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Airside Capacity Utilization in a Nigerian Airport: A Case Study of Murtala Muhammed International Airport

Stephens, M. S
Department of Transport Management Technologyn
Federal University of Technology Akure, Nigeria
E-mail: msstephens@futa.edu.ng

Ayo Agunbiade O.T
Department of Transport Management Technology
Federal University of Technology Akure, Nigeria
E-mail: ayofisayo90@gmail.com

Abstract
Airport Capacity generally refers to the ability of an airport to handle a given volume of traffic (demand) and should be assess to ensure they are adequate for lay down Standards. This study was based on the assessment of Airside Capacity Utilization at an International Airport; the Runway is the focus of this study. Capacities are very important and this dictates the level of patronage made by airlines at the Airport. Murtala Mohammed International Airport (MMIA) as a case study was examined; the domestic and international traffic flow well assessed on a daily basis, over a period of sixteen (16) years, to determine the traffic intensity of the airport was obtained from Federal Aviation Authority of Nigeria (FAAN) and Nigerian Airspace Management Agencies (NAMA). This experimental research involved the estimation of the traffic flow, installed capacity of the Runway, the intensity of traffic on hourly, daily, monthly bases. The model adopted for the research was Queue Theory. Findings show that the domestic wing generates more traffic flow than international wing of the Runway. The through put at the Runways shows that the runway is adequately utilized to accommodate existing traffic, expansion in the form of construction will not be necessary.

Keywords: Runway, Arrivals, Departures, Traffic, Intensity.

I. Introduction
Aviation operation over the years has been on the increase over time with various flights emanating from different part of the country for different purposes. Mike (2008) stated that over 22,000 turbine-powered airliners are in service worldwide. Flight can be boarded for a number of reasons, some of which are business, recreational, educational, occupation, medical, relief efforts etc. For these diverse purposes there arises the need for flight planning. Flight planning is the process of producing a schedule of activities and paths describing a proposed aircraft flight for the aircraft being booked for various purposes. Air traffic service uses the complemented flight plan and available capacity for separation of aircraft in air traffic management (Simpson, Bashroum and Carr, 1965). Capacity generally refers to the ability of an airport to handle a given volume of traffic (demand). There are two commonly used definitions of airfield capacity: "throughput" and "practical" capacity. The through put definition of the capacity is the rate at which aircraft can be handled while practical capacity is the number of operations (takeoffs and landings) that can be accommodated with no more than a given amount of delay.

The capacity of an airport is a bit complex, several elements of the airport facility have to be examined, namely the airside and landside. The physical characteristics and layout of runways, taxiways and apron are basic determinants of the ability to accommodate various types of aircraft and the rate at which they can be handled. Also important is the equipment (lighting, navigation aids, radar and the likes) installed on the airfield as a whole or a particular segments. Due to constraints of limitation of time and other resources this study is limited to the airside components, with more concentration on the runways as the capacity of the airport to consider.

Antonio (2003) reveals that there are several factors affecting runway capacity such as runway configuration (number of runways in use, location of runway exits etc.), aircraft mix (percent of aircraft in various wake vortex categories), weather conditions (visibility, wind direction and speed), airport equipage (ATC equipment) and operating procedures (noise considerations, special approach and departure procedures). The rules and procedures of air traffic control, intended primarily to assure safety of flight, are basic determinants of airfield capacity and delay. The rule governing aircraft separation, runway occupancy, spacing of arrivals and departures, and the use of parallel or converging runways can have an overall effect on throughput or can induce delays between successive operations. When the traffic demand for an airport approaches or exceeds its capability, the result is delay.

When traffic occurs in bunches or peaks, there may be delays even when the number of aircraft using the airport is less than the capacity for that peak time period. Some amount of delay arises every time two aircraft are scheduled to use a runway at the same time. The probability of simultaneous arrivals increases rapidly with traffic density, so that average delay per aircraft increases exponentially well before traffic levels reach capacity levels. There are other factors instituting delay apart from simultaneous arrivals in airline operations. For instance, demand(through put) to available capacity of an airport might result in delay if not balanced.

From 2005 to 2007, the Nigeria aviation industry experienced some growth, which resulted in a passenger movement increase by 21 per cent in 2008, cargo movement increased by 74.6 per cent and aircraft movement improved by 2.3 percent (Olalerin, 2009). Due to the large traffic volumes, high frequencies and traffic intensity at hub stations flight operations at these hubs becomes very dangerous and more tasking as airport capacity cannot increase immediately to meet the change in demand. A problem of flight operations, planning and handing calls for serious concern and this research attempted to studied the arrival and departure of aircraft and their characteristics, to know the throughput per day/the traffic intensity for peak and off peak period were the gaps addressed to understand the flight planning procedure and handing of aircrafts in the airport of study.

In summary, the research have provided an accurate overview of the literature related to aircraft flight scheduling and capacity utilization by building upon the sections addressing this topic in the literature reviews by Antonio (2003) which reviewed the Airport Runway Capacity and the methodology deployed in the research was time space analysis, finding shows that the separation capacity of the airport depends on the configuration used. Jianfeng (2012), carried out a research on analysis of gate-waiting delays at major US Airports and identified that 30% of the arriving aircraft are delayed at the Gate, waiting delays are rare events, gate-waiting delays are usually different among major carriers due to different scheduling strategies and functional origins of gate-waiting delay included compressed arrivals, extended gate occupancy times, reduced number of gates, and inflexible queuing disciplines (across carriers and within one carrier), jianfeng 2012was majorly on conditions of US airport and its recommendation. These research conducted a field based qualitative research and quantitative research on the assessment of the airside capacity utilization at the airport at Murtala Muhammed Airport.

The aim of the article is to assess airside capacity utilization in the Murtala Muhammed International Airport, Lagos, Nigeria. To achieve this aim, the following objectives are to assess airsides capacity utilization; and to evaluate the aircraft traffic intensity of the runways.

2. Theoretical Framework

Analytical Model is easier and faster to execute, is good for preliminary airport/ airspace planning and the generally less accurate but appropriate. Examples of Analytical model are:

- Time-Space Analysis
- Queuing Models

2.1 Time Space Analysis

Time space analysis is a simple technique to assess runway and airspace capacity if the headway between aircraft is known. It is a method to ascertain the time complexity and space complexity of an algorithm. Time complexity is a measurement of how much computational time an algorithm uses as its input size changes. Analyzing algorithms in this way provides an indicator as to how quickly the runtime increases, how it does so in relation to the input and weather the algorithm is costly for small/large inputs (Trani, 2013).

2.2 The Basic Queuing Process

The basic process assumed by most queuing models is the following. *Customers (Passengers)* requiring service are generated over time by an *input source.* These Passengers enter the *queuing system* and join a *queue.* At certain times, a member of the queue is selected for service by some rule known as the *queue discipline.* The required service is then performed for the customer by the *service mechanism,* after which the customer leaves the queuing system. Input source (Calling Population), one characteristic of the input source is its size. The size is the total number of customers that might require service from time to time, i.e., the total number of distinct potential customers. This population from which arrivals come is referred to as the calling population. The

size may be assumed to be either infinite or finite (so that the input source also is said to be either unlimited or limited). Because the calculations are far easier for the infinite case, this assumption often is made even when the actual size is some relatively large finite number; and it should be taken to be the implicit assumption for any queuing model that does not state otherwise(Fredick, 2001).

2.3 Airport System

Airports activities are diversified and descends from nature of airports' operations, which involve both airside and landside services. In addition, non-aeronautical commercial businesses including revenues from retail activities and license allotment to external operators supplying ship, restaurant, duty-free, car parking services, etc. are assuming growing importance. This gives rise to the strategic opportunity for an airport to focus on traditional airside activities or to enter commercial activities, which are not traditionally considered as core business (Oum*et al.*, 2004).

The basic functions of an airport are to provide access for aircraft to the national airspace, to permit easy interchange between aircraft and to facilitate the consolidation of traffic. To effectively deliver these functions, an airport must have several basic infrastructure elements present such as runway, taxiways, aprons (airside infrastructure) and airport ground resources for passengers or cargo. The ground resource elements as well as airside infrastructure capacity dictate the airport's air traffic capacity.

2.4 Concept of Airport Capacity and Capacity Utilization

Infrastructure capacity development is necessary in determining the operational efficiency of an airport. Caves *et al.* (1984) and CCSF (2003) opines that capacity can conceptualize based on the area or field of study. Capacity according to TRB (2004) refers to the ability of an airport to handle a given volume or magnitude of traffic (demand) within a specific period of time. It was further emphasized that, operational capacity is generally expressed by the maximum number of units or demand that can be accommodated at an airport during given period of time and under given conditions.

3. Research Method

This study relies on secondary data sourced from the Federal Airport Authority of Nigeria (FAAN), Nigeria Airspace Management Agency (NAMA) and Nigeria Civil Aviation Authority (NCAA).The data obtained were records of flights over a period of sixteen (16) years. To address the first objective, the installed airside capacity, and the hourly and daily traffic movements were examined. Daily traffic flow for two months and report of flight delay for a month were obtained. Queue theory was deployed for the second objective which estimates the traffic intensity of the runway.

Queue theory is the process whereby customer enters a system and service is being rendered. For this research the customer in passenger's aircraft and cargo aircraft, the input source is the gate, the queue discipline is mostly First to Come First Serve, Last in last out and emergency and the size is the total number of the aircraft per day for a period of 2 months.

- Arrival Rate $=\lambda$
- Service Rate $=\mu$
- Utilization Rate $=\lambda/c\mu$

4. Results and Findings

4.1 Assessment of Airside Capacity Utilization

The elements of airside capacity are the Runway, Taxiways, Aprons, Gates and Hydrant pump. For this research Runway is the point of consideration. The runway capacity was assessed in-line with daily throughput of both domestic and international runway. MMIA formerly West African Airways Corporation in 1947, later Lagos International Airport, the airport consist of international and domestic terminal, initially uses the same Runway until it was separated. The runway is the major capacity being assessed in the study. There are two runways at the airport, one for the international and domestic flight.

The runway orientation for international flight is 18Right-36Left and the runway for local flight is 18L-36R.There are two major flows of aircraft traffic; the inbound and the outbound traffic. The dimension of each domestic and international runway is 2743 X 45m and 3900 X 60m respectively. They both have asphalt concrete. The critical designed aircraft, the runway and the apron can accommodate at a time is B747 Concord. For the installed runway capacity, the runway is designed to accommodate 1 aircraft in 7 minutes.

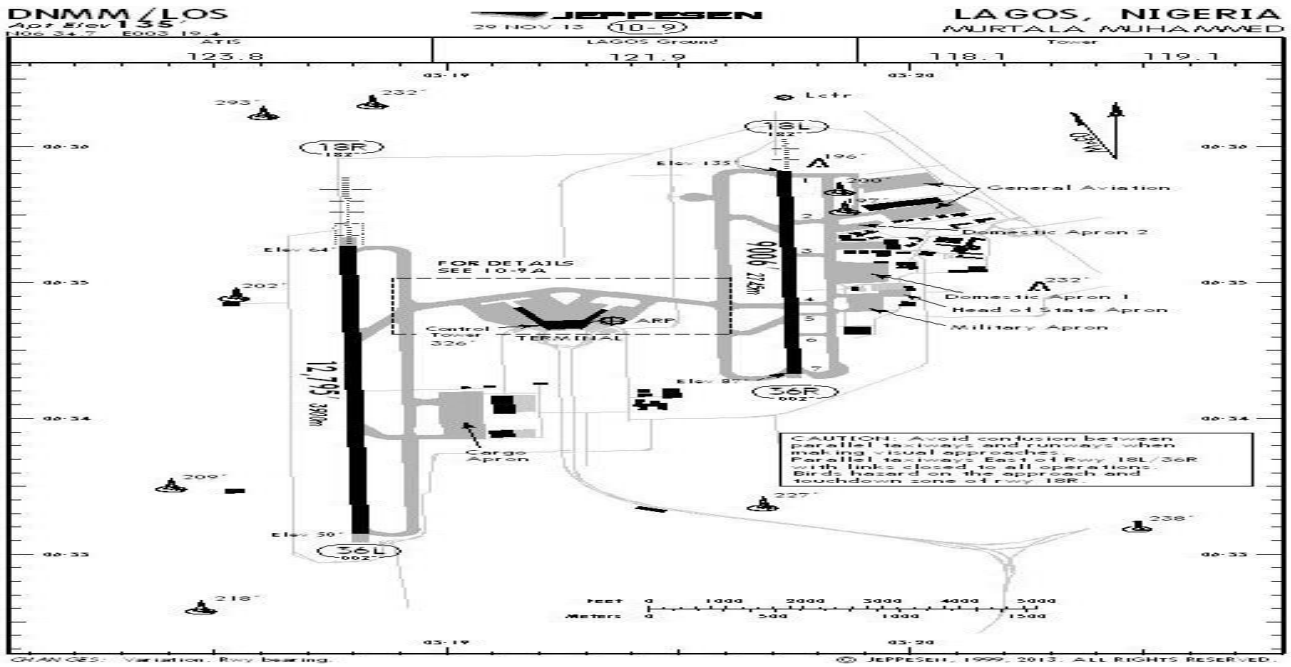

Figure 1:MMIA Runway
Source: Jeppesen, 2013

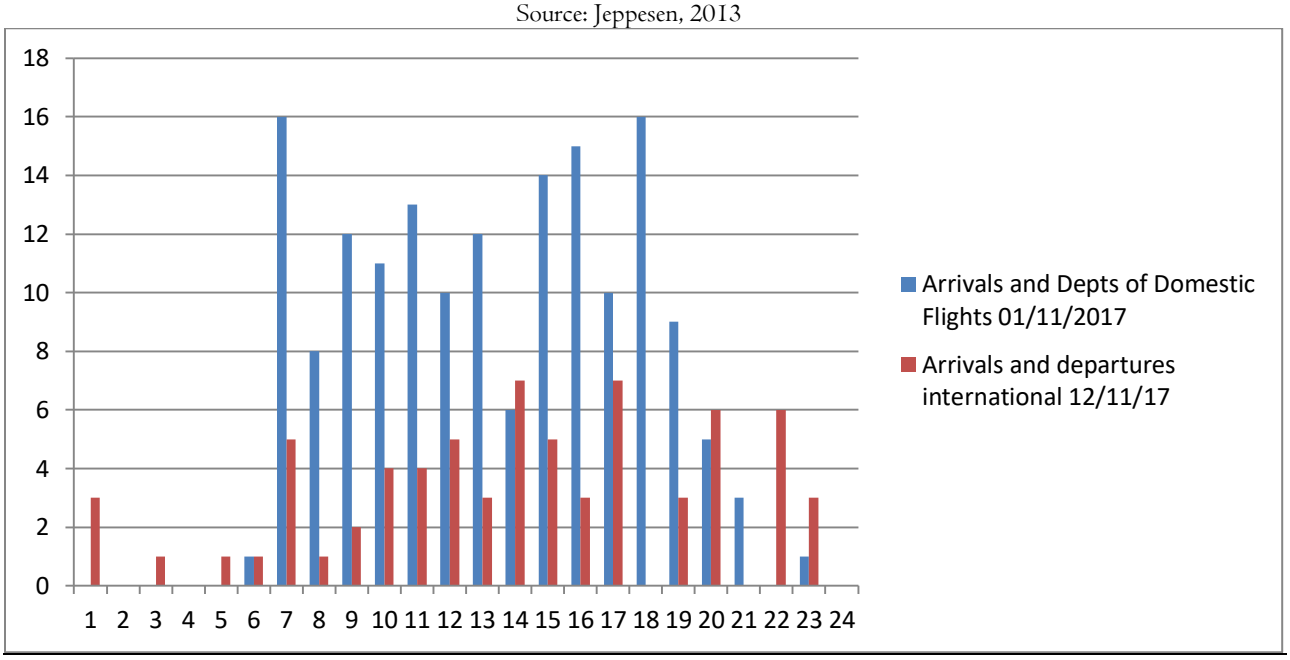

Figure 2: Arrivals and departures of domestic and international flights for 01/11/17
Source: Author's Compilation, 2018

From Figure 2 the operation started around 5am to 11pm but traffic is more intense with a traffic flow of 16 flights per hour. The highest throughput is between (7, 16,18) hours with (16,15,16) throughput respectively, the throughput is higher than the installed capacity of the Runway. For international flights, in figure 2, the operation started around 1am to 11pm but traffic is more intense with a traffic flow of 7 flights per hour. The highest throughput is between 14 and 17 hours with 7 through-put respectively, the throughput is lower than the installed capacity of the Runway.

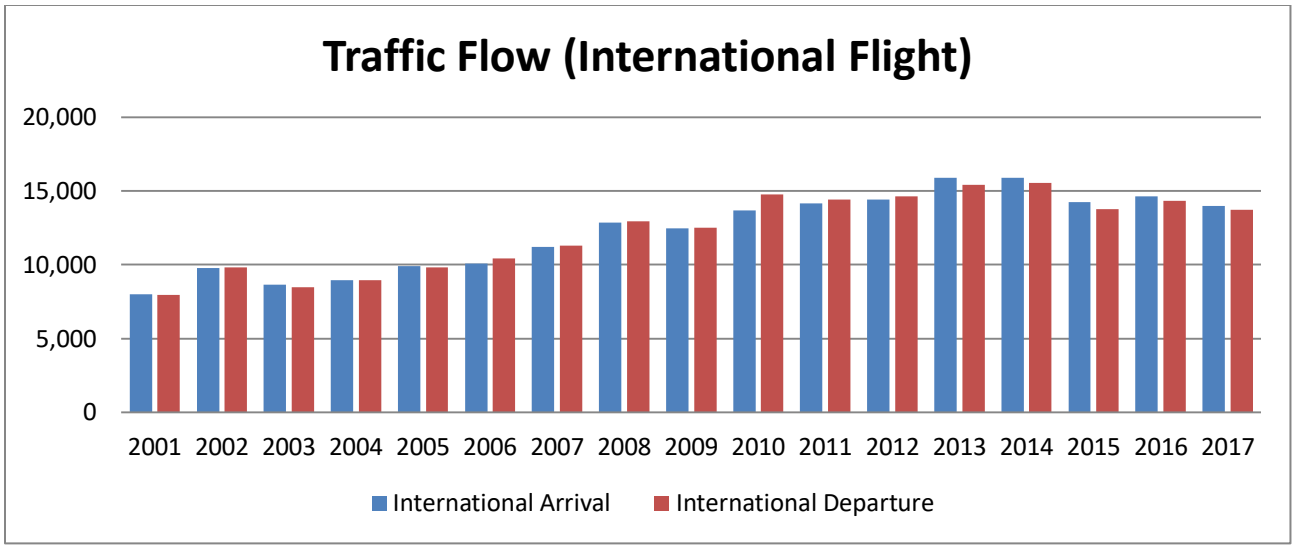

Figure 3: Arrivals and Departure of International Flight 2001-2017
Source: Author's Compilation, 2018

From figure 3, the trend depicts that, the rate of arrival of international flight increased from 2000 to 2010, reduced in 2011 to 2012 by certain percent, and later improved in 2013 by certain percent, and there has been decline since 2015 till 2017by certain percent. The reduction in flight might be attributed to various factors such has financial constraints, lack of satisfaction in service provided, for domestic flights the incessant delay experienced by passenger and a number of other factors which have made passenger opt for other modes of transport, but the fact remains that the capacity is utilized hourly, daily, monthly and annually.

Airside capacities can be categorized into three categories based on capabilities:

- Analyses of the runway component
- Analyses of the runway and apron components
- Analyses of the terminal airspace.

The flow follows FSFC except in situation of special scenarios of emergency or government movement. The aircraft movement follows the FCFS model.

Figure 3 establishes the fact that the domestic and international runways are utilized but rate of utilization differs from each other. From figure 2, the throughput for domestic flow is higher than international flow. Which confirms that the aircraft utilization of domestic is higher than international, therefore the capacity at the domestic wing requires more attention in terms of planning, upgrading, repair and other necessary maintenances required. The rate of utilization occurs more in the day than in the night. The runway is designed to accommodate 1 aircraft in 7 minutes. On the domestic wing of the airport, the number of aircraft arrival and departure are more than installed capacity therefore, the airport is operating within its capacity that is, it is moderately serving demand. In figure 2, on the 7th hour 16 aircraft landed and departed within an hour.

4.2 Evaluation of Air Traffic Intensity

Queues at airport operate on a FIFO strategy, the capacity of an airport is influenced by the capacity of the runway. For simplicity, the following assumptions are made Koopman (1972) and Bookbinder (1986). During peak periods on a single runway, controllers will alternate between landing and takeoffs to increase throughput. In contrast during off peak periods, they will assign to landing a non-preemptive priority over takeoffs. These assumptions enable a clearer cut difference between the heavy and light traffic behavior of the runway operations, another reason to conduct a separate analysis between the peak and off-peak periods.

During peak periods, the terminal area's control zone is heavily crowded with landing and takeoff aircrafts. During the peak period the aircraft handled are more than those handled during the off peak period. The time between arrivals is shorter for peak period. Arrival has been known to follow a Poisson process while the service time follows a general distribution. The aircraft requesting service will be referred to as a customer while the gates is the server. During off peak Period the customers follow normal arrangement. Time between arrival=second flight - first flight. From this formula we were able to deduce the time between arrivals of aircraft as they arrive at the airport.

From appendix, aircraft beyond 1hour interval of arrival flight is just 3 that is, 6% of the whole distribution. The time between arrivals are usually (2, 4, 5, 14, 40) minutes interval. There is an average of 87 arrivals and 81 departures on daily bases, at the domestic airport of MMA.

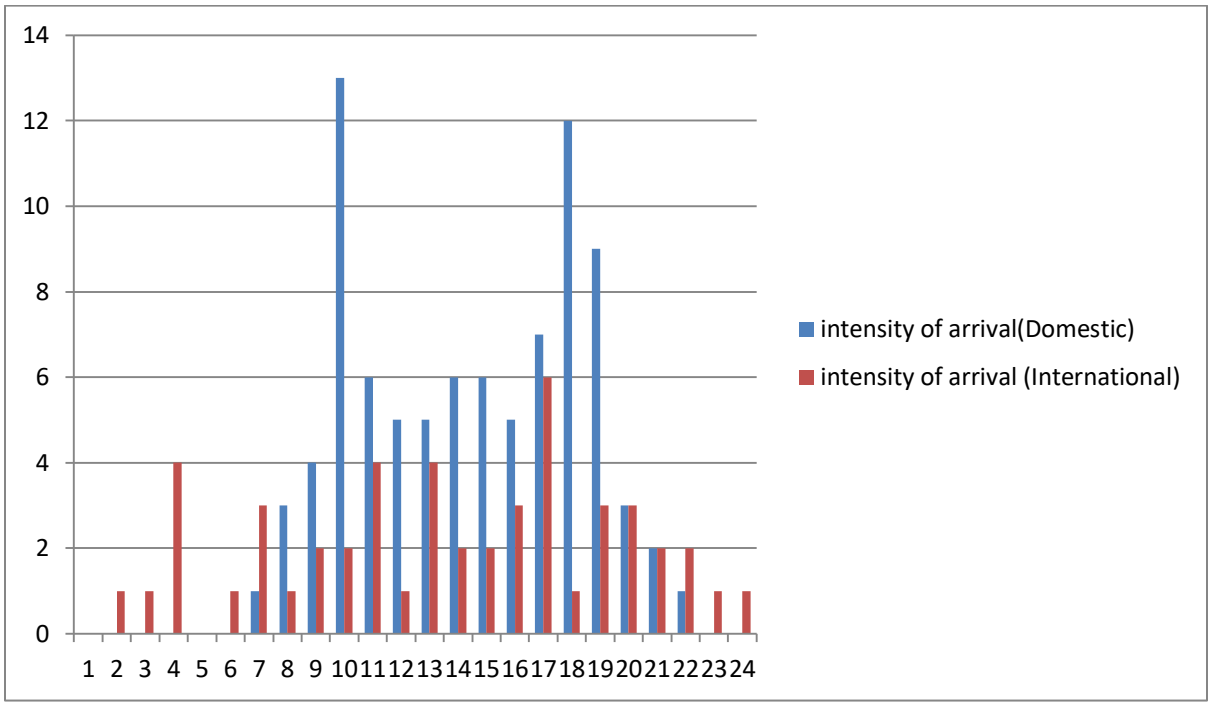

Figure 4: Intensity of Arrival for Domestic and International Flight
Source: Authors' Compilation, 2018

The Peak Period from figure 4 states that for arriving aircraft is between 10 am to 7 pm, while the off peak is between 8pm to 9am.

4.3 Time between Arrival and Departure of International Flight

Time between arrival = Actual Time of Arrival for second flight (ATA_2) - Actual Time of Arrival for first flight (ATA_1)
From this formula, deduction was made on the time between arrivals of aircraft as they arrive at the airport.

Aircraft beyond 1hour interval of arrival flight is just 3 that is, 6% of the whole distribution. The time between arrivals are usually (2, 4, 5, 36, 1:57) minutes interval. There is an average of 49 arrivals and 46 departures on daily bases at the international airport of MMIA. From figure 4, the peak period for arriving aircraft is between 4am to 10pm, while the off peak is between 11 pm to 3 am. The traffic for 4am, 11am, 1pm and 5pm are specifically higher than other parts of the day.

Table 4 Result of Queue Theory Calculation for Domestic Airport (MMA) 1/12/17

		1/12/17	Dec,2017 (Domestic)	December, 2017 (International)
1	Total Time Between Arrival	14:40	1:10	
2	Total Service Time	914:52:00	3:56	2:46
3	Total Number of Aircraft	88	2085	1470
4	Arrival Rate, λ=number of planes served/total time between arrival	144.00	1029888:00	8467200:00
5	Service rate(at the Airport), μ=number of planes served/total service time	2.31	305475:15	19:22
6	Traffic Intensity=$\lambda/c\mu$ (c=10)	6.23	3:37	27:66

Source: Authors' Compilation, 2018

For Dec. 1, 2017 as shown in table 4, the Average time between arrivals is 14 hours 40 minutes on daily bases, with the total service time being 914 hours 52 minutes. On this particular day the total number of aircraft is 88, with most of their arrivals in the morning, aircraft arrival beyond 12am in the mid-day will result in the aircraft departure on the following day. The arrival rate is 144, the service rate is 2.31 and the overall traffic intensity is 6.23.

For December 2017, the average time between arrival for domestic flight is 1hour, 10minutes on a daily bases, with the service time being 3 hours, 56 minutes, which happened on December, 2017. The total number of aircraft is 2085 with most of their arrivals in the morning; aircraft arrival beyond 12am in the mid-day will result in the aircraft departure on the following day. The arrival rate is 1029888:00, the service rate is 305475:15 and the overall traffic intensity is 3:37.

For December, 2017, the Average time between arrival of international flight is 6 minutes on a daily bases, with the service time being 2hours 46minutes. The total number of aircraft is 1470, with most of their arrivals in the morning; aircraft arrival beyond 12 pm in the mid-day will result in the aircraft departure on the following day. The arrival rate is 8467200:00, the service rate is 19:22 and the overall traffic intensity is 27:66. The intensity of domestic traffic is higher than that of international flight. The arrival rate is the total number of aircraft per time between arrivals. The arrival rate for domestic flight is higher than international flight.

5. Conclusion

The rate of arrivals and departures of aircrafts per hour affect the Capacity Utilization rate of the runway. Adequate allowance needs to put into consideration to accommodate changes in subsequent time of arrival and departure, which might affect the turnaround process and scheduling of flight planning.

The intensity of arrivals and departures varies with from the domestic to the international runway. The rate of utilization differs as the domestic wing accommodates more traffic than the international.

It is evident that delay is highly experienced by passengers who utilized the aircraft. Airports staff admits that the capacity of the airport is moderately meeting demand. It was observed that most aircraft follows a regular schedule which is submitted every six Months. This disruption will result in crew, fleet and maintenance schedule.

The aircraft traffic intensity at the airport shows the level of utilization of the airport, during the peak period the time between arrivals for MM2 is lower than that of MM1. The traffic intensity of MM2 is 6.23 and for MM1 1.06. Queue theory was used to analyze the traffic intensity with runway as the service points.

The capacity of the airside has been assessed and it has come to the notice that these capacity are adequately utilized i.e. not underutilized or over utilized but delay actually occur due to disruption in the operation of the aircraft. *It is therefore recommended that the construction of new capacity in Murtala Muhammed International Airport (MMA1) is not advisable as the major cause of disruption is operational, as it is not the lack of capacities e.g. the runway, gates and Hydrant Pump.*

The research recommends that there is a great increase in the global patronage and available disposal of wealth which has made the demand for transport to keep raising, therefore the available airport capacities already in place must be adequately utilized to remain acceptable for the allocated resources to attract more. These capacities depend on schedule, but one disruption or the other arises to alter the schedule and might lead to complains from the passenger and lack of reliability on the airline providing the services. Schedules should be structured in a way to accommodate other form ofdisruptions. Airline should intimate their passenger with reasons for delay.

The Airside capacity should be constantly maintained by contacting NCAA/FAAN to liaise necessary agency to replace fuel hydrants and other capacities, if the old ones will cost a lot of money to be fixed and the supply points should be connected to the airports. The representative of FAAN Management to ensure that action is expedited on the upgrade the Runway 18L/36R (MMIA).For further studies, the period of assessment can be increased from 2months to a year and all the Airport capacity can be assessed.

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