TRANSPORT & *LOGISTICS:*
the International Journal

Article history:
Received 31st July 2020
Accepted 28th December 2020
Available online 30th December 2020

ISSN 2406-1069

Article citation info: Ikeogu, V. N., Ejem, E. A., Okafor, C. L., Chukwu, O. E. Terminal airspace system capacity assessment of Muritala Mohammed International Airport, Ikeja Lagos, Nigeria. Transport & Logistics: the International Journal, 2020; Volume 20, Issue 49, December 2020, ISSN 2406-1069

TERMINAL AIRSPACE SYSTEM CAPACITY ASSESSMENT OF MURITALA MOHAMMED INTERNATIONAL AIRPORT, IKEJA LAGOS, NIGERIA

Vivian N. Ikeogu [1], Ejem A. Ejem [2], Chinenye L. Okafor [3], Oluchi E. Chukwu [4]

[1]Department of Transport Management Technology, Federal University Technology, Owerri, e-mail: viviroseitu234@gmail.com

[2]Department of Transport Management Technology, Federal University Technology, Owerri, e-mail:ejemflagospel@yahoo.com

[3]Centre for Environmental Studies and Sustainable Development, Lagos State University, Ojo, e-mail: chinenyeokafor2017@yahoo.com

[4]Department of Transport Management Technology, Federal University Technology, Owerri, e-mail:chukwuoly81@gmail.com

Abstract:
This paper aims to assess the predictability of terminal airspace capacity. To deliver the required predictability and performance levels, it becomes imperative to determine the available LOS airport capacity effectively from daily operations time frames. Data needed for this study was collected from secondary sources- a survey of existing documents such as published flight strips of Nigerian Airspace Management Agency (NAMA). A modified version of Aviation System Performance Metrics (ASPM) of the Federal Aviation Administration (FAA) was adopted in the paper. From the findings, the levels of the daily arrival and departure utilization score for a typical week ranges from 72-87%. The trend shows that all through the week the LOS airport experiences majorly zero airport performance score between the hours of 00.00 am to 2 am, with few international arrivals and departures from the hours of 00.00 am to 4 am. But from 4.01 am till midnight every day, the LOS airport has airport performance score ranging from 44% to 100%. Hence the airport is adjudged to be slightly underutilised. However, the airport performed better on Saturday with a utilisation score of 85%, and this is closely followed by Wednesday with a score of 84%. The least performance rating was seen on Sunday with a 78% score. For LOS airport current demand exceeds capacity, terminal capacity assessments should provide a framework for the most appropriate management of capacity with excess demand, capacity assessment can highlight the options for growth and the risks of over scheduling.

Keywords:
arrival, departure, utilisation, airport, performance, airspace and terminal capacity

INTRODUCTION

Globally there has been a consistent rise in air transport demand owing to trade and commerce expansion. Still, this rapid growth has not to be equalled by a similar increase in the National airspace infrastructure resulting in congestions, delays and widespread disappointments. The Nigeria Aviation industry is at the forefront of these challenges. It has been pushed beyond its limits, but the operating system cannot grow accordingly that causes most of the delays faced by passengers. Generally, according to [11], Air traffic resources consist mostly of two parts: air traffic controller (ATC) and physical system resources, such as the airspace. Proper assessment and management of these resources are the foundation of ensuring the safety and efficiency of air traffic management systems since estimations indicate that by 2025, global air traffic could be triple of the present amount [11].

With the increase of air traffic demand, the terminal airspace becomes more and more congested. Future air transport systems are expected to handle increasingly massive demand on air traffic, especially in a highly constrained terminal airspace. Therefore, the realizable capacity of current terminal airspace is a challenge for future air transport development [6]. Operational capacity is the most detailed capacity assessment performed in the days before and the day of operations. Its objective is to integrate the latest detailed constraint information to update capacity figures. It is used by all airports to refine any identified demand balancing plans or contingency plans. Operational capacity is also a critical input into the tactical flow management process [1]. The capacity analysis for the airport is composed of two distinct elements: the ability of airport facilities to accommodate existing and projected aircraft operations (airfield capacity) and the ability of airport facilities to adapt existing and planned ground vehicle operations (airport access capacity). The capacity of an airfield is primarily a function of the significant aircraft traffic surfaces (runways and taxiways) that composes the facility and the configuration of those surfaces. Still, it is also related to, and considered in conjunction with, wind coverage, airspace utilization, and the availability and type of navigational aids. The airport access capacity is a function of the existing and future vehicular roadways located in the vicinity of the airport and their interface with the various airport specific access roads [5].

The airport now faces the challenge of meeting the growing demand for air transport. A lock of airport capacity has been fare coated by FAA to be one of the most severe constants to the growth of commercial and private aviation [8]. According to [9], one main reason for this lack of capacity is that airport development projects are enormously capital intensive and probably one of the most significant infrastructure development projects that are undertaken. Hence, it is a challenging task for airports to keep pace with rapidly growing demand for air transport [3]. The above facts also accentuate the importance of thorough analysis of the various option and outcomes at the planning stage. Demand capacity analysis, therefore, plays a crucial role in defining the physical requirement of the airport facility to meet future demand.

According to [4], the worldwide commercial aviation accident rate has been nearly constant over the past two decades. Although the pace is languid, increasing traffic over the years has resulted in the absolute number of accidents also increases. Despite the event of September 11, 2001, the worldwide demand for air is coming two decades, doubling or tripling by 2017 [7]. [5] further opine that capacity assessment and also the airspace management in Nigeria has been so poorly organized that this has resulted to outright lack of confidence in the Nigeria air space by the global community for fear of Mid-air collisions. Besides, [2] opined that the air traffic management system must ensure the safe and orderly flow of air traffic, which will allow commercial operators the flexibility to manage their economic assets effectively. The globalisation of the trade expansion has caused a boom in air

travel. A similar development has not matched this rapid growth in the national airspace infrastructure resulting in congestions delay and widespread frustration. It is also interesting to know that a bank of arrivals is immediately followed by a bank of departures, possibly reflecting on the day interconnectivity of flights. It is evident that airline schedules to maximize passenger's convenience and utilization of aircrafts results to the peal of arrivals and department at sure of the day. The number of operations of these peak times often approaches or surpasses the capacity limits of the Nigerian Airports. The capacity of the system must grow and keep pace with demand, lest it hampers transportation and the economic wellbeing that it signifies [5]

The distinct attribute of terminal airspace lies in the fact that it serves as a "bridge" between an airport and its entire airspace [10]. The terminal area has a very complex operating environment. This is due to a verity of factors such as runway configuration, safety /shorter separation between aircraft, equipment at the ATC (Air Traffic Control) centres, navigation aids within the aircraft and the weather conditions, complicated aeroplane routes with ascending, descending, turning, and accelerating aircraft, and multiple hand-off procedures between controllers. These factors cause terminal delays which contribute substantially to overall capacity problems in any National Airspace System. However, they are not entirely sufficient to characterise the capacity of a system. Airspace capacity was correctly defined by [11] as an index to measure the ability of the airspace system to deliver services to meet the air traffic demand. Therefore a scientific and accurate forecast of airspace capacity is a key to the effective management and rational allocation of the airspace resources.

This paper presents the assessment of terminal airspace capacity of Muritala Mohammed International Airport Ikeja Lagos Nigeria using the calibrated metrics formula of the US FAA (Airport arrival, Airport departure and Airport performance Utilizations). It assessed the actual hourly arrival and departure of aircraft, determined the aircraft arrival and departure demand, evaluated the operational performance and finally identified the variables limiting capacity maximisation.

1. METHODOLOGY

Data needed for this study was collected from secondary sources only. The secondary source was a survey of existing documents such as published flight strips of Nigerian Airspace Management Agency (NAMA) as well as the Directorate of Air Traffic Services (ATS). To measure system performance and to develop strategies to improve that performance, basic metrics used to need a form of a mathematical definition, and the basis for calculation shall also be validated. A modified version of Aviation system performance metrics (ASPM) of the Federal Aviation Administration (FAA) was adopted in the study. Utilisation metrics indicate how well arrivals, departure and the trade-offs between the two were handled at an airport during the previous day. System performance at an arrival airport is assessed for each one hour in the day in terms of the number of arrivals and departures handled versus the airport's ability to accommodate demand. In each one hour, overall airport performance is evaluated to take into account the need to give priority to arrivals or departures depending on the demand mix.

1.1. Arrival Utilisation

Arrival utilisation (t) assesses how well the Arrival demand was satisfied for a given arrival capacity in that period. Arrival utilisation compares what an airport did to what it could have done. Arrival utilisation will be 100% when either: the target arrival rate is met, or all arrival demand is met. Since both demand and capacity may vary over time, the day is divided into the one hour and the metrics calculated for each period. Arrival utilisation for

each period is determined by comparing actual arrivals to the target AAR for the period or the demand, whichever is less. If the numbers of actual arrivals exceed the target utilisation, it is capped at 100%. For the utilisation metrics to be meaningful, it is vital to have a realistic airport target rate. The one-hour arrival utilisation scores are combined to provide an overall daily arrival score. The formula used is provided as:

$$\text{Arrival utilization performance} = \frac{\sum t \text{ (Arrival utilization x Arrival demand t)}}{\sum t \text{ (Arrival demand t)}}$$

That is the proportion of the arrival demand in that period. This weighing scheme emphasises to the periods of high demand, making it particularly important to perform well in those periods.

1.2. Departure Utilisation

Departure utilisation (t) assesses how well the departure into account the mix of Arrival and Departure, demand was satisfied for a given period, taking into account the mix of arrival and departure demand. The computation for Departure Utilisation is similar to that of Arrival Utilization and is defined as:

$$\text{Departure Utilization (t)} = \text{Departure}_t/\text{min departure Demand}_t/\text{min (Demand}_t, \text{Departure Target Rate).}$$

Again, individual utilisation scores are combined to provide an overall departure score. The formula is provided as:

$$\text{Departure utilization performance} = \sum t \text{ (Departure utilization x Departure demand}_t)/ \sum t\text{(Departure demand)}$$

As with arrivals, departure utilisation in each period is weighted by the proportion of the departure demand in that period, which emphasises excellent performance at times of high demand.

1.3. Airport Utilization

Both arrival and departure measures are combined to give an overall indicator of airport performance in that period. At some airport, this is an explicit trade-off between accommodating arrivals and departures. The airport performance metric recognises the need to give priority to arrivals during arrival pushes and departure during departure pushes. In the present formulation, the airport performance score is weighted according to the relative amount of arrival demand as compared to departure demand.

$$\text{Airport Utilization} = (\text{Arrival importance x Arrival Utilization}_t) + (\text{Departure importance x Departure utilization}_t)$$

The relative importance or weighing of meeting arrival demand as opposed to departure demand in period t is calculated as:

$$\text{Arrival Importance t} = \text{Arrival demand}_t / (\text{Arrival Demand}_t + \text{Departure Demand}_t)$$

Similarly,

$$\text{Departure Importance t} = \text{Departure demand}_t / (\text{Arrival Demand}_t + \text{Departure Demand}_t)$$

Note that the sum of Arrival Importance and Departure Importance equals 1. Therefore the airport performance always lies between arrival performance and departure performance. The airport performance score is calculated weighting the periods according to the percentage of total demand.

$$\text{Airport Utilization Performance} = \sum t\ (\text{Airport Performance x Arrival demand}_t + \text{Departure demand}_t) / \sum t\ (\text{Arrival demand}_t + \text{Departure demand})$$

The weighting scheme has the effect of placing the most emphasis on performance in the period when the demand is high, so that meeting the target rate in those periods is essential for a high-performance score.

The utilisation scores reflect the performance relative to the demand at the terminal airspace facilities despite problems caused by airspace infrastructure limitation. These metrics can help to distinguish between satisfactory or excellent performance (High airport utilisation regardless of delays) and performance that could be improved. However, the utilisation study conducted over a while will show whether there is increased user access to the terminal airspace or vice versa.

2. RESULTS AND DISCUSSION

This study investigated a typical week operation at LOS terminal characterised by the researcher as a week of optimum level of airport operation. It is based on the good daily flight in which the maximum number of aircraft can be routinely handled using visual approaches during periods of unlimited ceiling and visibility. It comprises of flight schedules from June 1 to July 7 of the year 2013 daily.

2.1. Analysis of Arrival and Departure Utilization Performance

Arrival utilisation performance measured how well arrivals were handled given the number of aircraft that could have landed and the target rate called in by the facility for that period or the demand. Similarly, the departure utilisation measured how well departures were handled given the number of aircraft that could have departed and the departure demand placed on the ATS facilities. The LOS terminal facility had a vague record of periodic target rate, and hence comparisons were restricted to the demand function. Since demand may vary over time, the day is divided into periods, and the metric is calculated for each period. In selecting the period, the researchers did apply an hourly period to determine the arrival and departure utilisation performance for seven (7) days.

Arrival utilisation thereby compared what the airport did to what it could have done. In this case periods of the first day which is Saturday, June 1 2013, periods of 0.01-3.00am revealed imaginary utilisation score owing to zero arrival and zero arrival demand, so also are the time intervals 10.01-11.00pm and 11.01-00.00am. Although there was an arrival demand it was not for time bins of 4.01-5 am, and 8.01 am-2 pm, 3.01-4 pm, 5.01-7 pm, 8.01-9 pm while the 100% utilisation score was between the periods of 5.01-8 am, 2.01-3 pm, 4.01-5 pm, 7.01-8 pm and 9.01-10 pm. Besides, the periods from 0.01-4 am, and 11.01-00.00am showed imaginary departure utilisation score owing to zero departure and zero departure demand (meaning that LOS airport was not able to grant departure clearance to aircraft waiting to depart). 100% utilisation score periods were from 5.01-6 am, 12.01-1 pm and 7.01-11 pm while the remaining time bins recorded less than 100% departure utilisation score.

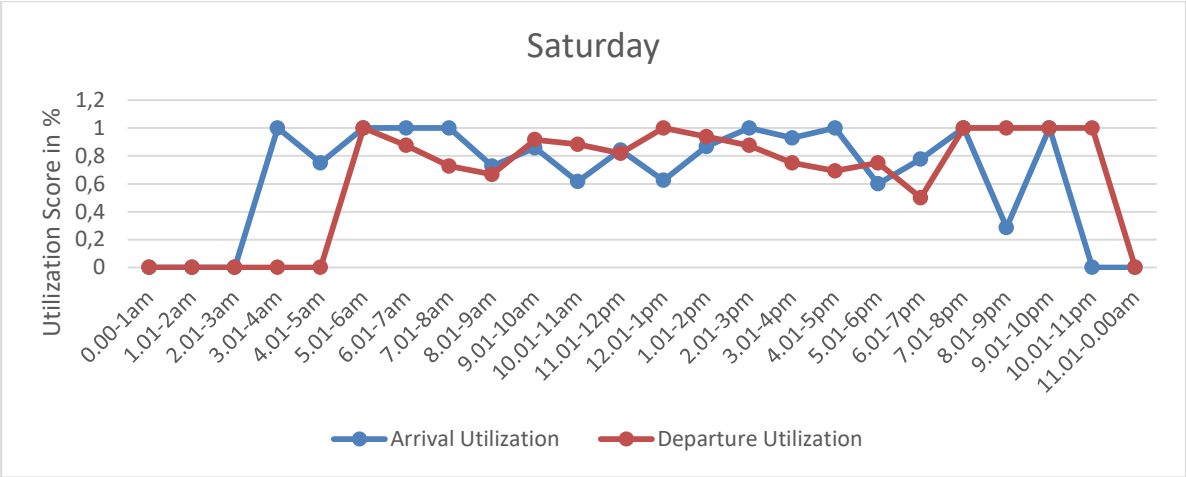

***Fig. 1** Arrival and Departure Utilization Performance for Saturday 1/6/2013*

On Sunday, periods of 0.01-3 am, 6.01-8 am and 11.01 pm-00.00 am showed imaginary utilisation score owing to zero arrival and zero arrival demand. Time bins of 5.01-6 am, 10.01-11 am, and 9.01-10 pm as revealed in the chart showed 100% utilisation score while the rest showed less than 100%. In the same day, the imaginary utilisation score that revealed zero departure and zeroes departure demand of the hourly periods of 0.01-1 am, and 2.01-4 am while 100% utilisation score were recorded from the periods of 1.01-2 am, 6.01-7 am, and 7.01-00.00am. Between 4.01-6 am, 7.01 am – 7 pm recorded varying departure utilisation score ranging from 50-88%, indicating that the said period represents times of busy departure schedules at the Lagos airport on that day.

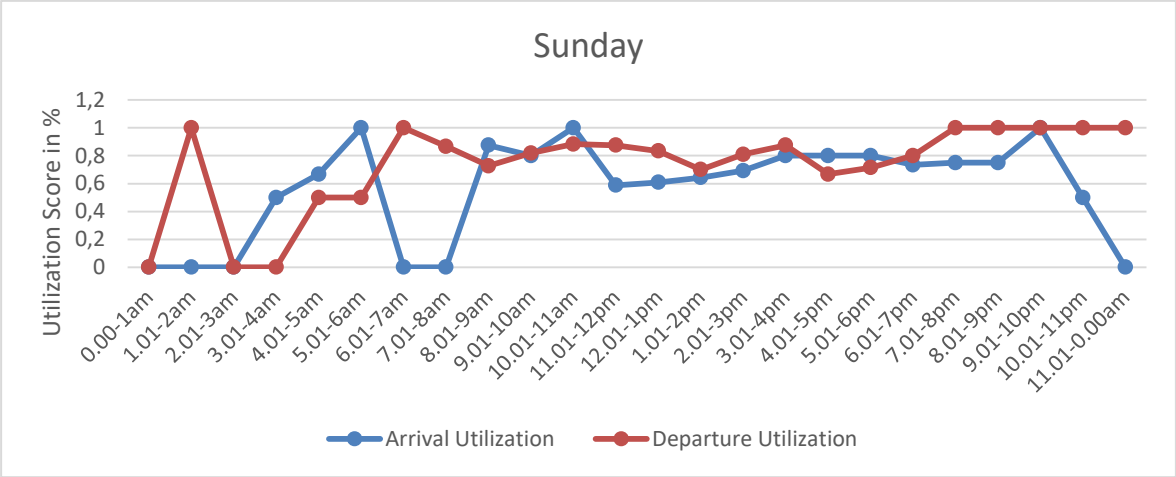

***Fig. 2** Arrival and Departure Utilization Performance for Sunday 2/6/2013*

On Monday, periods of 0.01-3 am, and 11.01 pm -0.00 am showed imaginary utilisation score owing to zero arrival and zero arrival demand. Time bins of 3.01-5 am, 6.01 am–9 pm and 10.01-11 pm revealed arrival utilisation score ranging from 33-91% while time bins of 5.01-6 am and 9.01-10 pm only showed 100% arrival utilisation score. On the contrary, periods from 00.01-4 am recorded imaginary departure utilisation score owing to zero departure and zero departure demand on Monday and on the same Monday 100% utilisation score periods were from 4.01-6 am, 12.01-1 pm, 4.01-5 pm, 7.01-9 pm and 10.01-11 pm. The remaining time intervals had departure utilisation score ranging from 68-91%.

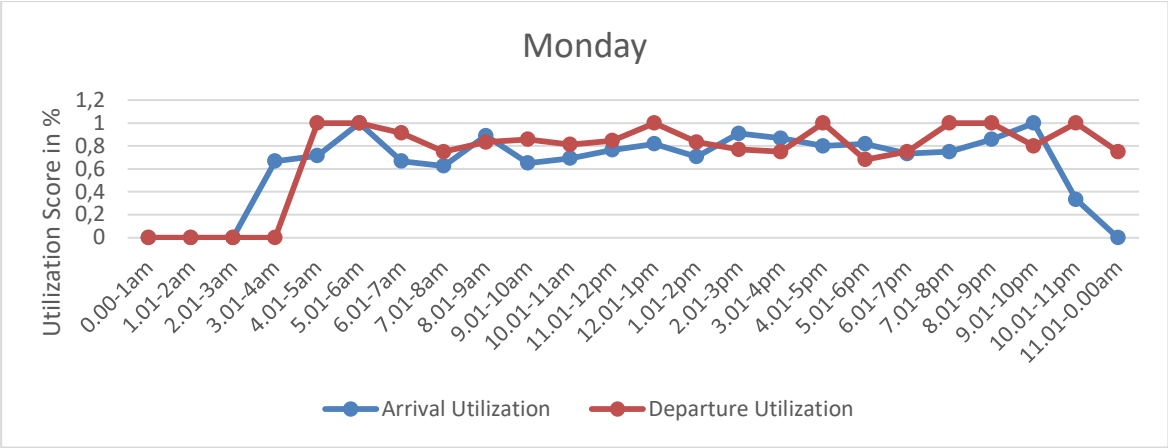

Fig. 3 *Arrival and Departure Utilisation Performance for Monday 3/6/2013*

Tuesday, June 4 2013, the researchers found out that the periods of 00.01-3 am and 10.01 pm-00.00 am showed imaginary utilisation score owing to zero arrival and zero arrival demand. Time bins of 3.01-4am, 5.01-8am, 2.01-3pm, 4.01-5pm, 7.01-8pm and 9.01-10pm as revealed showed 100% utilization score. Others were less than 100%. On the same day, the periods from 0.01-5 am, and 11.01-00.00 showed imaginary departure utilisation score owing to zero departure and zero departure demand and 100% utilisation score periods were from 5.01-6 am, 12.01-1 pm and 7.01-11 pm.

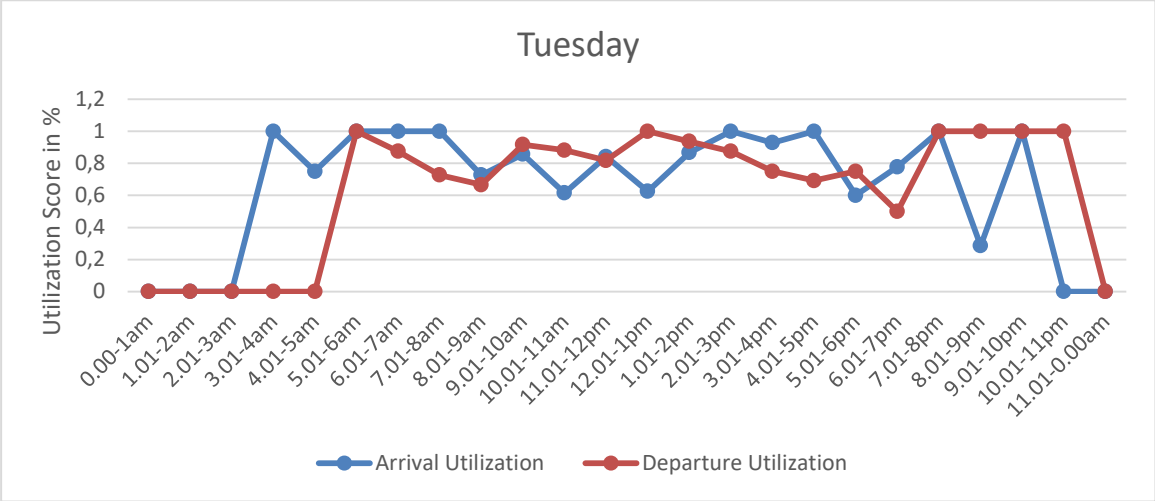

Fig. 4 *Arrival and Departure Utilization Performance for Tuesday 4/6/2013*

On Wednesday, it was seen that 00.00-2.00am, 3.01-4 am, 6.01-7 am, and 10.01-11 pm showed imaginary utilisation score owing to zero arrival and zero arrival demand. Time bins of 2.01-3.00am, 4.01-6am, 5.01-6pm and 11.01pm-00.00am as revealed 100% utilization score. However, the periods from 00.01-4 am, 8.01-9 pm and 11.01-00.00 am showed imaginary departure utilisation score owing to zero departure and zero departure demand while 100% utilisation score periods were from 4.01-15 am, 9.01-11 am and 12.01-3 pm.

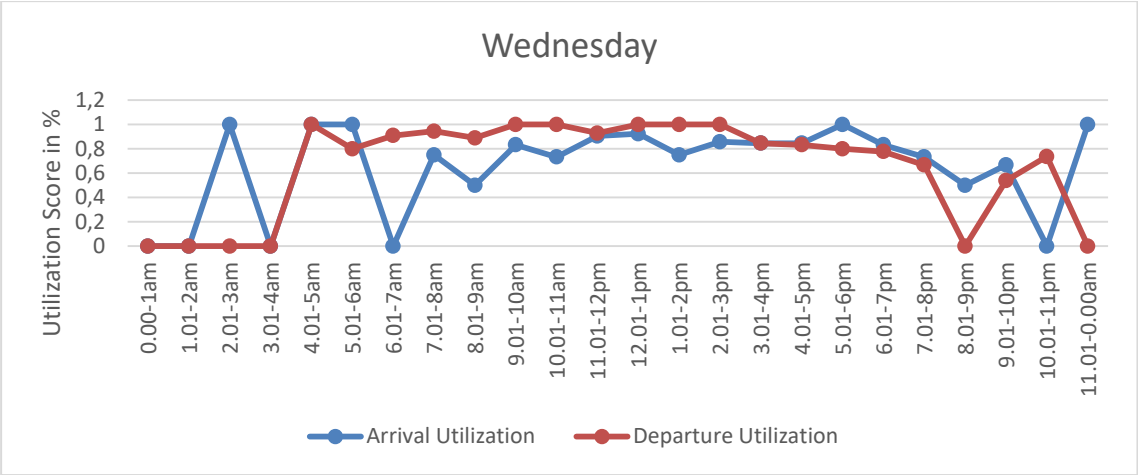

Fig. 5 *Arrival and Departure Utilisation Performance for Wednesday 5/6/2013*

On Thursday, periods of 00.01-3 am, 6.01-7 am and11.01-00.00am showed imaginary utilisation score owing to zero arrival and zero arrival demand. Time bins of 3.01-6 am, 2.01-3.00am, 5.01-6 pm and 11.01-00.00am as revealed 100% utilisation score while the rest showed less than 100%. In the same vein, the periods from 0.01-5 am, and 11.01-00.00am showed imaginary departure utilisation score owing to zero departure and zero departure demand and 100% utilisation score periods were from 4.01-6 am, 7.01-9 am, 6.01-9 pm and 10.01-11 pm and the rest departure utilisation ranges from 67-93%.

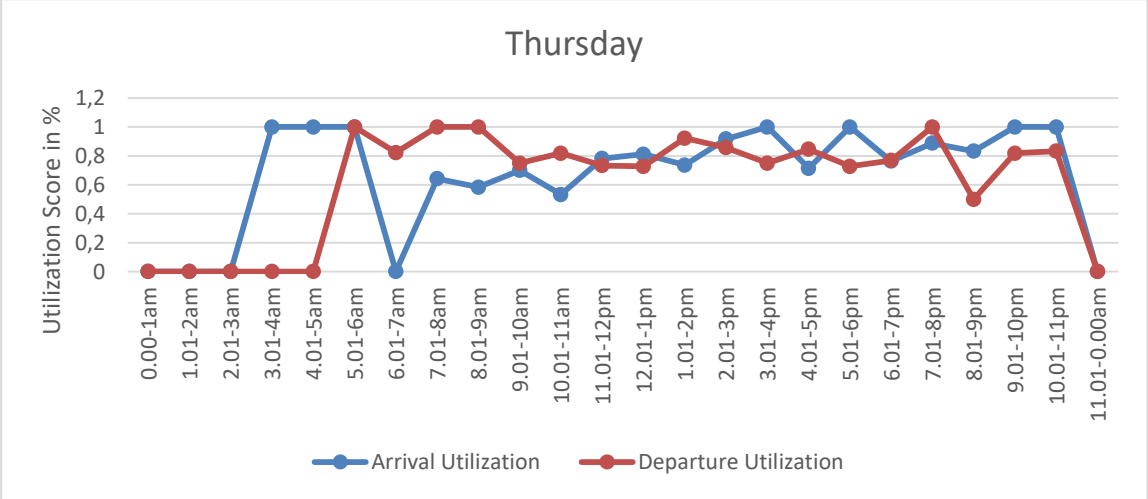

Fig. 6 *Arrival and Departure Utilization Performance for Thursday 6/6/2013*

On Friday, periods of 0.01-2 am, 6.01-7 am, and 10.01-00.00am showed imaginary utilisation score owing to zero arrival and zero arrival demand. Time bins of 2.01-6 am, 9.01-11 am, and 8.01-9 pm showed 100% utilisation score while the rest showed less than 100%. Still, on that day, the periods from 0.01-4 am, and 11.01-00.00am showed imaginary departure utilisation score owing to zero departure and zero departure demand while 100% utilisation score periods were from 4.01-6 am, 7.01-9 am, 6.01-9 pm and 10.01-11 pm and the departure utilisation ranges from 67-90%.

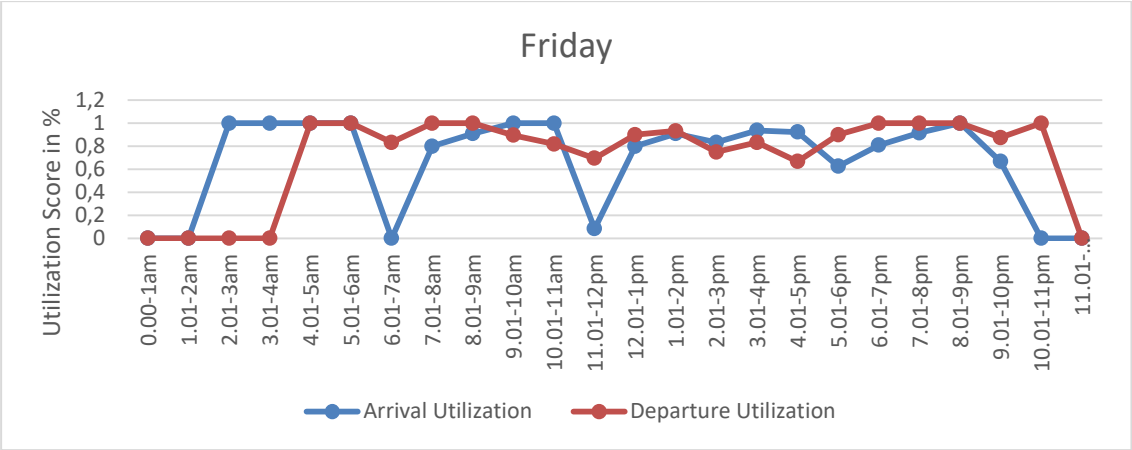

Fig. 7 *Arrival and Departure Utilization Performance for Friday 7/6/2013*

Besides, the levels of the daily arrival utilisation score for all the seven days range from 72-87%. It indicates that there are periods at which the LOS airport frequently witness concurrent arrival operation in a typical week. However, the arrival demand was never met during the entire week. Saturday had the overall best arrival utilisation score of 87%., and this is closely followed by Wednesday with a score of 83% (see Table 1). This depicts the need for improvement in ATM capabilities at Lagos airport.

Tab. 1 *Daily arrival and departure utilisation score of LOS airport*

Day	Arrival Utilization	Departure Utilization
Saturday	0.87	0.87
Sunday	0.72	0.84
Monday	0.76	0.84
Tuesday	0.80	0.83
Wednesday	0.83	0.86
Thursday	0.78	0.82
Friday	0.81	0.85

Source: Authors' Computation

But generally, all the seven days showed that the airport was quite busy, but the departure utilisation was also met in a full day. As with the arrival performance, the departure demand was never achieved. Departure demand was sometimes high and unmet. This is explained by the fact that in a typical week, those perusals represents the time of few departures for international departure flights and hence does not put service workload on the ATM facilities at Lagos airport. In comparison, departure utilisation performances showed a score almost the same as the arrival utilisation performance. Again, further investigations reveal that the utilisation performance at Lagos airport was as a result of inadequate airport infrastructures, few competent ATM personals and obsolete airspace management facilities compared to those obtainable in the developed nations.

2.2. Analysis of Airport Performance

Terminal capacity may broadly be defined as is the ability of an airport to handle a given volume of traffic (demand). Congestion, however, occurs when demand approaches or exceeds capacity. Airspace system capacity utilisation metrics arrival and departure indexes were computed under varying levels of hourly operation. The objective is to make a

comparison between the actual service and respective demand on the airspace infrastructure from a planning perspective. It would allow more informed decision making by providing estimates of efficiency in forms of design functionality, sensitivity to technological and procedural improvement and overall utilisation potential capacity. At some airports, there is an explicit trade-off between accommodating arrivals and departures. The airport performance metric recognises the need to give priority to arrivals during arrival pushes and departure during departure pushes. In the present formulation of FAA, the airport score is weighted according to the appropriate amount of arrival demand as compared to departure demand. The airport performances in Table 2 shows the analytical score performances all through the days of the week.

Tab. 2 *Airport performance scored for the 7days shows*

Time Frame	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
0.00-1am	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.01-2am	0.00	1.00	0.00	0.00	0.00	0.00	0.00
2.01-3am	1.00	0.00	0.00	0.00	1.00	0.00	1.00
3.01-4am	1.00	0.50	0.50	1.00	0.00	1.00	1.00
4.01-5am	1.00	0.60	0.75	0.75	1.00	1.00	1.00
5.01-6am	0.33	0.80	1.00	1.00	0.88	1.00	1.00
6.01-7am	0.89	1.00	0.88	0.88	0.91	0.82	0.83
7.01-8am	1.00	0.87	0.70	0.81	0.87	0.81	0.94
8.01-9am	0.95	0.79	0.86	0.69	0.68	0.76	0.94
9.01-10am	0.85	0.81	0.70	0.88	0.88	0.73	0.92
10.01-11am	0.63	0.90	0.76	0.77	0.85	0.65	0.90
11.01-12pm	0.86	0.73	0.80	0.83	0.91	0.76	0.49
12.01-1pm	0.91	0.69	0.91	0.74	0.96	0.78	0.85
1.01-2pm	0.90	0.67	0.76	0.90	0.85	0.81	0.92
2.01-3pm	0.80	0.76	0.83	0.93	0.92	0.88	0.79
3.01-4pm	0.90	0.83	0.83	0.85	0.85	0.86	0.89
4.01-5pm	0.86	0.76	0.89	0.86	0.84	0.78	0.77
5.01-6pm	0.79	0.77	0.75	0.68	0.94	0.88	0.73
6.01-7pm	0.80	0.75	0.74	0.73	0.81	0.77	0.84
7.01-8pm	1.00	0.81	0.81	1.00	0.72	0.90	0.93
8.01-9pm	1.00	0.83	0.88	0.44	0.50	0.79	1.00
9.01-10pm	1.00	1.00	0.83	1.00	0.58	0.85	0.82
10.01-11pm	1.00	0.83	0.80	0.78	0.74	0.86	1.00
11.01-0.00am	1.00	0.67	0.75	0.00	1.00	0.00	0.00

Source: Authors' Computation

The system capacity of the Lagos terminal airspace was assessed based on arrival utilization metric. The indicator assessed the ability of the Lagos terminal airspace system to support the number of users entering and exiting the system. In the airport performance, about 21 out of 168 periods for an hour of all the seven days involved showed nil utilization score implying that there was no arrival and departure demand at those periods.

However, the trend shows that all through the week the LOS airport experiences majorly zero airport performance score between the hours of 00.00 am to 2 am, with few international arrivals and departures from the hours of 00.00 am to 4 am. But from 4.01 am till midnight every day, the LOS airport has airport performance score ranging from 44% to 100%. Hence the airport is adjudged to be reasonably underutilised. However, the airport

performed better on Saturday with a performance score of 85%, this closely followed by Wednesday with a score of 85%. The least performance rating was seen on Sunday with a 78% score (see Table 3).

Tab. 3 *Daily LOS Airport Performance score*

Day	Airport Utilization Score
Saturday	0.85
Sunday	0.78
Monday	0.80
Tuesday	0.82
Wednesday	0.84
Thursday	0.80
Friday	0.83

Source: Authors' Computation

3. CONCLUSIONS

The theoretical demand for air traffic at the Nigerian terminal airspace dramatically exceeds the actual level of traffic associated with the system; therefore; the Nigerian terminal airspace is still under-utilised. Nigeria should pursue a program of airspace management infrastructural restructuring and standardisation in line with the global standards vigorously and recommend practices to enhance user's perception and confidence in the Nigerian airspace. The government should adequately fund the responsible agency (NAMA), stakeholders, and all aviation customers to discharge their functions more credibly. Above all, aviation industry stakeholders and the Nigerian government should invest in the development of revolutionary improvements and modernisation for the air traffic management (ATM) system. This will enable new aircraft technologies and air traffic technology to safely maximise operational efficiency, predictability, airspace safety, flexibility and access into airspace. The significant challenges are to accommodate projected growth in air traffic while preserving and enhancing safety, provide all airspace system users more flexibility and efficiency in the use of airports, airspace and aircraft and provides for doorstep to destination transportation development.

References

[1] ACAM Manual (2016). Airport Capacity Assessment Methodology. The European Organisation for the Safety of Air Navigation (EUROCONTROL).

[2] Cocanower, A. B. & Voss, W. (1998). National Airspace Capacity Estimate. 2nd USA/Europe Air Traffic Management R&D Seminar. Orlando, USA.

[3] Dempsey, P. S. (2000). Airport Planning and Development Handbook: A Global Survey. New York: McGraw-Hill.

[4] Ejem E. A. (2004). Terminal Airspace Management Performance Metrics in Nigeria. Unpublished M.Sc. A thesis submitted to the Postgraduate School, Department of Transport Management Technology, Federal University of Technology, Owerri, Imo State, Nigeria.

[5] Ejem, E. A, Ibe, C. C., Dike, D.N., Chikwendu, D. U, Igboanusi, C. C., Chukwu, O. E (2017). Analysis of Air Traffic Capacity in Nigerian Airports. International Journal of Business, Management and Allied Sciences (IJBMAS), 4(4).

[6] Li, S. (2016). Air Traffic Performance Improvement of Congested Terminal Airspace with Genetic Algorithm based Optimisation. https://www.semanticscholar.org/paper/Air-Traffic-Performance-Improvement-of-Congested-Li

[7] NASA (2002). NASA Aviation Systems Capacity Program. Retrieved http://www.asc.nasa.gov

[8] Wells, A. T. (2002). Airport Planning & Management. 5th Ed. New York: McGraw-Hill.

[9] Subramanian, Prakash (2002). A Simulation Study to Investigate Runway Capacity Using TAAM. Theses - Daytona Beach. 194. https://commons.erau.edu/db-theses/194

[10] Xie Y, Shortle J, Donohue G. (2004). Airport Terminal-Approach Safety and Capacity Analysis Using an Agent-Based Model. Proceedings of the 2004 Winter Simulation Conference.

[11] Zhang M, Shan L, Zhang M, Liu K, Yu H and Yu J. (2016). Terminal Airspace Sector capacity estimation method based on the ATC dynamical model. *Kybernetes.* 45(6):884 – 899