

PASSENGER DEMAND MODEL FOR DOMESTIC AIRLINE IN NIGERIA: A CASE STUDY OF ARIK AIR

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Abstract- In this paper, a passenger demand model for domestic was built. This model considers roles of airline service variables such as; service frequency, aircraft size, ticket price, flight distance, and number of airports in the route. It takes into account the influence of originating passengers in the metropolitan areas. The airport capacity, which has significant impact on service quality in airport and in the airline network, is considered. Researchers confirm importance of originating passengers, finds that, interestingly, airlines' services in first flight leg are more important, and attracting passengers than those in the second flight leg. Based on study data, it was discovered that *DIST*, *ORIG*, *DOMI* and *CAPA* has positive individual elasticities of 0.027, 0.654, 0.558 and 1.137 with respect to passenger demand in airline route. This implies that 1% increase in each variable will increase passenger flow by 0.2%, 6.5%, 5.6% and 11.4% respectively in airline routes under study. These findings are helpful for airlines to understand effects of changing services, and also useful for us to quantify benefits of airport expansion projects.

Keywords- Airline, Airport, Capacity, Passenger, Demand and Gravity Models

I. INTRODUCTION

Management of transport demand are in two ways: i) by limiting (traffic diversion) in some way the demand for access to busy airports or to congested airspace, and/or ii) by modifying spatial and temporal distribution of demand to bring it closer to available capacity. The first approach can be achieved through administrative means that will ease the congestion by diverting some traffic on basis of certain slot allocation criteria where it can be handled efficiently, while the second alternative dictates design of a pricing system so that market forces allocate capacity (mostly on a temporal basis) among competing users [22].

Several measures can be adopted to manage demand at individual airports in Nigeria. Among these are [41]: i) required diversion of some traffic to reliever airports, ii) more balanced use of metropolitan airports, iii) restriction of airport access by aircraft type or use, and iv) establishment of quotas either on number of operations or on passenger enplanements. Finally, at national level, demand might be managed by administrative actions to encourage "rehubbing" or redistributing transfer traffic from busy airports to underused airports. All of the above described actions deny some users free or complete access to choice of airport, which might be viewed as a violation of traditional policy of freedom of airways to allocate use of airport facilities, that is, a distortion of the concept of "freedom to accord unrestricted access to users". (EU, 2003). Moreover, there are criticisms for adversely affecting the growth of aviation industry. Nevertheless, since demand has outpaced supply in most metropolitan airports, several practices of demand management have come into use, and many industry observers agree that these

measures have great potential in successfully dealing with delay and more efficient airport capacity utilization [41]

Certainly, the objective of these policies should be to enhance efficiency of airport operations, while interfering to the least possible extent with aim of developing a competitive, market-driven air transport system [41]. The current administrative efforts on applying demand management measures undoubtedly distort the market nature in the long run, and they might constitute step back toward re-regulation of air transport industry [15]. The potential demand management methods that are oriented towards market mechanisms include purely economic incentives and instruments (e.g., congestion or peak period pricing, slot trading) or combinations of administrative measures and market-based policies (e.g., slot auctions) [29],[31]. Administrative options, although offering immediate and relatively low-cost relief of airport congestion may not be as attractive and efficient as compared to market-based approaches to demand management. The opinion of several economists is that this situation occurs because administrative options tend to bias outcome towards maintenance of status quo when applied over long period [29], [31].

[32] provides a framework to study competitive equilibria analytically on a global basis, drawing on the idea that four or five global HS airlines are likely to serve the industry, with numerous specialty airlines within continents [36]. Industry consolidation may be accelerated by expected relaxations in international regulations on formation of alliances and mergers [21]. As airlines push for wider deregulation [17], it is critical to consider impact of any changes on expected responses from airlines. The modeling approaches applied here include the p-hub median formulation [35] and discrete choice market share models [7]. Unlike the more general economic-based research, such as [10] and [38], this framework enables airlines and regulatory authorities to examine specific, potential mergers and alliances and their effect both on air transport and passengers. The framework can be applied to fields such as maritime shipping lines, telecommunications, computer routes and any industry whereby HS routes are essential to production plan. As this is a first step in developing such a framework, it presents a stylized version of problem in which some complexities have been removed. More in-depth analysis with additional real world complications is certainly possible, given sufficient demand data and more detailed analysis of market share model variables and parameters. [13] argues that effect of pricing and competition in hub and spoke route design has received insufficient attention in literature. [23] develops sufficient conditions for existence of equilibrium route designs using non-cooperative game theory. [22] develop a mathematical program to obtain optimal schedules and airfares for airlines operating HS routes under competition.

Multiple Nash sub-game perfect equilibria are found using a three-stage heuristic. [24] examine route and schedule choice by a profit maximizing airline, using four route types, and find that, is optimal for airlines to design routes and schedules to minimize the sum of airline and passenger costs. Based on sensitivity analyses, is shown that for sufficiently large distances and intermediate demand levels, HS routes are preferable, otherwise direct connections can be supported. [27] discuss relocation of hubs in competitive environment given changes in the

origin-destination demand matrix over time. Demand, in terms of flow, is captured through a minimum cost breakdown in order to avoid use of prices. [2] evaluates airline profits based on micro-economic theory of behavior under deregulation and its connection to routes.

[8], [3] examine real world industry conditions. [8] uses on-cooperative game theory to examine domestic air travel in India based on a non-zero sum game that searches for a focal point amongst Nash equilibria. Bhaumik's paper studied how a regulator could ensure a reasonable equilibrium outcome by setting airfares, license fees or essential air service requirements. [3] develops a model framework to provide information on the most adaptable and profitable hub-spoke routes available under competition and applied it to Western Europe. [4] assert that one of the key methods of airlines, in order to be profitable, is the choice of route. An open skies deregulation agreement permits airlines to set prices and quantities freely. It has been shown in many research papers and in the real world that a hub and spoke (HS) route ensures not only profit maximization but entry deterrence too [12]. [5] argued that in a long-run equilibrium, large portion of city-pair markets cannot support convenient nonstop service, [thus] hub-and-spoke operations should continue to be a major routing strategy of air carriers.

[5] also argued that load factors were likely to rise, restricted discount and leisure fares would vary with demand, specialist carriers would serve distinct types of passengers and that "deregulation is leading to a substantially more efficient airline system". [37] stated that the US aviation industry is among the most efficient in the world, partly due to the fact that US was the first to deregulate its aviation industry. [30] look at effects of deregulation and competition on US air transport market. Based on an analysis of North Atlantic aviation market, [26] concluded that US market reform resulted in significant benefits to passengers in form of substantial traffic growth and fare reduction. On the supply side, liberalization resulted in cost reductions too, though not all carriers fully realized concurrent profits. In summary, there is an extensive economic literature that evaluates the cost, marketing and competitive advantages associated with hubbing phenomenon ([16], [28], [10], [32], [6], [39], [11], [4]).

The most important breakthroughs so far appear to be [13], [14], in which the problem was linearized and solved for up to approximately 40 nodes; the table search procedure described in [40]. Later, [19] presented two models for air passenger volume forecasting between city-pairs in Nigeria. The models used mainly geo-economics variables rather than service related factors. The model moderately showed a good fit to the observed data which contains 2954 quarters- all quarters between year 2009 and 2013. This model assumes that marginal effects of each variable on demand are not constant but depend on both the value of variable and the values of all other variables in demand function [1]. In other words, the explanatory variables affect demand in multiplicative manner. Partial derivation of any independent variable proves aforementioned relationship. However, this model was made suitable for multiple regressions by applying logarithmic transformation [34]. It is obvious that interdependency is resolved in this form so that multiple regression model can be applied. Following the demand function used by [1], this study specifies the demand for air travel service as a function of geo-economics and industry related factors [34]

Models may also be differentiated by form. Broadly, most demand generation models are regression models, while most assignment models are random utility models. Random utility models range from simple multinomial logit [18], to nested logit [18] and to mixed logit [3]. Although the sophisticated models may perform better in explaining travel behavior, the increased complexity generally make them harder to estimate.

II. RESEARCH PROBLEM

Increasing demand for air transport service has compelled airline management to take advantage of opportunities in different markets. At same time, increasing competition among airlines necessitates that airline management seek efficiency in all their decisions to promote their profit. It is no surprise that many airlines throughout aviation history have been unable to remain in business, and in most cases, it is agreed that the demise of these airlines has been attributable to deficient management.

This development has contributed to recent advances in computation and communication technologies and, importantly, the need to reduce costs and increase revenues. Nowadays airlines seek to perform efficiently in a competitive environment that only provides marginal profits. The airline business is characterized as being one of the most complex, involving multiple conflicting decisions that need to be optimized at the same time. Several tactics have been developed and used to operate airlines. These tactics bank on scientific approaches available in operations research and mathematics literature to optimize airlines' decision-making processes, and are usually modeled within computerized systems. Therefore, these scientifically-based tactics promise an easier decision-making practice for the airlines. The need for these tactics becomes more crucial as the size of the airline increases, and making decisions based on individuals' judgment or experience becomes more difficult.

III. JUSTIFICATION FOR STUDY

Quantitative study on passengers' travel demand in airline's route has seldom been seen either in research literature or in industry practice in Nigeria, and it is urgently called for now when airlines need to make a decision on whether they should and how to adjust their routing structures.

The purpose of this study is to build an aggregate demand model for air passenger traffic in airline routes that, can be used by airlines to evaluate the overall passenger, and to see how demand changes if any of airlines' service variables are adjusted. It can also be used by airport and government to study the impact of airport capacity on passenger service quality.

IV. METHODOLOGY

Demand forecasting is the process of estimating the expected number of travelers on each flight in the schedule, given the flight schedules of all competitors in different travel market. The demand forecasting and modeling process has to predict passenger counts on each flight in the schedule and also estimate possible changes in demand due to changes in schedule, pricing, competition, and so on. The demand forecasting process also estimates airline share in each city-pair (OD market).

To arrive at a statistically estimable probabilistic model, the linear (or nature logarithm) form of the gravity model equation has been commonly applied. The linear form of gravity then can be expressed as follows: $\log (T_o) = \beta_0 + \beta_1 * \log (P_i) + \beta_2 * \log (A_j) - \beta_3 * \log (dij) + \ell$ Where ℓ is an error term and β 's are statistically estimable coefficients.

Simple gravity models considering only population and distance variables were adopted in the early studies of cross-border passenger flows [25]. These were later modified by considering more variables that can produce or attract air passengers such as income, education level, the accumulation level of enterprises, and measures of city characteristics such as location advantages and climate. It should be noted that this present study focuses on air passenger flows in a hub and spoke route. The aggregate data at national level will be used.

We take route operated by an airline as a unit, and study travel demand originating from each airport in the route. The factors in our model include the number of airport in the route, the number of flights between the airports, the number of originating trips from an airport, airlines' service frequency and aircraft size provided between any specific service, ticket price and flight distance. The airport capacity, which presumably has a significant impact on airlines' service quality in the airport and in the whole route, is also taken into consideration.

A log-linear demand model is specified as follows:

$$\log (PAX) = \alpha + \beta_1 * \log (FREQ) + \beta_2 * \log (SIZE) + \beta_3 * \log (AIRP) + \beta_4 * \log (FARE) + \beta_5 * \log (DIST) + \beta_6 * \log (DOMI) + \beta_7 * \log (ORIG) + \beta_8 * \log (CAPA)$$

Where

PAX is the number of passengers flying with airline;

FREQ is the service frequency provided by airline;

SIZE is the average aircraft size (number of seats) provided by airline;

AIRP is the total number of airports served by airline;

FARE is the average fare per passenger charged by airline;

DIST is the average flight distance;

ORIG is the number of local passengers who travel by airline;

DOMI is the total number of initiated passenger trips originating from an airport;

CAPA is the aircraft arrival capacity at airport, in terms of acceptance rate. Airport runway capacity, CAPA, is represented by the maximum of the 15-minute average arrival acceptance rate obtained on the 12th day of each month from January of 2013 to January of 2014. The airport arrival acceptance data are obtained from the database of Nigerian Airspace Management Agency (NAMA).

The researchers build this demand model in a log-linear format, and, therefore, the coefficient for each explanatory variable is the elasticity of demand with respect to each corresponding variable in the model.

V. OBSERVATIONS AND DISCUSSION

I. Model Estimation and Implications

The source data for the coefficient estimation for our demand model mainly come from the database of the Arik airline which has the highest number of flights in Nigeria (see Table 2). To estimate the coefficients of our demand model, we use data from the second quarter of 2011. Totally, there are airports, used as hubs MMA and NAAA used as hubs by Arik Airline. From the Table 1, it is clear that the major hubs in Nigeria are Lagos and Abuja airports:

TABLE 1

DOMESTIC AIR CAPACITY IN NIGERIA (NON-STOP WEEKLY DEPARTURES)

Rank	Airport	Weekly Departures	Weekly Seats	% Capacity
1	Lagos Murtala Muhammed International (LOS)	542	68,363	37.6 %
2	Abuja Nnamdi Azikiwe International (ABV)	382	48,296	26.6 %
3	Port Harcourt (PHC)	166	24,200	13.3 %
4	Enugu (ENU)	57	7,123	3.9 %
5	Owerri Sam Mbakwe International (QOW)	55	7,039	3.9 %
6	Calabar (CBQ)	40	4,982	2.7 %
7	Benin City (BNI)	42	4,568	2.5 %
8	Kano Aminu Kano International (KAN)	34	3,942	2.2 %
9	Uyo Akwa Ibom (QUO)	34	3,888	2.1 %
10	Warri (QRW)	44	2,752	1.5 %
	(Others)	70	6,588	3.6 %
	TOTAL	1,466	181,741	

Source: Compiled by Authors

TABLE 2

DOMESTIC FLIGHTS IN NIGERIA

Domestic air capacity in Nigeria (Non-Stop Weekly Departures)				
Rank	Airline	Weekly Flights	Weekly Seats	% Capacity
1	Arik Air (W3)	626	72,659	40.0 %
2	Aero Contractors (AJ)	417	48,571	26.7 %
3	Air Nigeria (VK)	238	29,812	16.4 %
4	Dana Air (9J)	163	24,613	13.5 %
5	Air France (AF)	14	4,172	2.3 %
	(Others)	8	1,914	1.1 %
TOTAL		1,466	181,741	

Source: Compiled by Authors

II. Test of Reliability Statistics of Arik Airline Data

The major test of reliability is coefficient alpha, a measure of the extent of internal consistency between, or correlation among, the set of questions making up each of the dimensions. The minimum reliability that is acceptable is difficult to specify. If reliability is low, such as below 0.60, one is faced with the choice of investing time and money in additional research in an attempt to develop a revised measure with greater reliability, or using the measure, recognizing that fluctuations in measured choice variable may be due only to measurement rather than a change in choice variable of transport modes. High reliabilities, such as 0.90 or above are desirable. From the table above, the Cronbach's Alpha of 0.977 shows high reliability (Table 3).

TABLE 3
RELIABILITY STATISTICS

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.966	.977	10

III. Aggregate Demand Model

Parametric linear regression method is a natural choice for estimating the gravity model. The results of the linear regression estimation of the gravity model are presented in the Tables 4 and 5 below. The signs of all model coefficients are plausible and the model has a reasonable overall statistical fit as indicated by R^2 statistic.

TABLE 4
MODEL SUMMARY

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.999 ^a	.998	.998	.0099406

Nine variables are found statistically significant in determining passenger flows between the routes. The negative signs of *FREQ*, *SIZE* and *AIRP* variables indicate that of need for

improvements to enhance airline passenger flows in the route. The estimated result shows that there are increased air passenger flows between the various routes in the study occasioned by *DIST*, *DOMI*, *ORIGIN* and *CAPA* variables of the demand model.

TABLE 5
AGGREGATE MODEL COEFFICIENTS

Model	Estimated coefficients	t-statistics	Sig.
(Constant)	0.071	5.389	.000
FREQ	-.110	-5.154	.000
SIZE	-.218	-11.705	.000
AIRP	-.344	-16.629	.000
FARE	-.061	-5.863	.000
DIST	.027	4.171	.000
DOMI	.654	33.254	.000
ORIG	.558	27.247	.000
CAPA	1.137	16.570	.000

The aggregate demand model in the study is repeated thus:

$$\log(PAX) = \alpha + \beta_1 \log(FREQ) + \beta_2 \log(SIZE) + \beta_3 \log(AIRP) + \beta_4 \log(FARE) + \beta_5 \log(DIST) + \beta_6 \log(DOMI) + \beta_7 \log(ORIG) + \beta_8 \log(CAPA)$$

Using the values from the Table 5 of model coefficients and applying conventional linear-exponential transformations, the passenger demand model for operation of a typical Nigerian airline can be shown as follows:

$$PAX = 0.0710 * FREQ^{-0.11} * SIZE^{-0.218} * AIRP^{-0.344} * FARE^{-0.061} * DIST^{0.027} * DOMI^{0.654} * ORIG^{0.558} * CAPA^{1.137}$$

The aggregate demand model is modified to consider the possibility of strategic factors. First, we introduce eight factors between the two allied hubs of Arik airlines i.e. Abuja and Lagos airports.

Above equation presents the results from the route operations. Under the strategic arrangement of Arik airline operation, eight potential demand variables are identified, namely *FREQ*, *SIZE*, *AIRP*, *FARE*, *DIST*, *DOMI*, *ORIG* and *CAPA*. The four variables *FREQ*, *SIZE*, *SPOKE*, and *FARE* showed individual elasticities of -0.11, -0.218, -0.344, and -0.061 with respect to airline passenger operation. However, *DIST*, *DOMI*, *ORIG* and *CAPA* has positive individual elasticities of 0.027, 0.654, 0.558 and 1.137 with respect to passenger demand at the airline routes. This implies that 1% increase in each of these variables will increase passenger

flow by 0.2%, 6.5%, 5.6% and 11.4% respectively at the routes of the airline under study. These results have strong managerial implications for the airline.

VI. CONCLUSION

Linear regression was proposed to establish empirical relationship among variables of air passenger flows between routes. The results obtained here, by exploring broad range of variables, provide valuable insight into underlying relationship of factors in air passenger flows in Nigeria. The results of this study can be employed to predict demand for airlines, particularly for planning to operate new line. This study also demonstrates good alternative for estimating gravity model by comparing analysis results from linear regression model. This represents important methodological step. In terms of future work, studies should explore more variables that can influence air passenger flows. The effect of airport, fare and many other factors as climate and socioeconomic variables of airport host environment are potential factors that can determine air passenger flows between specific routes. Further exploration by more variables might be able to identify more critical factors that can affect air passenger flows in Nigeria. Moreover, an application of methodological approach used in this study to examine other transport problems, as trip generation, energy use, population growth and traffic safety (e.g., accident rate prediction) would be interesting.

VII. RECOMMENDATION

As the first effort to build a demand model for air passenger traffic in the airline network in Nigeria, researchers' work in this field has much room for improvement in future. The most important comes from the need to further investigate correlations between all the explanatory variables and interdependences between demand variable and supply variables in the model. Improved estimation process may not only increase the accuracy of coefficients, but also help us understand complex system of passengers- airlines-airports. In the application part, we only consider passengers' direct benefit resulted from increased convenience and service improvement at airport, without considering passengers' indirect benefit resulted from airlines' adaptations in service frequency, aircraft size, number of airports covered and etc. It would be interesting to see how much direct and indirect benefits contribute respectively to passengers' total benefit, and how direct and indirect benefits are related.

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