = 0.1115 > 0.05$). Also, as presented in the correlation matrix result, flight delays, flight diversions and flight cancellations go in the same direction, such that they interact positively among themselves. Specifically, flight delays substantially increase the chances of flight cancellations ($r = 0.954$, $p = 0.0000$), while delays in flight infinitesimally (or insignificantly) increase the chances of flight diversions ($r = 0.223$, $p = 0.4868$) at the Murtala Mohammed International Airport, Lagos.

3.3 Regression estimates of the linkages between thunderstorms, flight delays, diversions and cancellations at Murtala Mohammed International Airport, Lagos

The regression estimates showing the level of influence of thunderstorms on a flight delay, flight diversion, and flight cancellation at Murtala Mohammed International Airport, Lagos, are presented in **Tables 5 through 7** below.

Table 3. Descriptive statistics of the research variables.

Variables	N	Min	Max	Mean	Std. Dev.	Skewness	Kurtosis
FDL	12	18.00	83.00	52.7500	23.14038	–0.301	–1.558
FCL	12	15.00	41.00	30.1667	8.91203	–0.454	–1.207
FDS	12	21.00	51.00	33.4167	9.08003	0.673	–0.061
TSM	12	29.00	327.00	169.0833	102.72245	0.076	–1.476

Source: Researchers' SPSS 25.0 computation, 2022

Note: FDS = Flight diversions; FDL = Flight delays; FCL = Flight cancellations; TSM = Thunderstorm.

Table 4. Correlation between occurrence of thunderstorm and flight delays, diversions and cancellations.

Correlation t-Statistic Probability Observations	FDS	FDL	FCL	TSM
FDS	1.000000 ----- ----- 12			
FDL	0.288262 0.951973 0.3636 12	1.000000 ----- ----- 12		
FCL	0.222625 0.722125 0.4868 12	0.954153** 10.08048 0.0000 12	1.000000 ----- ----- 12	
TSM	0.483197 1.745271 0.1115 12	0.861892** 5.374859 0.0003 12	0.813579** 4.424696 0.0013 12	1.000000 ----- ----- 12

Source: Researchers' computation 2022 using Eviews 10.

** Correlation is significant at the 0.01 level (2-tailed); FDS = Flight diversions; FDL = Flight delays; FCL = Flight cancellations; TSM = Thunderstorm.

Table 5. Regression estimate for FDL and TSM.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	19.921	7.066	2.819	0.018
TSM	0.194	0.036	5.375	0.000
R^2 = 74.3%				
DW stat. = 1.420				

Source: Researchers' Extract from SPSS 25.0 Result, 2022.

From the estimated regression relationship in **Table 5**, the regression line is:

$$FDL = 19.921 + 0.194TSM$$

The regression result shows that thunderstorms with a coefficient value of 0.194, a t-statistic value of 5.375 > 2 and an associated probability value of 0.000 < 0.05 exert a significant positive influence on flight delays at Murtala Mohammed International Airport, Lagos. Specifically, a 1% increase in the number of occurrences of a thunderstorm would lead to about 19.4% increases in flight delays at the airport.

The goodness of fit of the model as estimated by R-Squared (R2 = 74.3%) indicates that the explanatory power of the model is high, thereby confirming that the linear model is a good one for estimating the relationship between the occurrence of thunderstorms and flight delays at Murtala Mohammed International Airport, Lagos, for the period of study. In the same vein, the Durbin-Watson statistics which takes care of the residual statistics uncovered that the model is free from first-order autocorrelation problems. This is because, DW stat. = 1.420 is closer to 2 than to zero.

Table 6. Regression estimate for FDS and TSM.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	26.195	4.787	5.472	0.000
TSM	0.043	0.024	1.745	0.112
R^2 = 23.3%				
DW stat. = 1.254				

Source: Researchers' Extract from SPSS 25.0 Result, 2022.

From the estimated regression relationship in **Table 6**, the regression line is:

$$FDS = 26.195 + 0.043TSM$$

As shown in the regression line, a thunderstorm with a coefficient value of 0.043, a t-statistic value of 1.745 < 2 and an associated probability value of 0.112 > 0.05 has an insignificant positive influence on flight diversions at Murtala Mohammed International Airport, Lagos. From the coefficient result, a 1% increase in the number of occurrences of a thunderstorm would lead to about a 4.3% increase in flight diversions at the airport.

The R-Squared (R2) estimate shows that flight diversion did not have a good linear relationship with a thunderstorm. In other words, a thunderstorm is not a direct factor causing the diversion of flights at Mohammed International Airport, Lagos, as only about 23.3% of the total variations in flight diversions at the airport can be explained by a thunderstorm. The rest 76.7% are attributable to other factors not present in the model. More so, the Durbin-Watson statistic value of 1.254 is closer to 2 than to zero, an indication that the model is free from first-order autocorrelation problem.

Table 7. Regression estimate for FCL and TSM.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	18.232	3.120	5.843	0.000
TSM	0.071	0.016	4.425	0.001
R^2 = 66.2%				
DW stat. = 1.612				

Source: Researchers' Extract from E-views 10 Result, 2022.

From the estimated regression relationship in **Table 7**, the regression line is:

$$FCL = 18.232 + 0.071TSM$$

The regression result as presented in **Table 7** shows that thunderstorms with a coefficient value of 0.071, a t-statistic value of 4.425 > 2 and an associated probability value of 0.001 < 0.05 exert a significant positive influence on flight cancellations at Murtala Mohammed International Airport, Lagos. From the result, a 1% increase in the number of occurrences of a thunderstorm would lead to about a 7.1% increase in flight cancellations at the airport.

In the content of the regression result, the goodness of fit (R-Squared) estimate of 66.2% indicates that about 66.2% of the total variations in flight cancellations at Murtala Mohammed International Airport, Lagos, can be explained by a thunderstorm. The model, therefore, is not a bad one for estimating the relationship between the occurrence of thunderstorms and flight cancellations at Murtala Mohammed International Airport, Lagos, for the period of study. The Durbin-Watson estimate of 1.612 is closer to 2 than to zero, and therefore confirmed that the model is not affected by the serial correlation problem.

4. Conclusions and recommendation

For the annual trend, the study shows that between the years 2001 and 2003, there was an upward movement in the occurrence of a thunderstorm, while it declined in the year 2004 down to 2005. However, from the year 2006 through the year 2020, there was an up-and-down movement in the annual occurrence of a thunderstorm at Murtala Mohammed International Airport.

The monthly statistics of the occurrence of thunderstorms indicate that from January through June, the number of occurrences of a thunderstorm at the airport increases. However, in the month of July and August, it drops and rises again in September. From October through December, the frequency of occurrence of a thunderstorm at the airport drops greatly. The study however shows that thunderstorm is most experienced at the airport in June and less experienced in January and December during the year.

The result reveals that from the year 2008 to 2020, Murtala Mohammed International Airport in Lagos experienced an average of 52.75 ± 23.14 flights that were delayed; an average of 30.17 ± 8.91 number of flights were cancelled; and an average of 33.42 ± 9.08 number of flights were diverted. However, the study developed regression models that could be used for predicting flight diversions, delays and cancellations at the airport. Based on the findings, the study recommends consistent thunderstorm observation at the airport and steady forecasts using the regression models. Furthermore, more research on thunderstorms is also needed, particularly in Nigeria and other tropical nations that experience thunderstorms more than elsewhere on the globe.

Conflict of Interest

There is no conflict of interest.

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