Modelling of Aircraft Delays in Akure Airport

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ABSTRACT

As the economy of any nation grows, globally it also affect the rate of movement from one country to the other, whereby causing the increase in traffic and also delays in some facilities that should be accessed. Delay is a prominent event mostly experience at airport by both airlines and passengers. This study investigated if there are delays in Akure airport, secondary data were used for the study, data ranging from January 01, 2023 to March 31, 2023, the data were extracted from NCAA and FAAN records, nine hundred aircraft movement records combined for both arrival and departure were extracted respectively. Queue models were developed to ascertain the through situation of arriving aircraft traffic and departing aircraft. The result of the study reveal that there was no issue of delays for departing traffic in Akure Airport, Therefore, it can be concluded that the Akure Airport, is a transit or receiving airport with low aircraft traffic due to highly spaced headways and frequency of service in Akure airport, the study recommends that the state government should boost economic, commercial and tourism activities that will enhance air traffic so that the airport can have more patronage. It was also recommended that the state can float its own airline (carrier) so that the airport can become a hub for operations within a 24-hour period.

Keywords: Modelling, Aircraft, Delays, Airport, Passengers

INTRODUCTION

The study of aircraft delays at the airport has become a significant area of research due to the increasing volume of air traffic and the economic consequences of delays. Recent studies have focused on leveraging advanced machine learning models and big data to improve the accuracy and reliability of delays predictions. Aircraft delays can result from a range of factors, which include weather condition, air traffic congestion, and operational inefficiencies, which affect both passengers and airlines. These delays are not only costly for airlines but also leads to passenger's dissatisfaction and broader economic impacts, including disruption to tourism and business sectors. Air transport is relatively expensive when compared with other modes of transportation like water, road and rail system respectively. Aviation industry plays important role in providing for the world economies by providing the vital connectivity on the regional, national and the international scale. Air transportation support long-term economic growth, it facilitates country integration into global economy, provider direct benefit to the users and wider economic benefits through its positive impact on productivity and growth. One of the main challenges facing the aviation industry is to develop air infrastructure capacity to meet demand; by reducing flight delay which is one of the key performance indicators (KPI) for aviation industry. Traffic delay is experienced whether in the departure (enplanement), enroute (flight) or arrival stage (deplanement) of flight operations.

If an aircraft arrives late at its destination, the delayed inbound flight may not only be delayed on its next flight leg but it may also affect other flights within the airline network, which could reduce the network load factor of the airline and also affect the use of the ramp by other airlines. Consequently, it is difficult to apply an analytical method to model the dynamics of system-wide delays. There are also a large number of factors that result in flight delays Cheng, Zhang, Hao, Liu, Luo and Lou, (2019). Apart from the direct costs imposed on the airline industry and its customers, flight delays have indirect effects on the national economy. Specifically, the role it plays toward inefficiency in the air transportation sector therefore increases the cost of doing business for other sectors, making the associated businesses less productive. There are vast records of flight delays at many commercial airports all over the world. The study developed queuing model to predict the different possibility of subsequent delays and the numbers of passengers that could be delayed at any point in time in the selected airport. It is on this background that the study seek to address the problem with the following objectives.

1. develop a queue model for aircraft movements in Akure airport.
2. determine the length of arrivals and departure delays in the study area;

LITERATURE REVIEW

Scarce resources, human, material and time and the increase in the level of activities, which further competes with tight schedule and the need to be safety and security conscious in the aviation industry, there is an increased call for prediction of aviation resources deployment and management. This has led various studies to consider diverse ways to predict so many issues and activities in the sector. Such prediction can include and not limited to runway usage, delays, traffic throughput, possibility of the occurrence of accidents or air crashes, resource utilization and so and so forth.

Different research has been carried out and much literature has been written to address the prediction of flight delays via its causal factors and these predictions are being carried out either by statistical analysis or used machine learning algorithms to analyze air traffic management actions and achieve the prediction of GDP incidence Liu et al. (2019). used a generic algorithm to fit delay data and study long and short flight departure trends. The model included seasonal influences, daily trends, and random trends, enabling users to grasp general delay characteristics. Through econometric analysis of the contribution rates of various factors to delays, the model explained more than 72% of the variation in the average if flight delay information can be accurately obtained in advance. Therefore, the important significance of flight delay prediction has prompted researchers to try various methods to achieve higher precision on a larger scale Alice, (2017), delay used econometric and simulation models to calculate and decompose delays, considering the controllable factors that can cause flight delay such as demand and arrival rate. However, the prediction results consisted of statistical guidance rather than tactical operation. Machine learning (ML) and Deep learning (DL) are developing rapidly to predict possible flight delay. Manna, Biswas, Kundu, Rakshit, Gupta, and Barman, (2017), In their work divided flight delay data into temporary such as day of the week, month of the year, and time of the day and spatial data such as the state of delay and type of delay. They used a random forest model to predict departure delays in the next two hours, with an average error of about 21min on the test dataset. However, some only conducted a sensitivity analysis of the influencing factors and not the primary factors or time points of delays. Manna *et al.* (2017) used the gradient booted decision tree model (GBDT) to predict the delays of flight with six controllable factors.

Ai, Pan, yang, Wa, and Tang., (2019) used a convolutional LSTM algorithm to analyse the flight delay distribution, considering factors such as pre-order flight delays, route congestion and airport capacity. Hao et al. (2021) make a multi-step prediction of airport delay with spatio temporal data.

The analysis of flight delays and discovery of influencing factors are becoming more and more detailed. Li, and Jing., (2021) combine several machine learning and deep learning methods with information on weather, airport and factors that influence flight delay and regress airport delays. Some scholars also built eight widely used modes including linear regression, non-linear regression models, and tree base assemble model, and they found that if the feature set could capture the arrival characteristics, even simple linear regression model or algorithm could fulfil the prediction task. Muilti-airport delay prediction needs to consider high data dimension such as origin-destination (OD) data between airports.

Factors that Causes Delay at the Airport

Weather: landing and Take Off are subject to weather conditions. If there is a bad weather and if the airport lacks the basic navigational and visual aids flight is always delayed. The airline will be forced to delay its movement since visibility is very paramount to Take Off and Landing, it can be risky for planes to Take Off or Land during a bad weather condition though it take extreme weather condition like hurricane, thunderstorm, snowstorm, wind shear, icing and fog or blizzard to delay aircraft from taking off and most of the air flyers are already know the implication of bad weather event in the cause of flying which can result to either delays or even cancellation in some cases. Air traffic Control Restrictions: Air traffic control is responsible for managing the flow of aircraft in the air and on the ground and they can sometime cause delays when there is heavy traffic within the air space, if the flight control is not quite up to date to cope with the traffic. For an aircraft to land at the airport it needs Air traffic control permission with so many aircrafts in the air, sometime the Air traffics control staff need some time to process and follow the right procedure for the safe landing at the airport. Air traffic control procedure and regulations often cause flight delays, especially during the peak travel times. With so many aircrafts in the air, air traffic controller need to prioritize landing and aircraft separation. Late-arriving Aircraft: If a plane runs late, it can cause delays for the subsequent flights on its schedule. This is most common reason for flight delays, the late arrival of aircraft will result to tight schedule of the subsequent flight and late arriving can be as a result of technical issues, weather or other factors that can cause flight delay.

Technical issues: Aircraft are complex machine with many moving parts and sometime, things can go wrong. Maintenance issues, such as problems with the engines or other mechanical components can lead to flight delays. In this case, the airline may need to repair the aircraft and make provision for another aircraft to lift the passengers to their destination without further delay or cancellation. In adequate Staffing: Airlines rely on a large number of staffs to operate flights, including pilots, flight attendants, and ground crew. Issues related to staffing such as sick leave, staff shortage or strike can lead to flight delays.

Overbooking: Sometime, the airlines sell more tickets than their capacity, hoping that some passengers will not show up. However, if everyone does show up, the airline may delay the flight until they can accommodate all the passengers. Connecting flight: If a passenger has connecting flight, a delay on the first flight can cause delays or missed connections on the second flight. Waiting on cargo: Many passenger jets transport additional goods while in the air. Planes attempt to balance things out and maximise the use of space to increase their profitability. They tend to carry goods for money to reduce the cost of flight.

Security: Security incident can cause flight delays. Airport can experience security breaches and passenger safety and security is very important to airline and the airport authority that is why every procedure of checking the passenger before boarding the planes though nobody likes the long queues checking before boarding the plane sometime passenger experience violation of their privacy but the procedure has to be followed to ensure safety.

Aircraft preparation: If it is a turnaround flight, a lot of procedures need to be kept in mind before boarding the next set of passengers. Refueling of the aircraft, aircraft cleaning, the preparation of the beverage, and safety and security are some of the preparation that needs to be done before boarding of an aircraft. Without these mandatory checks, flight will not leave the ground, hence causing delay.

THE STUDY AREA

Akure city is located in Akure South Local government area located in the Central Senatorial District of Ondo state, with over 353,211 populations (National Polulation Commission, 2006). It has a land area of 331km square. The town is located within $7^0 15'$North of the Equator and Longitude $5^0 05'$ East of the Greenwich

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Meridian (Figure 1). Presently, as the state capital of Ondo State, it has only one airport for which is called Akure Airport.

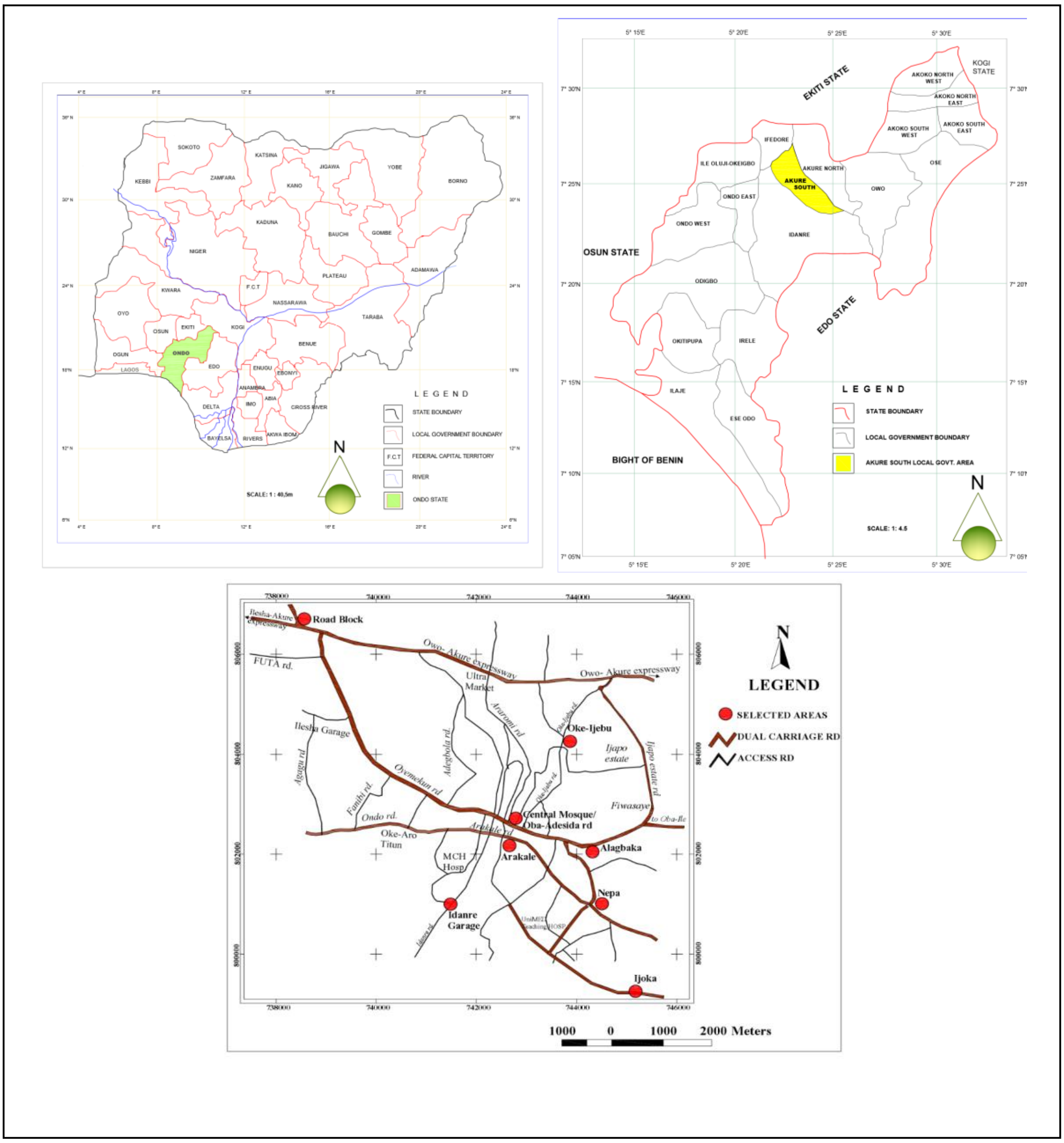

Figure 1: Map showing the study area

Source: Ministry of Works, Akure Ondo State, 2024

METHODOLOGY

The research methodology involves developing of a queue model for the Akure Airport using data of aircraft movements and numbers of passengers enplaned and deplaned over a three-month period from January 01, 2023 to March 31, 2023 using extracted data from NCAA and FAAN records (secondary data). The following were noted for each aircraft movements: operator (airline); aircraft type; estimated time of arrivals; actual time of arrivals; arrivals delays; time between arrivals; number of passengers deplaned (brought in by the aircrafts); estimated time of departure; actual departure time; departure delays; time between departures; number of passengers enplaned (taken away from the study area); difference between deplaned and enplaned passenger for each aircraft; reported and observed causes of delay in arrivals and departures respectively such as bad weather, air traffic congestion at departing airport, and repositioning of aircraft for the journey.

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Research Design

The research design for this study is descriptive and experimental in nature as it attempts to study recorded delays in the boarding process and airport in general and using queue model to assess aircraft movement in Akure Airport. Being a descriptive dataset, the research used mathematical model to depict what is happening in the airports with regards to delays.

Sample Size and Sampling Technique

The study's sample size is the same as the research population since the study is using the records of all aircrafts that called at the airport during the study period.

This simply mean that there is no sampling technique adopted because the entire data retrieved from the records of the Federal Airport Authority of Nigeria for the period were used as recorded.

Assumptions in Model Building

When fitting dynamic models, their theoretical analysis can occasionally inform us of the best model form and the accurate numerical values of the model's parameter. They are:

3.0 the model theory's findings, which are based on the notion that variables are stationary;
4.0 where data is non-stationary, conventional approaches are generally ineffective;
5.0 the data utilised in the model do not contain any white noise;
6.0 the non-stationary nature of the time series may lead to autocorrelation and
7.0 the spurious regression may also be caused by non-stationary time series regress

Model Specification

For objectives one.

Here the various parameter or variable for the formation of the queue models are presented for clear understating. Queues of arriving and departing aircrafts in the study area, their respective queues scenarios can be depicted using the general form for any queue which is denoted by the following variables:

A denotes the distribution of inter-arrival times;

B denotes the distribution of service times;

m denotes the number of servers in parallel;

L_Q = average queue length (average number of aircraft in queue);

L = average system length (average number of aircraft in system, including those being served);

W_Q = average waiting time in queue (average time an aircraft spends in queue);

W = average time in system (average time an aircraft spends in queue plus service)

N = number of aircraft in system ($E[N] = L$);

T = time aircraft spends in system ($E[T] = W$);

m = number of servers;

λ = arrival rate (number of aircraft arriving per unit time);

$\frac{1}{\lambda}$ = mean inter-arrival time;

μ= service rate at one server (number of aircraft served per unit time);

1/μ = mean service time;

$\rho = \lambda/_{m\mu}$= traffic intensity ($\rho < 1$)

σ_a^2 =variance of inter-arrival times

σ_s^2 =variance of service time

$C_a^2 \lambda^2 6_a^2$ = squared coefficient of variation of inter-arrival times

C_s^2 =$\mu^2 6_s^2$ = squared coefficient of variation of service times

For exponentially distributed service times, C_s^2=1, and for deterministic

Service times, C_s^2=0 (similarly for inter-arrival times).

RESULTS AND DISCUSSIONS

Queue models for Aircraft Movement in Akure Airport

For queues of arriving and departing aircrafts in the study area, their respective queues scenarios can be depicted using the general form for any queue which is denoted by the following variables:

A denotes the distribution of inter-arrival times;

B denotes the distribution of service times;

m denotes the number of servers in parallel;

L_Q = average queue length (average number of aircraft in queue);

L = average system length (average number of aircraft in system, including those being served);

W_Q = average waiting time in queue (average time an aircraft spends in queue);

W = average time in system (average time an aircraft spends in queue plus service)

N = number of aircraft in system ($E[N] = L$) =450

T = time aircraft spends in system ($E[T] = W$); = 54 mins

m = number of servers = 1

λ = arrival rate (number of aircraft arriving per unit time); = 1/4hr47min = 1/ ((4*60) +47) = 1/287 = 0.0035

$\frac{1}{\lambda}$ = mean inter-arrival time = 287

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μ= service rate at one server (number of aircraft served per unit time) = 1/54 mins = 0.019

1/μ = mean service time = 54

$\rho = {}^{\lambda}/_{m\mu}$= traffic intensity ($\rho < 1$) = 0.0034843/ (0.01851) = 0.188153

σ_a^2 = variance of inter-arrival times = 0.075800034

σ_s^2 = variance of service time = 0.002652152

Little's Law and general queuing System Relationships (Raton, 2009)

$\left.\begin{matrix} L_q = \lambda W_q \\ L = \lambda W \end{matrix}\right\}$ Little's Law ……………………………………………………5

$L = L_q + \frac{\lambda}{\mu}$…………………………………………………………………….. 6

$L = 1 + \frac{0.0035}{0.019}$ = 1 +0.1842 = 1.1842

$W = W_q + \frac{1}{\mu}$………………………………………………………………………7

$W = 9.02 + \frac{1}{0.019}$ = 9.02 + 52.632 = 61.652 min.

Extension of Little's Law

For the M/G/1 queue, Little's Law L= λWgiven earlier can be extended to higher moments. For the Kth moment.

$E[N(N-1)(N-2)\dots\dots(N-K+1)] = \lambda^k E[T^k]\dots.8$

where

N= number of aircraft in system

T= time aircraft spends in system

Special cases:

$K = 1: E[N] = \lambda E[T](i.e., L = \lambda W)$ … … … … … … … 9

$K = 2: \ E[\,N(N-1)] = \lambda^2 E[T^2]$ … … … … … … … … … … … … … … … … … 10

Hence

$Var[N] = \lambda E\,[T] + \lambda^2 Var\,[T]$ … … … … … … … … … … 11

Formulae for Average Queue Length, $\boldsymbol{L_q}$

$$L_q = \frac{p(pc)^c}{c!\,(1-p)^2 c\mu} P_o + pc$$

Formulae for Average Time in Queue, $\boldsymbol{W_q}$

$$W_q = \frac{(pc)^2}{c!\,(1-p)^2 c\mu} P_o + \frac{1}{\mu}$$

Formulae for Average Time in the Queue plus the service, $\boldsymbol{W_t}$

$$W_t = \frac{(pc)^2}{c!\,(1-p)^2 c\mu} P_o$$

Formula for probability of queuing on arrival, $Q_{\boldsymbol{a}}$

$$Q_a = \frac{(pc)^c}{c!\,(1-p)} P_o$$

Formula for probability of queuing on arrival, $Q_{\boldsymbol{a}}$

$$Q_a = \frac{1-(pc)^c}{c!\,(1-p)} P_o$$

The queue model was used to assess the aircraft movements (incoming and outgoing) for Akure Airport which is the study area.

For objective two:

determine the length of arrivals and departure delays in Akure Airport

Simple descriptive analysis was used and the data collected revealed the average arrival and departure delays in Akure Airport.

Arrival delay is the deference between the actual aircraft arrival in time and date and estimated aircraft arrival in time and date.

Table 4.1: Arrivals Delays

Variables	Value in Time (h/m/s)
Total arrival delays in time	57:16:00
Average arrival delays in time	0:07:38

Source: Authors, 2024

The table 4.1, above shows that the average arrival delay is 7 minutes, 38 seconds, gives the details data analysis of the arrival delays.

Departure delay is the deference between the actual aircraft departure in time and date and estimated aircraft departure in time and date.

Table 4.2: Departures Delays

Variables	Value in Time (h/m/s)
Total departure delays in time	134:06:00
Average departure delays in time	0:17:53

Source: Author, 2024

The table 4.2 above shows that the average departure delay is 17 minutes, 53 seconds.

CONCLUSION AND RECOMMENDATION

This study considered the movement of aircraft in Akure Airport, length of arrival and departure delays experience by passengers. Queue model was develop to provide insight into possible causal factor of delays in the study area and the following are the findings, it was revealed from the data collected and the analysis performed, that aircraft movement in the study area can be modeled to predict arrival and departure delays in the study area and the model also provided the insight on the possible causal factor of the delay in the study area. The finding also reveal that the total arrival delay in time within the period of study was 57hours, 16minute and the average delay in time within the period of study was 7minute, 38 seconds. What this means is that the delays as has already happed before arrival at the Akure airport and this confirmed Akure airport as a transit airport. It also shows that the total departure delay in time within the period of study was 134hours, 6minute and the average delay in time within the period of study was 17minute, 53 seconds. This also confirmed that no delays happed on the departure at the Akure airport and this confirmed also that Akure airport is a transit airport. The study recommend that the state can float its own airline (carrier) so that the airport can become a hub for such an airline and seize being a mere transit airport where passengers can at least travel out and into the state within a 24-hour period

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