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Assessment of Thunderstorm-Related Flight Disruptions and Airport Preparedness in Nigeria: A 35-Year Retrospective Study

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Abstract

This study assesses the impact of thunderstorms on flight operations and the preparedness of airports in Nigeria over a 35-year period. Air transport plays a crucial role in economic development, yet it is frequently disrupted by adverse weather conditions, particularly thunderstorms. These meteorological events lead to significant delays, cancellations, and diversions in flight schedules, posing safety concerns for passengers and operational efficiency. The research employed an ex post facto study design, utilizing both primary and secondary data. Primary data were collected through structured questionnaires distributed to operational staff at six major international airports, while secondary data were sourced from the Nigerian Aerospace Management Agency. The analysis revealed a concerning trend of increasing flight disruptions, particularly at Lagos and Abuja airports. Although there were no thunderstorm-related crashes reported, the rising number of delays and cancellations undermines passenger confidence and operational stability. Hypothesis testing indicated that thunderstorms do not significantly predict flight disruptions, with an adjusted R^2 of -0.021, suggesting

that other factors might play a more critical role. The study highlights significant gaps in airport preparedness, despite the existence of weather monitoring systems and emergency training programs. Recommendations include enhancing airport infrastructure, improving weather forecasting technologies, and establishing robust communication networks among stakeholders. The findings suggest a comprehensive approach to mitigate the adverse effects of thunderstorms on aviation in Nigeria, thereby ensuring safer and more reliable air transport.

Keywords: Thunderstorms, Flight disruptions, Airport preparedness, Nigeria, Aviation safety, Weather forecasting

Introduction

Air transport is the key propeller of global economic progress through efficient movement of goods, services, and people across distances. It is also a foundation for international trade, tourism, and communication, particularly in developing nations that aim for economic integration. Although crucial, the reliability of air transport is frequently disrupted by adverse weather conditions, with thunderstorms being among the most disruptive. Such meteorological disturbances have the potential to lead to long-duration flight delays, cancellations, diversions, and even crashes, hence compromising passenger safety as well as operational effectiveness (Jardines et al., 2023). Thunderstorms are particularly hazardous to air travel due to the combination of heavy rain, gusty winds, lightning, hail, and turbulence. Such weather events not only present hazards to aircraft during flight but also lead to grounding operations such as take-off, landing, and refuelling operations. In areas where thunderstorms are common, such as in the tropics, their cumulative effect on airport operations can be severe, impacting airline timetables and increasing maintenance and operating costs (Oo, Jonah & Oo, 2023). The effective handling of such weather-related disruptions depends on accurate meteorological forecasting, strong airport facilities, and well-coordinated emergency readiness plans. These include early warning systems, crisis management protocols, and exhaustive training of airport employees to respond promptly in the event of storm incidents. Doppler radar has significantly improved real-time weather tracking, thus enhancing operational decision-making and safety margins (Kim et al., 2024).

In Africa, the aviation industry has experienced substantial growth owing to economic development and rising demand for domestic and global connectivity. The majority of countries on the continent are, however, marred by infrastructural and meteorological service deficiencies that constrain them from responding to weather-related risk.

Nigeria, the most populous country on the continent and one of the leading aviation centers, boasts several congested airports that often struggle with seasonal thunderstorms, particularly during rainy seasons. Such storms tend to be disruptive to flight schedules and are a serious safety concern (Onwuadiochi, Egede & Udeogu, 2023; Hosea, 2019).

Despite the growing menace, there are few empirical studies that have assessed the long-term patterns of thunderstorm-induced disruptions in Nigeria or the preparedness level of airports to address them. In spite of some attempts at modernizing infrastructure and upgrading meteorological facilities, widespread fears remain about the scope of preparedness initiatives at the airports nationwide. Others include the presence of real-time weather observation networks, the firmness of emergency response infrastructure, and the degree to which training is provided to personnel (Hsu, Chang, Li & Liou, 2024). As Nigeria's aviation sector is projected to grow, there is increasing need to understand the impact of weather conditions, especially thunderstorms, on air transport. The socio-economic impact of disruption to flights is significant: it results in a financial loss for airlines and airports, destroys the confidence of passengers, and leads to cascading delays in regional and international networks. Airport resilience has to be increased, therefore, through better forecasting, more efficient infrastructure, and coordinated emergency planning to ensure continuity, safety, and efficiency in Nigerian airspace (Odiase, Wilkinson & Neef, 2019). This study, therefore, seeks to analyze thunderstorm-caused disturbances within Nigeria's air transport industry over a 35-year period and assess the level of preparedness among sampled airports. Through a consideration of both past trends and feedback from organizations, the study seeks to develop evidence-based guidelines to enhance Nigerian airports' ability to manage weather issues effectively. Thunderstorms remain one of the world's most dangerous aviation threats, and in the Nigerian situation, where the climate is lively and air traffic is growing, the imperative of evidence-driven interventions is both timely and urgent.

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The Study Area

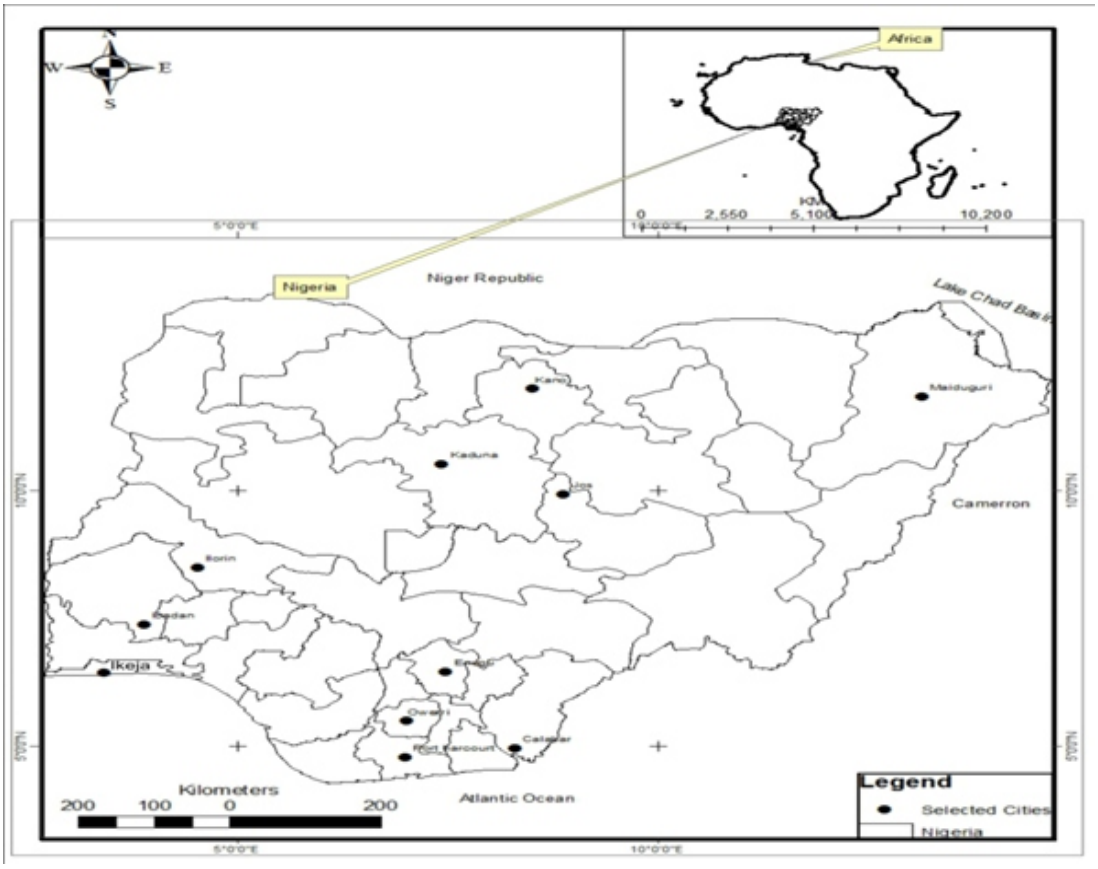

Figure 1. *Nigeria Showing the Geopolitical Zones and Selected Airport Locations*

Nigeria is in West Africa between latitudes 4°16′N and 13°52′N and longitudes 2°49′E and 14°37′E, covering a total area of approximately 923,768 km². Nigeria borders Benin to the west, Niger to the north, Cameroon to the east, and the Atlantic Ocean to the south. The country is made up of 36 states and the Federal Capital Territory, which are all grouped into six geopolitical zones: North Central, North East, North West, South East, South South, and South West. All these zones have their own peculiar climate and ecological conditions which determine the patterns of thunderstorms. In the south, you'll experience heavy rainfall and more intense storms, while it is drier in the north with shorter rain periods and fewer storms. The physical features, such as the Jos Plateau, Mambilla Plateau, and Niger-Benue River Basin, also play a significant influence on the weather in their vicinities. For the inclusion of this variability, airports within each of the zones were selected, for example, Lagos, Port Harcourt, Enugu, Abuja, Kano, and Maiduguri. These locations are key ecological and climatic conditions across the country and serve as reference sites for the study of thunderstorm behaviour over the

past 35 years (1989–2023). This national monitoring allows for spatial assessment of thunderstorm activity and helps to promote improved aviation safety and weather forecasting.

1. Materials And Methods

The study employed an ex post facto study design and sought to investigate the impact of thunderstorms on flight operations in selected major airports in Nigeria. The design was suitable since it studied past facts and operation outcomes that covered 35 years. Six international airports were chosen since they had been in operation for over 35 years, as per the length of the climate data employed. Both primary and secondary data were utilized. Primary data were gathered through structured questionnaires that were given to operational staff and operations directors of the six airports: Murtala Muhammed International Airport (Lagos), Nnamdi Azikiwe International Airport (Abuja), Mallam Aminu Kano International Airport (Kano), Port Harcourt International Airport (Rivers), Akanu Ibiam International Airport (Enugu), and Kaduna International Airport (Kaduna). 50 questionnaires were handed out purposively. Secondary data came from the Nigerian Aerospace Management Agency (NAMA), e.g., daily flight reports and operational statistics on thunderstorm-related delays, cancellations, and diversions.

The collection tools used were the completed questionnaires and NAMA historical data. Thunderstorms were classified as rain-influenced if they met the following: (i) wind gust below 23 knots, (ii) presence of thunder within 15 minutes after rain, and (iii) up to 1–2 hours storm duration. Observations on flight operations for a period of 35 years were analyzed in order to identify the impact of thunderstorms on air traffic activity. In addition, four operations directors who are officials of the Federal Airports Authority of Nigeria (FAAN) were purposively selected to provide expert opinions. Their expert opinions enriched the study with contributions to operational interruptions linked to thunderstorms. Data analysis involved frequency and percentage in their roles of counting up flight interruptions while the bar charts were used in visualization. Likert-scale responses were examined with the mean and standard deviation for readiness and mitigation levels across airports, and the hypothesis developed, which states that flights cancelled, delayed, diverted or crashed do not significantly depend on thunderstorms in Nigeria in the past 35 years, was tested using Multiple Linear Regression (MLR). The mathematical model for MLR is given by the equation below:

$$Y=\beta0+\beta1X1+\beta2X2+\beta3X3+\cdots+\beta nXn+\varepsilon$$

Where:

Y = Dependent variable (outcome or response variable)

$\beta0$ = Intercept (constant term)

$\beta1, \beta2\ldots, \beta n$ = Regression coefficients for each independent variable

$X1, X2\ldots, Xn$ = Independent (predictor) variables

ε = Error term (residual)

This formula explains how the dependent variable Y changes in relation to changes in the independent variables X1, X2..., Xn. All data were processed using the Statistical Package for the Social Sciences (SPSS).

4. Results and Discussion

4.1 Thunderstorm-Related Flight Disruptions at Nigerian International Airports (35-Year Review)

The analysis of thunderstorm-related flight disturbances in some Nigerian international airports shows an increasing trend in flight delays, diversions, and cancellations over the past 35 years. At Abuja Airport, flight delays increased with a rate of 160.48 cases per year, with the highest number reported between 2009 and 2019 (Figure 2). Flight cancellations also grew with an average annual rate of 51.04 cases during the period of review. Despite these interruptions, there were never any thunderstorm-related crashes.

Lagos Airport was most affected by disruptions, with delays in flights increasing by 192.40 cases per year (Figure 3). Cancellations of flights, just like delays, also increased by 87.09 cases per year. Flight diversions that also fluctuated had a steady annual increase of 14.28 cases. Although notable aircraft accidents such as the Dana Air Flight 992 crash occurred in 2012, these were not necessarily associated with thunderstorms. Port Harcourt Airport flight disturbances were prevalent, such as delays and cancellations, which grew by annual growth rates of 95.33 and 45.67 cases, respectively (Figure 4). The 2005 Sosoliso Airlines Flight 1145 crash under stormy weather brought up an issue of storm-related danger in aviation at the airport.

Delays at Enugu Airport increased by 63.29 cases annually, and flight cancellations also increased steadily to 39.81 cases (Figure 5). Diversions were comparatively less common than those at Lagos and Port Harcourt. Flight disruption at Kano Airport was low, with delays increasing by a rate of 48.22 cases annually and cancellations by 28.19 cases (Figure 6). While there was a fatal plane crash in 1956, this was not connected to thunderstorms. Kaduna Airport experienced the lowest number of disruptions compared to the airports covered in this study, with delays increasing at a rate of 21.10 cases per year and cancellations at 11.89 cases per year (Figure 7). The recent crash of the 2021 Nigerian Air Force Beechcraft King Air off the coast of the airport has not been certified as storm-related.

From these findings, the maximum increase in flight delays and cancellations every year was recorded for Lagos Airport and the lowest for Kaduna Airport over the examined period.

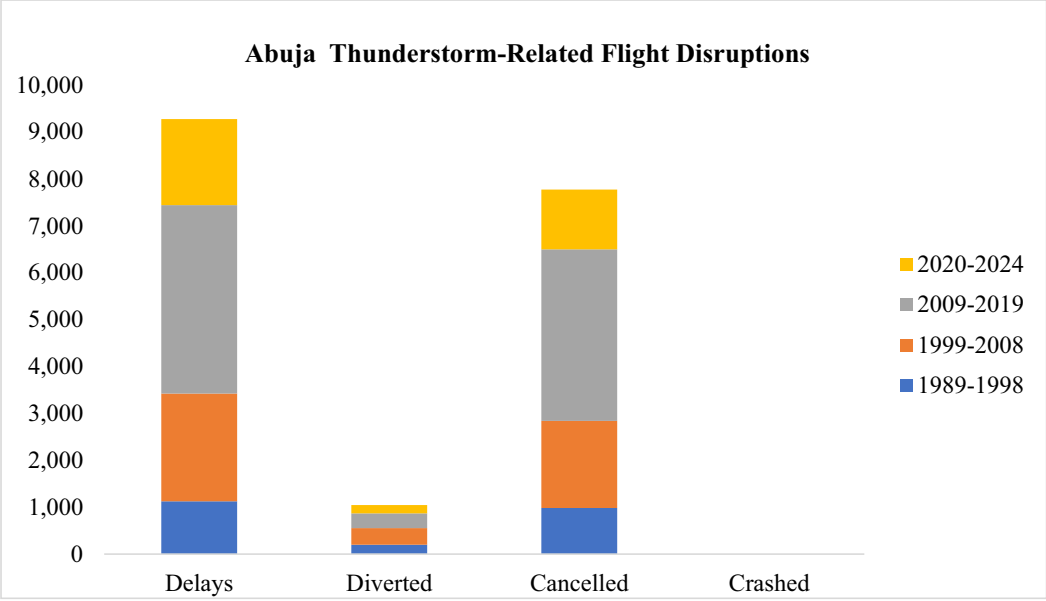

Figure 2 *Trends in Flight Disruptions at Abuja Airport (1989–2024)*

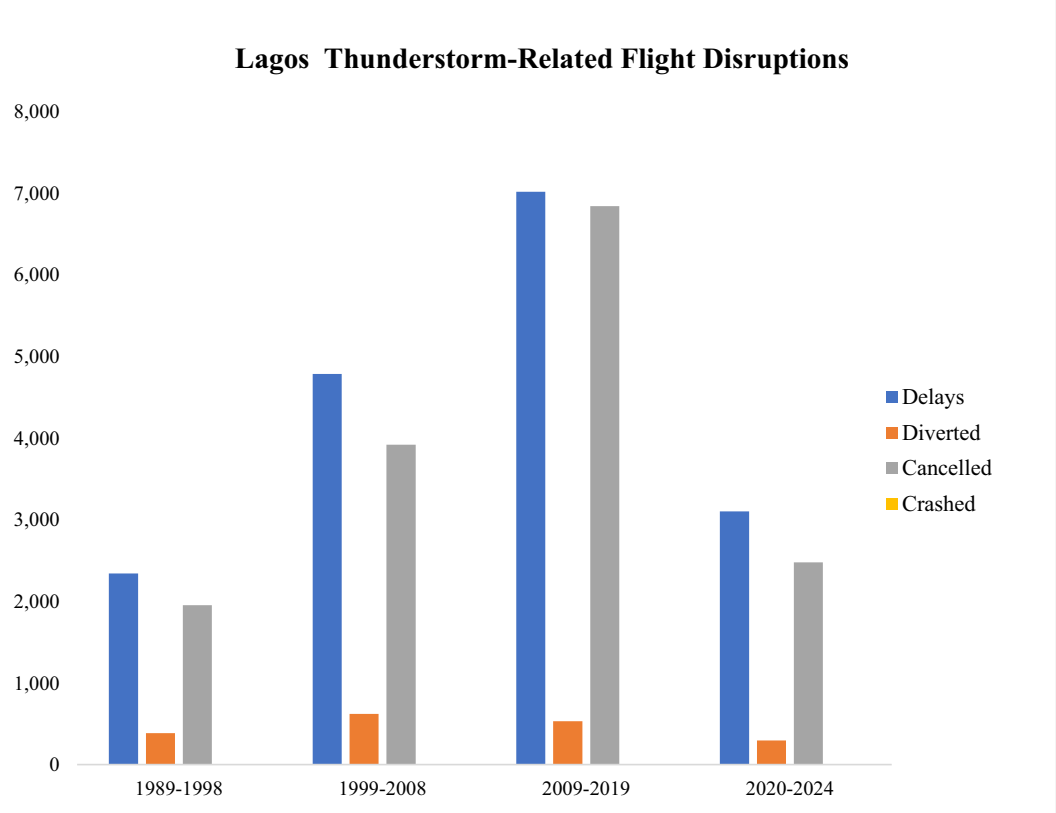

Figure 3 Trends in Flight Disruptions at Lagos Airport (1989–2024)

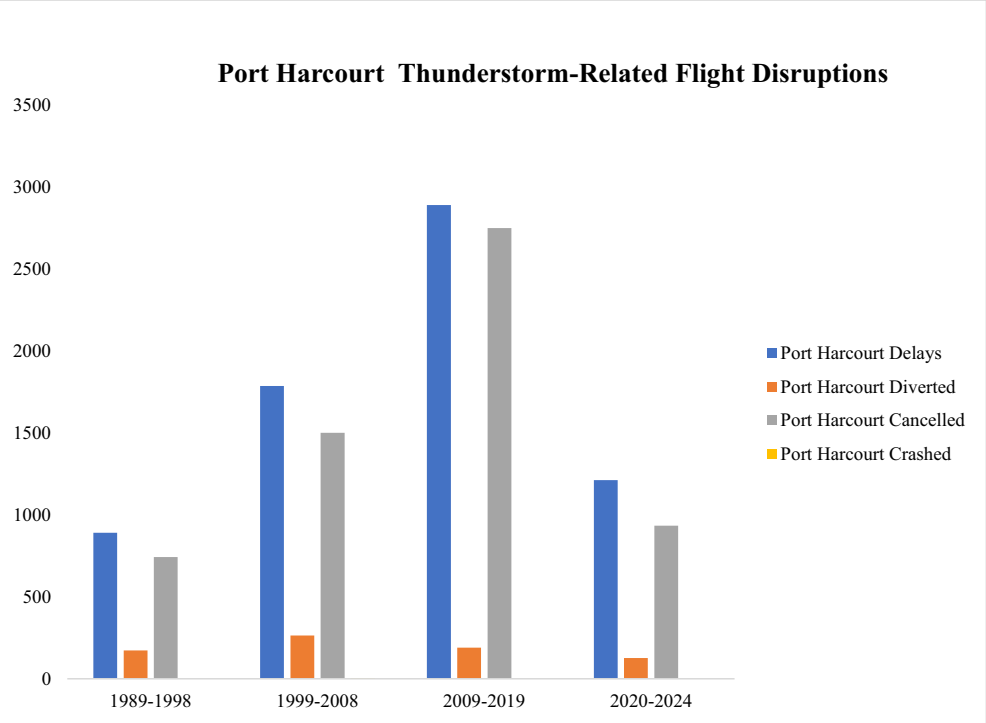

Figure 4 Trends in Flight Disruptions at Port Harcourt Airport (1989–2024)

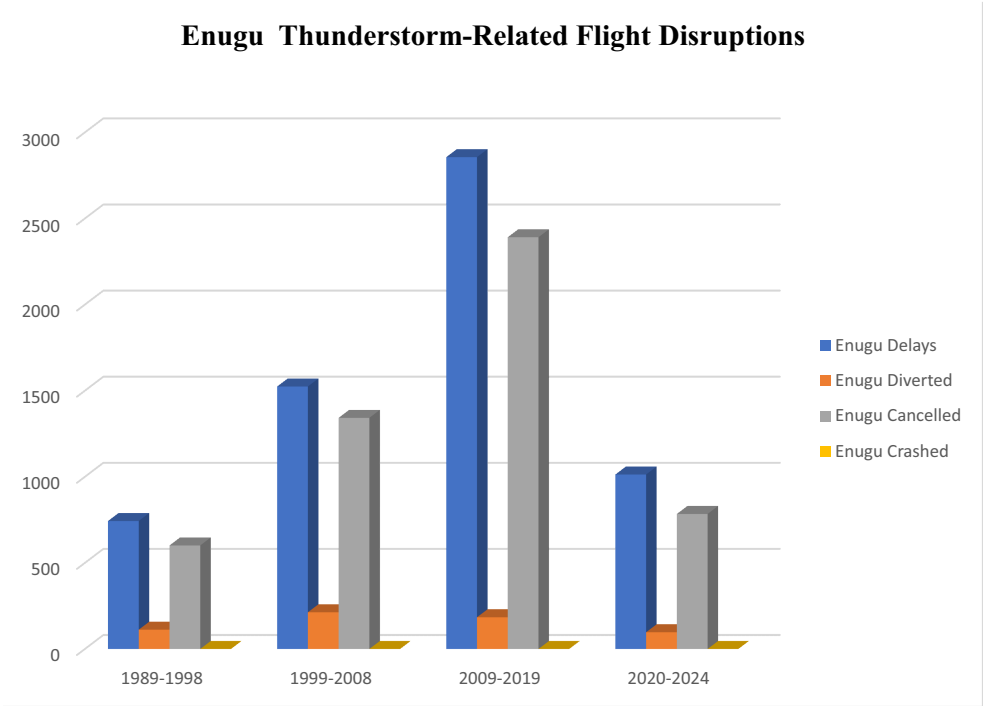

Figure 5 Trends in Flight Disruptions at Enugu Airport (1989–2024)

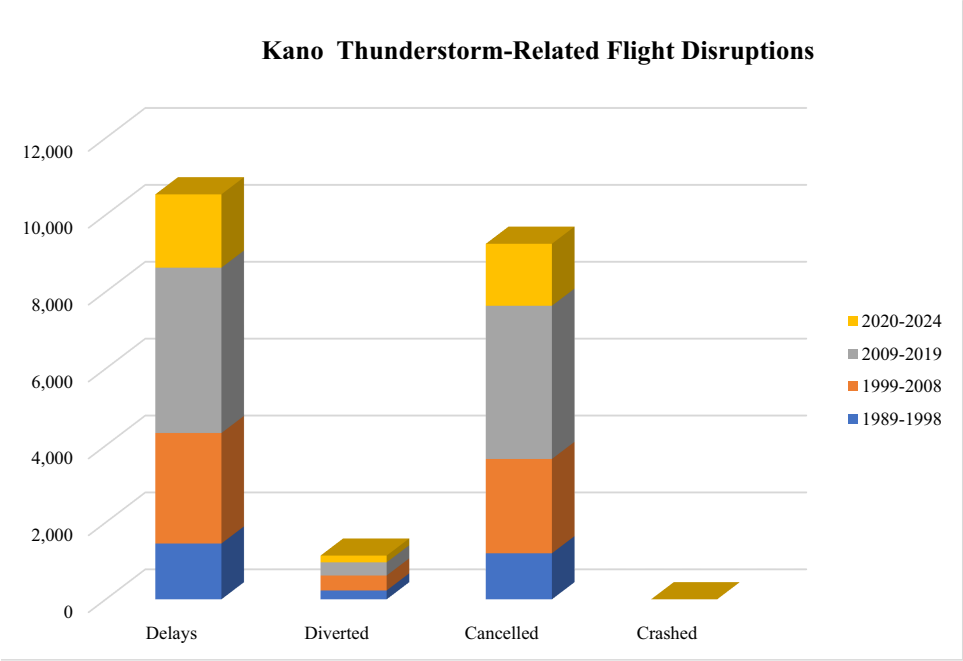

Figure 6 Trends in Flight Disruptions at Kano Airport (1989–2024)

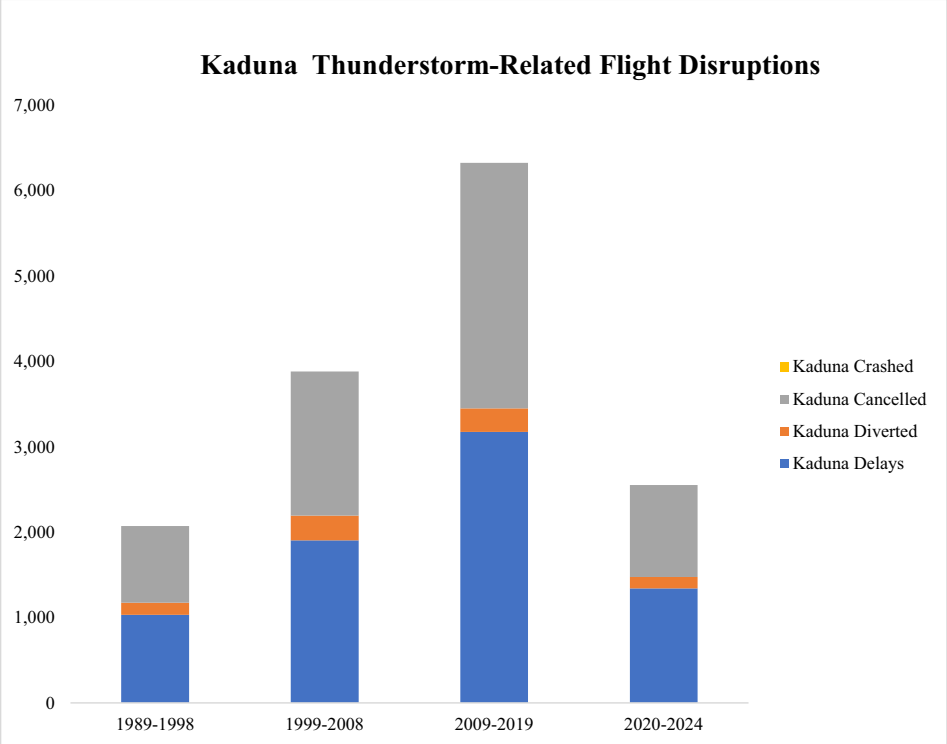

Figure 7 Trends in Flight Disruptions at Kaduna Airport (1989–2024)

Test of Hypothesis

H01: Flights cancelled, delayed, diverted or crashed do not significantly depend on thunderstorms in Nigeria during the past 35 years.

Table 1 indicates that the coefficient of determination (R^2) is .157. This implies that 15.7% of the variance in flights cancelled, delayed, diverted, or crashed by thunderstorms in Nigeria for 35 years is explained by variation in predictor variables. However, adjusted R^2 is negative (-.021), implying that the model might not have good explanatory power once the number of predictors is being controlled. The standard error of estimate is 1.763, which is the average difference in observed and estimated values in the model. This means that thunderstorms do have an effect on flight cancellations, delays, diversions, or crashes in Nigeria but with greater overriding influence from other non-explained factors.

Table 1: Model Summary of the Flights cancelled, delayed, diverted or crashed due to thunderstorms in Nigeria during the past 35 years

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.396	.157	-.021	1.763

a. Predictors: (Constant), Crashed, Cancelled, Diverted, Delays

Table 2 shows that the F-value of 0.882 is insignificant at 0.493. This indicates that the regression model does not account for the variations in flights cancelled, delayed, diverted, or crashed due to thunderstorms in Nigeria over the past 35 years substantially. The null hypothesis of no linear relationship between flight disruptions and the predictor variables cannot, therefore, be rejected. This indicates that thunderstorms by themselves might not be good predictors of such disruptions in flights, and other variables should be included to make a wider assessment.

Table 2: Analysis of variance of regression of Flights cancelled, delayed, diverted or crashed due to thunderstorms in Nigeria during the past 35 years

Model		Sum of Squares	df	Mean Square	F	Sig.
	Regression	10.961	4	2.740	.882	.493
	Residual	59.039	19	3.107		
	Total	70.000	23			

a. Dependent Variable: Airports

b. Predictors: (Constant), Crashed, Cancelled, Diverted, Delays

Table 3 shows individual predictors' contributions to flight disruptions by thunderstorms in Nigeria for the last 35 years. The findings indicate that all the predictor variables do not have statistically significant relationships with the dependent variable (airports). Specifically, there are delays (Beta = -2.355, t = -1.056, p = .304), delayed flights (Beta = -0.050, t = -0.113, p = .911), canceled flights (Beta = 2.235, t = 1.083, p = .293), and crashed flights (Beta = -0.135, t = -0.492, p = .629), all of whose p-values > 0.05, and thus their effects on airport operations are insignificant.

These findings suggest that thunderstorms alone do not significantly influence flight cancellations, delays, diversions, or crashes in Nigeria. Other determinants, such as airline policy, legal system, efficacy of air traffic control, and airport infrastructure, may be more important in determining flight disruptions and should be investigated further.

Table 3: t-values of regression of the Flights cancelled, delayed, diverted or crashed due to thunderstorms in Nigeria during the past 35 years

Coefficients						
		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	4.707	.949		4.960	.000
	Delays	-.003	.003	-2.355	-1.056	.304
	Diverted	-.001	.006	-.050	-.113	.911
	Cancelled	.003	.003	2.235	1.083	.293
	Crashed	-.696	1.415	-.135	-.492	.629
a. Dependent Variable: Airports						

4.2 Preparedness of the airports for thunderstorms in Selected International Airports

Figures in Table 4 indicate the mean scores and standard deviation of airports' readiness for thunderstorms in some selected international airports in Nigeria. From the table, the respondents agreed that the Nigerian airports are well-furnished with the weather monitoring system to observe thunderstorms (M = 2.87, SD = 0.994) and that pilots and air traffic controllers are well-informed about weather activities of thunderstorms (M = 2.86, SD = 0.905).

Also, the findings reveal that aviation personnel are also regularly trained in thunderstorm emergency response (M = 3.66, SD = 0.559) and that airport infrastructure is highly capable of withstanding weather impacts from thunderstorms (M = 3.38, SD = 0.897). In addition to this, airlines also have flight disruption management plans in the

event of thunderstorms (M = 3.10, SD = 0.772) and communication between meteorological agencies and aviation stakeholders' functions during thunderstorms (M = 3.67, SD = 0.530).

A grand mean of 3.26 shows that, overall, the respondents attested that Nigerian airports' preparedness for thunderstorms is adequate.

Table 4: Mean ratings and standard deviation on the Preparedness of the airports for thunderstorms in Nigeria

Preparedness of the airports for thunderstorms in selected international airports in Nigeria

S/N	Variables	$\overline{X}$	S.D	Remark
7.	Nigerian airports have adequate weather monitoring systems to track thunderstorms.	2.87	.994	Accepted
8.	Pilots and air traffic controllers receive sufficient weather updates on thunderstorm activities.	2.86	.905	Accepted
9.	Aviation personnel are regularly trained in emergency response during thunderstorms.	3.66	.559	Accepted
10.	Airport infrastructure is well -equipped to withstand adverse weather caused by thunderstorms.	3.38	.897	Accepted
11.	Airlines have contingency plans to manage flight disruptions due to thunderstorms.	3.10	.772	Accepted
12.	Communication between meteorological agencies and aviation stakeholders is effective during thunderstorms.	3.67	.530	Accepted
	Grand mean	**3.26**	**.776**	**Accepted**

Source: Survey Data 2023

4.3 Mitigation and adaptation options to the effects of thunderstorms on aviation in Nigeria

Figures in Table 5 show the mean scores and standard deviation on the mitigation and adaptation options to the effects of thunderstorms on aviation in Nigeria. As seen in the table, the respondents agreed that several strategic measures should be put in place to address the consequences of thunderstorms on aviation operations. Specifically, the provision of improved radar facilities at all Nigerian international airports to improve thunderstorm forecasting (M = 3.76, SD = 0.428) and investment by airlines in improved flight scheduling to minimize disruption (M = 3.59, SD = 0.492) were ranked highly.

Further responses suggest that better coordination between meteorological agencies and airports would mitigate thunderstorm impacts (M = 3.48, SD = 0.501) and that more

frequent training of airport personnel and pilots on procedures for dealing with thunderstorms is necessary (M = 3.88, SD = 0.329). Respondents also supported the establishment of passenger awareness campaigns to inform travelers about thunderstorm-caused delays and safety measures (M = 3.38, SD = 0.506) and demanded that the regulatory bodies implement stricter weather preparedness policies for airlines and airports (M = 3.76, SD = 0.428).

The grand mean of 3.64 indicates that, in general, the respondents strongly agreed that there is a need to put in place effective mitigation and adaptation strategies to manage the effects of thunderstorms on aviation in Nigeria.

Table 5: Mean ratings and standard deviation on the mitigation and adaptation options to the effects of thunderstorms on aviation in Nigeria

Mitigation and adaptation options to the effects of thunderstorms on aviation in Nigeria				
S/N	**Variables**	$\overline{X}$	**S.D**	**Remark**
13.	Advanced radar systems should be deployed in all Nigerian international airports to improve thunderstorm forecasting.	3.76	.428	Accepted
14.	Airlines should invest in improved flight scheduling to minimize disruptions caused by thunderstorms.	3.59	.492	Accepted
15.	Enhanced coordination between meteorological agencies and airports will help mitigate thunderstorm impacts.	3.48	.501	Accepted
16.	Pilots and airport personnel require more frequent training on thunderstorm management protocols.	3.88	.329	Accepted
17.	Passenger awareness programs should be implemented to educate travellers on thunderstorm -related delays and safety measures.	3.38	.506	Accepted
18.	Regulatory bodies should enforce stricter weather preparedness policies for airlines and airports.	3.76	.428	Accepted
	Grand mean	**3.64**	**.447**	**Accepted**

Source: Survey Data 2025

Discussion

The assessment of thunderstorm-induced flight disruptions and airport preparedness in Nigeria reveals significant challenges to the aviation sector over the past 35 years. The findings indicate a troubling upward trend in flight delays, cancellations, and diversions due to thunderstorms, particularly at major international airports such as Lagos and Abuja. This aligns with previous research highlighting the adverse impact of severe weather on air operations (Zhang, Wen & Wang, 2024; Onwuadiochi, Egede & Udeogu, 2023). While advancements in weather forecasting technologies have been made, the physical and operational readiness of Nigerian airports remains below international standards (Garba et al., 2022; Olabode, 2021).

The study further reveals notable gaps in airport preparedness. Although some measures, such as weather observation systems and emergency response training, are in place, there is a pressing need for enhanced infrastructure and coordinated communication strategies among stakeholders. The findings underscore the necessity of not only upgrading technological capabilities but also fostering a culture of preparedness and resilience within the aviation sector (Prihartanto, Rohman, Putu & Wiguna, 2023; Zhou & Chen, 2020).

From a health and safety perspective, the absence of serious crashes directly linked to thunderstorms is encouraging. However, the increasing frequency of flight disruptions poses concerns for passenger confidence and financial sustainability (Zhou & Zhang, 2024; Lee, 2023). Addressing these challenges requires a comprehensive and prioritized policy response that tackles both operational and infrastructural deficiencies in mitigating the adverse effects of thunderstorms on aviation.

Conclusion

In conclusion, the study reveals that while thunderstorms significantly affect flight operations in Nigeria, the preparedness of the airports for managing the disruption remains low. The increasing trend of flight delays and cancellations compromises the safety and confidence of passengers and needs urgent attention towards infrastructure development and emergency planning strategies. Resolving these problems entails a three-fold approach that includes harnessing the latest technology, extensive training of aviation personnel, and improved communication between meteorological offices and airport authorities. Implementing these initiatives ahead of time will render Nigeria's aviation sector more resilient to thunderstorm-related disruptions, which will mean safer and more reliable air transport.

Recommendations

Based on the findings of this study, the following recommendations are proposed to enhance airport preparedness and mitigate the impact of thunderstorms on aviation in Nigeria:

i. Local and federal governments should prioritize investments in airport infrastructure to improve resilience against adverse weather conditions. This includes upgrading runway systems, enhancing drainage capabilities, and implementing advanced weather monitoring technologies.
ii. Regular training programs for aviation personnel should be established to ensure they are well-prepared for emergency situations related to thunderstorms. This includes simulations and drills to improve response times and effectiveness.
iii. Airports should develop robust communication networks to ensure timely dissemination of weather updates and operational changes to all stakeholders, including airlines and passengers.

4. Airlines and airport authorities should develop and regularly update contingency plans to manage flight disruptions effectively. This includes establishing protocols for passenger care during delays and cancellations.
5. Strengthening partnerships between airports and meteorological services will enhance the accuracy of weather forecasts and improve the overall response to thunderstorm events.
6. Implementing public awareness campaigns about the potential impacts of thunderstorms on air travel can help manage passenger expectations and improve overall satisfaction with the aviation experience.

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